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Kernel Density Analysis and Mapping of Ecosystem Functions in the NAFO Regulatory Area

by

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Abstract

In support of the 2021/2022 NAFO review of the closed areas to protect vulnerable marine ecosystems (VMEs) in the NAFO Regulatory Area, previously established kernel density estimation (KDE) methods were applied to four important ecological functions provided by benthic communities: A) Bioturbation; B) Nutrient cycling; C) Habitat provision; and D) Functional diversity (FRic), in order to evaluate significant adverse impacts of NAFO bottom-contact fishing on vulnerable marine ecosystems against the wider benthic contributions to those functions. Fish and invertebrate species recorded in the EU and Canadian surveys from 2011-2019 were classified *a priori* as contributing to each of bioturbation, nutrient cycling and habitat provision functions, using literature references. The resultant catch biomass data for each function were examined using K-S statistics and cumulative biomass distribution plots to determine whether data from the different surveys could be combined. With few exceptions the surveys were analyzed separately and the KDE polygons overlain *a posteriori* to produce combined polygon areas for each function. A suite of species were important contributors to the biomass of catches used to delineate each of the KDE polygons. For bioturbation, the sea cucumber *Cucumaria frondosa* and sea pens, both considered surficial modifiers, contributed most to the biomass. Nutrient cycling and habitat provision functions were delineated by catches where sponges dominated the biomass. Details of the analyses and the species that contributed to the delineation of the polygons are provided. Functional diversity was not assessed as information needed on a wide variety of traits and modalities was not completed. However published data from a survey in 2007 of Division 3M was used to run the KDE analyses with equivocal results. The KDE polygons generated matched published maps of FRic created using the same data and interpolated using random forest modeling. However the data were not sufficiently aggregated to allow for a clear KDE threshold to be determined. All other KDE analyses performed well and showed good congruence to the published maps of their corresponding functions.

Introduction

At the 19-28 November 2019 meeting of the NAFO Working Group on Ecosystem Science and Assessment (WG-ESA) it was recognized that in order to evaluate the significance of fishing impacts on the benthos (and VMEs in particular), at the ecosystem level, it would be desirable to have knowledge of the ecosystem functions of the benthos as a whole, so that specific significant adverse impacts (SAIs) on VMEs could be evaluated and placed into a broader context (NAFO, 2020a). Specific traits linked to four important ecological functions provided by benthic communities were identified for initial consideration: A) Bioturbation; B) Nutrient cycling; C) Habitat provision, and D) Functional diversity.

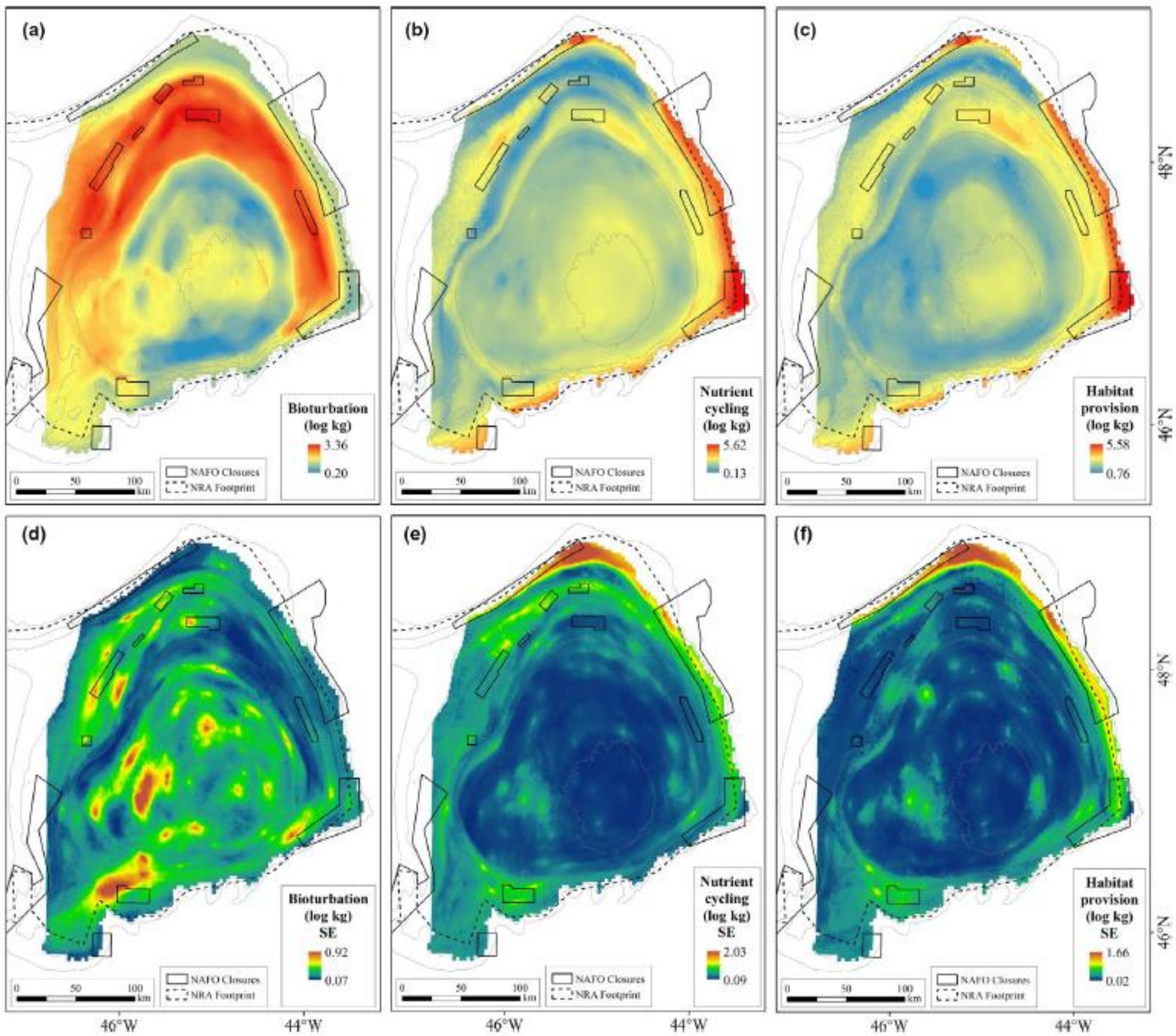

Figure 1. Predicted distribution maps created through random forest modeling of a) bioturbation, b) nutrient cycling and c) habitat provision with associated standard error (SE) for each surface reproduced from Figure 7 in Murillo et al. (2020a).

Murillo et al. (2020a) have analyzed and mapped these for the Flemish Cap ecosystem (Figures 1, 2) using data collected from the 2007 EU Flemish Cap bottom-trawl research survey, conducted by the Instituto Español de Oceanografía together with the Instituto de Investigaciones Marinas and the Instituto Português do Mar e da Atmosfera. The survey sampled the Flemish Cap and the eastern side of Flemish Pass between 138 and 1,488 m depth, following a depth stratified random sampling design (Vázquez et al., 2014; Murillo et al., 2016). It was conducted on board the Spanish research vessel *Vizconde de Eza*, with standardized sets of a Lofoten bottom trawl, with a swept area of ≈0.04 km^2 each. A total of 288 taxa from 176 trawl sets were initially recorded, and the biomass (kg wet weight) for each was determined. Further taxonomic examination lead to a reduction of the total number to 285 discrete taxa.

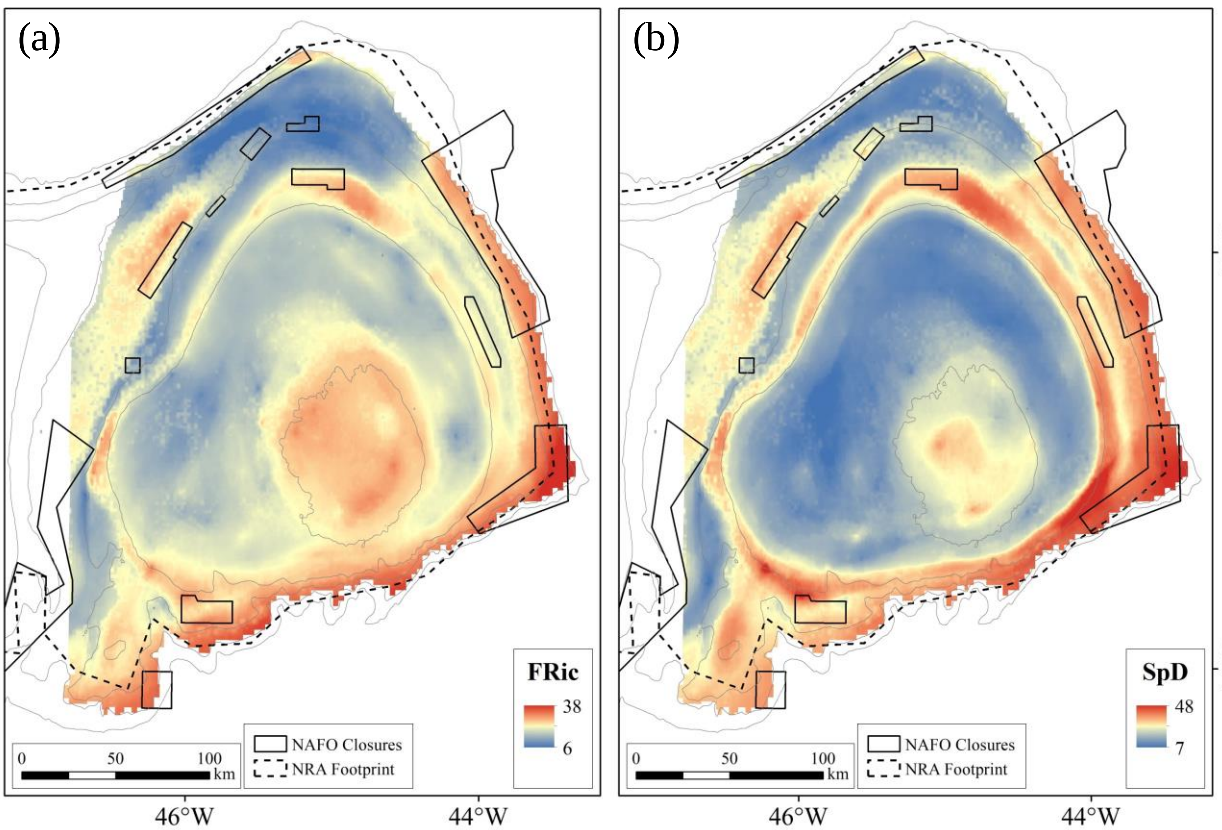

Figure 2. Predicted surfaces from random forest modelling of (a) sample functional richness (FRic), (b) sample species density (SpD) (modified from Murillo et al., 2020b). Reproduced from Supplementary Figure S6.1 of Murillo et al. (2020a).

Here, we utilize a data set with a broader temporal coverage (10 years, Table 1), but with a lower taxonomic certainty, with most of the specimens having been identified at sea by multiple individuals over the time frame. For each ecosystem function we assessed the presence or absence of the function for each taxon in the species lists for the respective cruises, using the available literature and expert opinion from within the authorship of this document.

Methods and Results

The abundance and biomass data associated with these ecosystem functions contain records using different gear types and tow lengths (Table 1), with associated catchability differences, and differing locations (NAFO Divisions) (Figure 3) with different bottom types, which could also affect catchability. To assess whether the different survey data should be used separately or in combination for each ecosystem function, we applied non-parametric statistics (Kolmogorov–Smirnov two sample test (K-S test)) to the catch biomass from each of the three gear/duration data sets for each function data set and for fish and invertebrates separately where relevant (Table 1). [See Discussion for explanation for the use of biomass over abundance]. These were augmented with biomass accumulation curves for comparative data sets. Because each of the surveys covered different and largely non-overlapping spatial extent and depth ranges (Figure 3), natural differences in biomass are confounded in this approach and could enhance or mask differences between gears and/or trawl duration. This effect is most likely to affect the statistical tests involving gear comparison as the Lofoten gear was used almost exclusively on the Flemish Cap while the Campelen trawls were deployed in the Flemish Pass and on Grand Bank. Comparison of trawl duration effects between the surveys using Campelen gear cover a similar spatial extent and so are less likely to be confounded by geospatial differences in catchability, but the EU surveys are deeper and have more deep-water sets which will sample a different fish and invertebrate community (Figure 3).

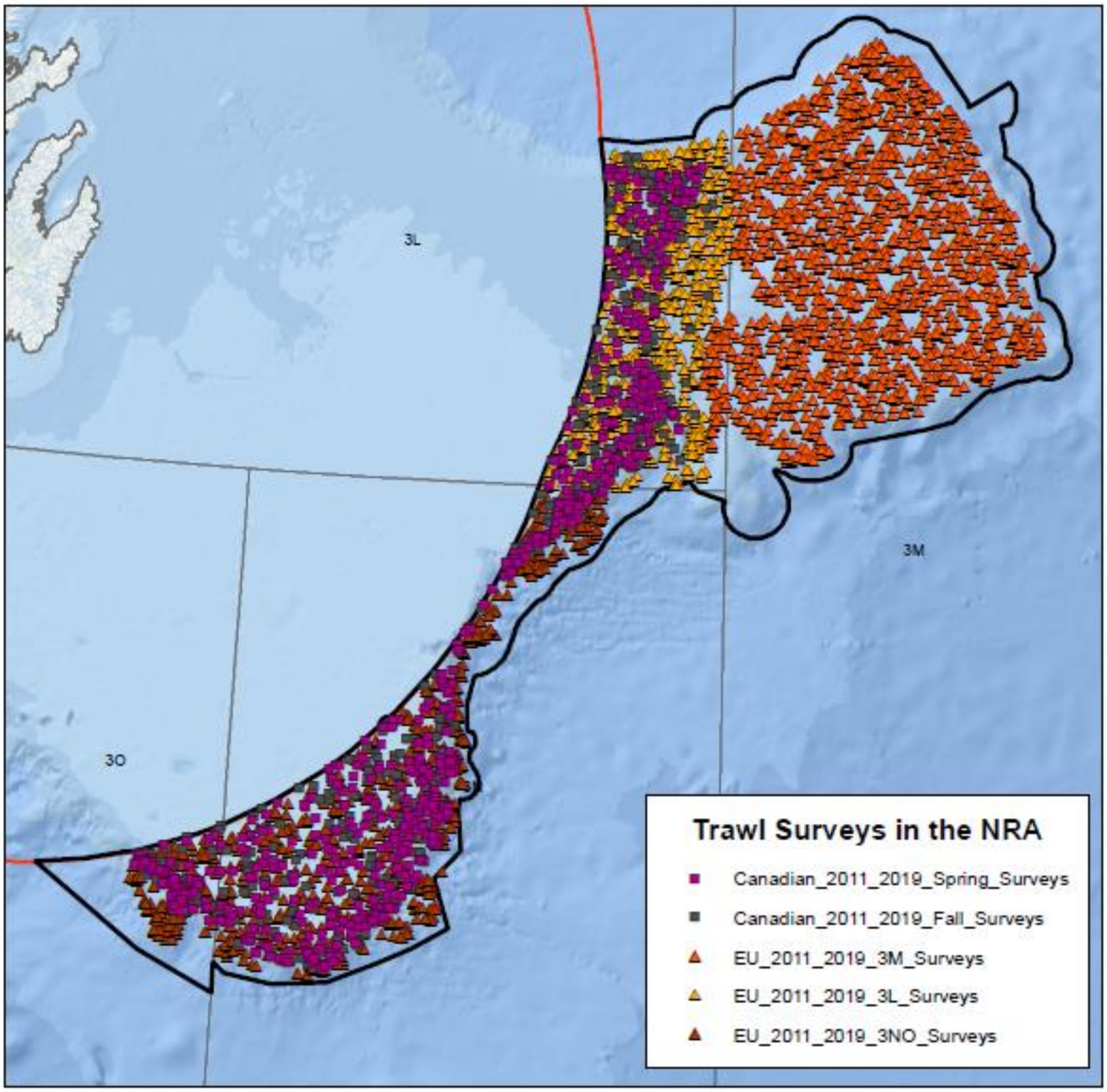

Figure 3. Location of the surveys detailed in Table 1. The Canadian spring and fall surveys are distinguished. European surveys run between May and August (summer).

Murillo et al. (2020a) considered the longevity of each of the 285 taxa that they evaluated. They observed that 63% of the species lived longer than 10 years (and 31% more than 50 years) and that 25% of the species had lifespans of less than 5 years. Additionally, from the 285 taxa, they selected those taxa that constituted 95% of the biomass from each community (Murillo et al., 2016) complemented by the top 20 taxa based on occurrence to account for common species with low biomass (105 taxa). Of this selection, based on taxa with high biomass or occurrence, 75% live more than 10 years. Although the taxonomic identification of those species was more precise than in the current data, it was considered to be representative of the trawl-caught epibenthic species in the region. Given the ten year period of the surveys considered here, we conclude that it is not necessary to further breakdown the data into time periods and that the combined data across the period of collection is sufficient to identify significant concentrations of biomass for each of the functions using the KDE analyses. Longevity is further discussed *post hoc* for the species which contributed most to the significant concentrations of biomass for each function in the analyses.

Table 1. Data sources from contracting party research vessel surveys: EU, European Union; DFO, Department of Fisheries and Oceans Canada; NL, Newfoundland and Labrador; EIO, Instituto Español de Oceanografía; IIM, Instituto de Investigaciones Marinas; IPMA, Instituto Português do Mar e da Atmosfera. *Depth determined from Canadian Hydrographic Service (CHS) bathymetry.

Programme	Period	NAFO Division	Gear	Mesh Size in Codend Liner (mm)	Trawl Duration (min)	Average Wingspread (m)	Depth Range (m) of Trawl Start Data
Spanish 3NO Surveys (IEO)	2011-2019	3NO	Campelen 1800	20	30	24.2-31.9	41-1462
EU Flemish Cap Surveys (IEO, IIM, IPIMAR)	2011-2019	3M	Lofoten	35	30	13.89	129-1460
Spanish 3L Surveys (IEO)	2011-2019	3L	Campelen 1800	20	30	24.2-31.9	106-1433*
DFO NL Multi-species Spring and Fall Surveys (DFO)	2011-2019	3LNO	Campelen 1800	12.7	15	15-20	38-725 (Spring) 36-1379 (Fall)

Kernel density estimation (KDE) utilizes spatially explicit data to model the distribution of a variable of interest. It is a simple non-parametric neighbour-based smoothing function that relies on few assumptions about the structure of the observed data. It has been used in ecology to identify hotspots, that is, areas of relatively high biomass/abundance. It was first applied within NAFO to the identification of significant concentrations of sponge biomass in the NAFO Regulatory Area in 2009 (Kenchington et al., 2009) followed by an application to sea pen biomass (Murillo et al., 2010). Since then it has been applied to all VME Indicator taxa to identify VMEs (Kenchington et al., 2019). In applying KDE to the trait data herein we have followed the same approach as used previously to identify the VME polygons, that is, we have used biomass data (see Discussion). The default search radius was used based on the spatial extent of the data and only adjusted if there were gaps in the coverage. We have performed the analyses separately for the different surveys based on an assessment of the catch biomass data so that catchability issues are reduced. The resultant KDE polygons were then presented together in a single map to appreciate the full spatial extent of the significant biomass concentrations for each of the traits in the NRA.

Bioturbation

Sediments play a key role in the exchange of nutrients in marine ecosystems and in the marine nitrogen cycle in particular, where they influence global biogeochemical cycles (Laverock et al., 2011). Bioturbation, defined here as "the mixing of a sediment by the burrowing, feeding or other activity of living organisms, forming a bioturbated sediment" (Froese & Pauly, 2000), affects ecosystem functions and properties such as energy and nutrient cycling, habitat stability/vulnerability and habitat heterogeneity (Degen et al., 2018). Deposit feeding and ventilation of burrows by infauna are two of the most common and widespread bioturbation processes (Shull, 2009). The activity of large burrowing macrofauna (bioturbators) in soft sediments can significantly affect microbial processes associated with remineralisation by altering the properties of the sediment, principally through oxygenation (Queirós et al., 2013). Fish (Villéger et al., 2017) and marine mammals can also cause bioturbation through the construction of burrows and through their foraging and defense behaviours (Shull, 2009). Examples include the sand lance (*Ammodytes dubius*, Ammodytidae) which burrows into the sand or gravel (Scott, 1973; Staudinger et al., 2020), and walruses which dig in the sediments for molluscs (Ray et al., 2006). Bottom-contact fishing gears may directly affect sediment geochemistry (particle size distribution, porosity, organic matter, oxygen uptake, denitrification, sulphate reduction and sediment–water nutrient exchange) through their physical contact with surficial sediments. In a study examining the long-term impact of benthic trawl disturbance on biogeochemical processes in the upper layers of sediment, no evidence of an effect was found, however, in deeper anoxic sediment, mineralisation processes involving sulphate reduction were stimulated by the extra disturbance (Trimmer et al., 2005). Such studies are area-specific and nothing similar has been undertaken in the NAFO Regulatory Area to contrast the positive and negative effects of fishing on sediment geochemistry.

Herein, adult-stage bioturbation trait presence/absence was assessed for each of the recorded taxa in the research vessel catches conducted by Canada and the EU. To do so, we used the comprehensive assessments of Queirós et al. (2013) for European marine infaunal invertebrates (N=1033), Murillo et al. (2020a) for epibenthic species from Flemish Cap (N=285), Sutton et al. (2020) for epibenthic species from the Beaufort (N=246) and Chukchi Seas (N=247), and Kaminsky et al. (2018) for the San Jorge Gulf, Argentina (N=61), in addition to literature searches for species not covered by those sources.

Murillo et al. (2020a) assessed bioturbation using their motility category 'burrow' which included active and tube burrowers, and did not include surficial modifiers in their classification of bioturbators. Sutton et al. (2020) assessed bioturbation using the trait modalities 'burrow dwelling' and 'burrower' for traits 'Living habit' and 'Movement' respectively. Queirós et al. (2013) provided a database just for bioturbation classification and identified further bioturbation categories [Reworking types: surficial modifiers; biodiffusors (animals that transport sediment particles randomly over short distances as they move through sediments); upward and downward conveyors; and regenerators (animals that release sediment to the overlying water column, which is then dispersed as they burrow)]. Herein, notes were made for taxa that were so identified from that database. Kaminsky et al. (2018) also classified bioturbation activity as one of "active burrower (diffusive)", "gallery burrower", "surface dweller", or "tube burrower". For taxa referenced from that publication we included all categories except for "surface dweller" and also noted which category they were assigned to. The "surface dweller" category was excluded as it did not equate to "Surficial modifiers" as used in Queirós et al. (2013) but rather seemed to separate out epifauna from the others and included taxa such as *Gammarus* sp. which are not considered bioturbators by others (e.g., Queirós et al., 2013). Species listed in that publication as surface dwellers were instead used to support bioturbation absence in our data. Our data come only from trawls and so capture primarily epibenthic species. Given that bioturbation includes infaunal species which are in some areas the most important bioturbators, we recognize that our assessment will not capture the full bioturbation activity of the study area. However, by including the surficial modifiers in our assessment, and the active burrowers, we hope to identify areas where bioturbation is potentially impacted by trawling through removal of species and changes to benthic community composition.

Table 2. List of taxa where bioturbation activity was inferred based on congeneric, confamilial or higher order aggregations. O=Order; F=Family; G=Genus; C=Class.

Taxon used for Consolidating Data	Rationale	Number of taxa affected
(P.) Annelida	Inferred to this general phylum level classification in the EU surveys based on the largest biomass of annelids (Sabellids).	1
(C.) Polychaeta	Inferred from the largest biomass of annelids (Sabellids) from EU surveys.	1
(C.) Pycnogonida	Inferred from the majority of species identified.	1
(C.) Bivalvia	Inferred from the majority of species identified.	2
(O.) Pennatulacea	All considered surficial modifiers due to rachis anchoring in substrate and ability to withdraw and relocate	5
(O.) Neogastropoda	Inferred from the majority of species identified; also applied to the Class Gastropoda category following Sutton et al. (2020) but not to other orders.	10
(O.) Pleuronectiformes	All of these flounders were considered surficial modifiers based on bioturbation reference for *Hippoglossoides platessoides*.	7
(O.) Rajiformes	All of these rays were considered surficial modifiers based on benthic classification and behaviour.	13
(O.) Nudibranchia	Inferred from *Tritonia*.	1
(F.) Aphroditidae	Extended classification to remaining species in family.	1
(F.) Crangonidae	All species included based on familial assignation from the literature.	7
(F.) Asteriidae	Extended classification to all species in family based on *Leptasterias*.	4
(F.) Pterasteridae	Infered from confamilial species *Pteraster pulvillus*	1
(F.) Ophiuridae	Inferred from confamilial species based on *Ophiura sarsii*.	1
(G.) Stereoderma	Cucumariidae are filter-feeders but can move across the surface creating trails on soft sediments.	1
(G.) Eualus	Extended classification to all species in genus based on *Eualus cranchii.*	5

When species information was not available Kaminsky et al. (2018) classified traits according to the taxa's Family, Order or higher classification, to include all species in the group analyses. However many groups have a diversity of bioturbation behaviour associated with feeding strategy. As a result we did not feel confident in following that example uniformly. However for some groups we extended the classifications based on our knowledge of the species in the region. Bioturbation activity was inferred for those groups listed in Table 2. We note that our analyses are based on biomass and so for many of the taxa in our data set with small associated biomass, correct designation of bioturbation will not likely influence our KDE results to a large degree.

Solan et al. (2004) described a metric of bioturbation which combines abundance and biomass data with information on the life traits of species (Queirós et al., 2020). Although both abundance and biomass data are available we did not attempt to combine them into a metric of bioturbation due to the assumed widely variable differences in catchability among the taxa and missing abundance data for some invertebrate records. The lists of taxa that were classified as bioturbators are provided in Appendix 1 and Appendix 2 for the Canadian and EU surveys (Table 1, Figure 3) respectively.

Table 3. K-S Tests for similarity of group biomass of the bioturbation data from the Canadian (DFO) surveys by season (Spring/Fall).

Groups Tested	K-S Test
Same gear and area, by seasons with different depths (Table 1)	
DFO NL Multi-species Spring vs. Fall Surveys (DFO)- Fish Species	K-S= 0.022; P<0.0002
DFO NL Multi-species Spring vs. Fall Surveys (DFO)- Non-fish Species	K-S= 0.136; P<0.0001

Table 4. K-S Tests for similarity of group biomass among subsets of data from the EU surveys, and between Canadian and EU surveys.

Groups Tested	K-S Test
Same gear and area, by tow length	
Campelen 1800 3LNO EU and Cdn Non-fish 15 min vs. 30 min	K-S= 0.315; P<0.0001
Campelen 1800 3LNO EU and Cdn Fish 15 min vs. 30 min	K-S= 0.106; P<0.0001

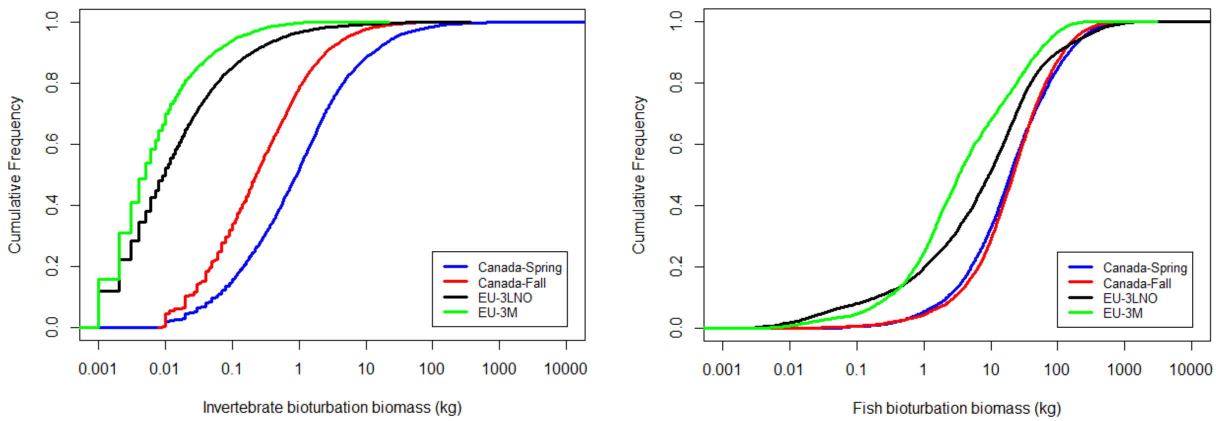

Figure 4. Cumulative bioturbator biomass distribution for invertebrates (left) and fish (right) for each of the four surveys from which data were collected (Table 1).

Analyses of the bioturbator biomass data showed significant differences between the spring and fall surveys in Canada, and with tow length using the Campelen 1800 gear for both fish and invertebrates (Tables 3 and 4). The two Canadian surveys also differed in depth. Cumulative biomass distribution plots (Figure 4) show that for fish the two Canadian surveys, one conducted in the spring and one in the fall in the same area with the same gear, are very similar throughout their biomass distributions, unlike for the invertebrates. Note that the two EU surveys of 3L and 3NO were combined for these analyses. Consequently we have combined the Canadian spring and fall surveys for the KDE analyses for the fish and kept the other surveys separate. This produced the following data sets for KDE analyses:

1. EU surveys invertebrate data 3M, 30 min tow length, depth range 132-1478 m;
2. Canadian invertebrate data 3LNO, 15 min tow length, spring, depth range 38-725 m;
3. Canadian invertebrate data 3LNO, 15 min tow length, fall, depth range 36-1333 m;
4. EU surveys invertebrate data 3LNO, 30 min tow length, depth range 40-1429 m;
5. EU surveys fish data 3M, 30 min tow length, depth range 129-1460 m;
6. Canadian fish data 3LNO, 15 min tow length, depth range 36-1379 m;
7. EU surveys fish data 3LNO, 30 min tow length, depth range 40-1433 m.

Kernel Density Analyses

EU Flemish Cap Surveys of Division 3M – Invertebrate Bioturbation Biomass

Following previously established methods and assessment criteria (Kenchington et al., 2019), a kernel density surface was created using the invertebrate bioturbation biomass data collected from the EU Flemish Cap research vessel surveys of NAFO Division 3M (Table 1, Figure 3). There were 4514 invertebrate records that had their biomass summed at 1357 trawl locations (Figure 5). KDE parameters were: Search Radius = 8.20 km; Contour Interval = 0. 00001; Cell size default = 984.4 m. These parameters are the default parameters and there was no need to increase the search radius as the default value created a continuous surface for the analysis to proceed (Figure 5).

The assessment of the change in area between successively larger catch weights (Table 5) shows the area building nicely until the 0.5 kg threshold and keeping very tight. In going from 0.5 to 0.3 kg some nearby areas are joined and some new ones are identified. The new areas have a lot of data in the gaps supporting that increase so this is considered a valid increase in area. Going from 0.5 kg to the area captured by the 0.2 kg threshold is supported by 16 points although some areas were combined with few points in the area between previously established polygons. The next area of large increase is going from 0.2 to 0.1 (Table 5, Figure 6). The polygons created using the 0.1 kg threshold greatly expand the area and there are few data points justifying the spatial extent. As a result the 0.2 kg threshold was used to delineate the KDE polygons with high concentrations of invertebrate bioturbators in NAFO Division 3M (Figure 6).

Table 5. The number of points attributing to the delineation of invertebrate bioturbation function KDE polygons based on successively smaller research vessel bioturbator catch weight thresholds (kg) from the EU 3M Surveys. The area and number of observations used to define each polygon and the percent change in area and the number of additional observations between successive thresholds are provided. The shaded row represents the threshold used to define the bioturbation function KDE polygons.

Invertebrate Bioturbator Catch Threshold (Kg)	Number of Observations in Polygon	Additional Observations Per Interval	Area of Polygon (km^2)	Percent Change in Area Between Successive Thresholds
2	8		15.9	2343.1
1	25	17	389.5	62.8
0.7	40	15	634.3	40.8
0.5	56	16	893.1	240.3
0.3	111	55	3039.6	98.0
0.2	154	43	6018.6	149.9
0.1	276	122	15041.6	24.2
0.07	360	84	18684.8	24.1
0.05	448	88	23180.8	10.6
0.03	574	126	25634.0	97.7
0.01	924	350	50684.8	1.9
0.005	1133	209	51625.5	3.6
0.001	1357	224	53460.5	

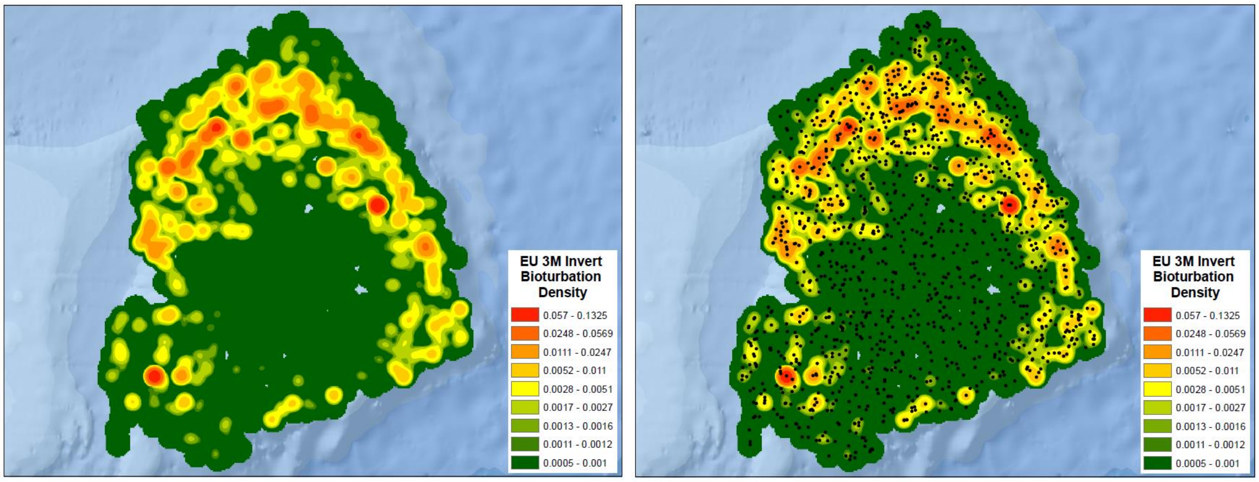

Figure 5. EU 3M Survey: Kernel density invertebrate bioturbation biomass (kg/km^2) surface in NAFO Division 3M. Left Panel: Kernel density surface. The green areas represent low bioturbation biomass densities while the red areas indicate high densities; Right Panel: EU Flemish Cap research vessel survey data points overlain on the kernel density surface showing spatial distribution of data.

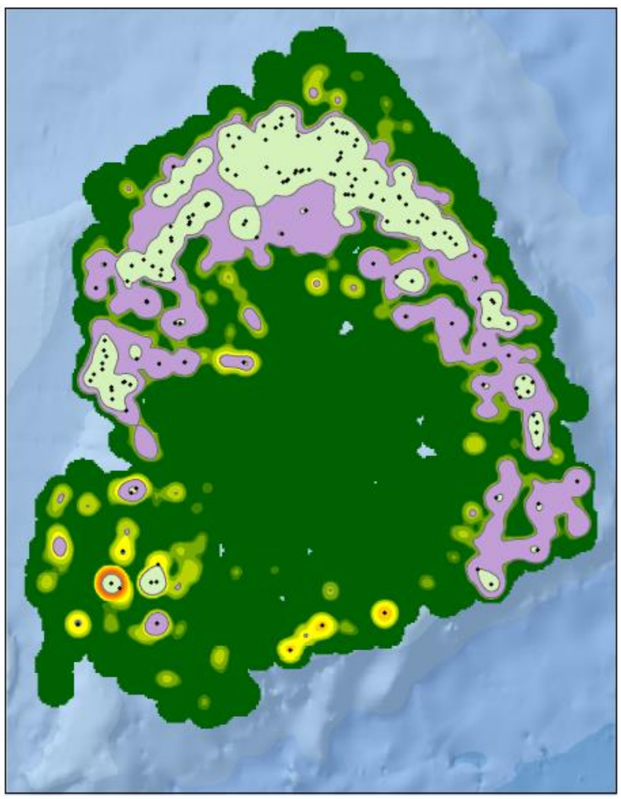

Figure 6. EU 3M Survey: The kernel density distribution of invertebrate bioturbation biomass in NAFO Division 3M based on analyses of the EU survey data. Comparison of the area covered by catches ≥ 0.2 kg (light green) and catches ≥ 0.1 kg (purple) showing the increase in area with the smaller threshold. Black dots indicate location of survey stations used to determine these areas. The KDE polygons encapsulating catches ≥ 0.2 kg (light green) are considered the KDE invertebrate bioturbation polygons.

The influence of the sea pens in the KDE analysis is strong, showing similarity in distribution with the KDE analysis of sea pens performed in 2019 (Kenchington et al., 2019). Appendix 3 provides the list of taxa found in the catches used to establish the KDE invertebrate bioturbation polygons (Figure 6). Of the 141 taxa listed as bioturbators in all EU surveys, 51 were caught in the EU surveys of Division 3M (Appendix 3) and 44 were found in the catches which created the KDE bioturbator polygons in Division 3M (Appendix 3). The 7 taxa not present in the catches used to construct the KDE polygons for bioturbation may still be present in smaller weight catches below the threshold used, and inside the KDE (not examined). As suggested by the location of the polygons, the sea pens *Anthoptilum* and *Halipteris finmarchica* contributed most to the total biomass of these trawls (71.4%) and both were prevalent, occurring in 137 and 108 (Appendix 3) of the 154 trawl locations (Table 5), respectively. The sea pens anchor into soft sediments using their rachis and some species such as *Pennatula rubra* can withdraw completely into the sediments (Chimienti et al., 2018). This behaviour oxygenates the sediments. Echinoderms (*Ctenodiscus crispatus*, Benthopectinidae, *Ophiomusa lymani*, Pterasteridae and *Brisaster fragilis*) and the solitary cup coral *Flabellum alabastrum* contributed to the 90% of the cumulative biomass in the catches (Appendix 3). The echinoderms and the cup coral are surficial modifiers, with the cup coral noted as moving slowly in the sediment leaving a trail (Buhl-Mortensen et al., 2007). Eleven of the 44 bioturbator taxa used to construct the KDE polygons were VME Indicator taxa (NAFO, 2020b) - all relatively long-lived sea pens (20-30 years, Murillo et al., 2018), collectively comprising 73.7% of the total bioturbator biomass in these catches. Molluscs, annelids, sipunculids, arthropods and nemerteans were also present in lesser biomass (Appendix 3).

EU Flemish Cap Surveys of Division 3M – Fish Bioturbation Biomass

Following the same methods and assessment criteria (Kenchington et al., 2019), a kernel density surface was created using the fish bioturbation biomass data collected from the EU Flemish Cap research vessel surveys of NAFO Division 3M (Table 1, Figure 3). There were 1549 trawl locations in the analysis (Figure 7). KDE parameters were: Search Radius = 8.20 km; Contour Interval = 0.005; Cell size default = 985 m. These parameters are the default parameters and there was no need to increase the search radius as the default value created a continuous surface (Figure 7). The high densities areas of bioturbating fish cover a greater spatial extent than that of the invertebrates (compare Figures 5 and 7), perhaps reflecting less aggregation in the fish due to the larger scale of their movements.

The assessment of the change in area between successively larger catch weights (Table 6) shows the area increasing (due to new areas being delineated) until the 75 kg threshold where the area increases 36.8% when moving to the 60 kg threshold (Table 6, Figure 8). The KDE polygons created using the 60 kg threshold expand the area using few data points and leave a large area unsupported by data (Figure 8). As a result the 75 kg threshold was used to delineate the KDE polygons with high concentrations of fish bioturbators in NAFO Division 3M (Figure 8). The polygons lie mainly on the northern Flemish Cap in deeper water similar to that seen in the invertebrate bioturbation polygons (Figure 6), however the fish also show bioturbation activity on the shallowest part of Flemish Cap and on the southeast slope (Figure 8).

The species contributing to the fish bioturbator KDE polygons in NAFO Division 3M are listed in Appendix 4. Fourteen of the 17 fish bioturbators identified in the EU surveys (Appendix 2) were found in the catches in NAFO Division 3M and 12 of those were found in catches used to create the fish bioturbator KDE polygons on Flemish Cap. Greenland halibut (*Reinhardtius hippoglossoides*) comprise 90% of the total fish bioturbator biomass used to construct the KDE polygons and therefore heavily influenced the analyses. This is a commercial species and it was found in 182 of the 201 (Table 6) trawl sets used to delineate the polygons. American plaice (*Hippoglossoides platessoides*) was the second most prominent species in terms of biomass but it was only found in 19 trawl sets (Appendix 4), all in the shallow part of Flemish Cap (Figure 8). Witch flounder, *Glyptocephalus cynoglossus*, was the most prevalent species in the catches after Greenland halibut, being found in 66 of the trawl catches (Appendix 4). The sand lance, *Ammodytes dubius*, and the smooth skate, *Malacoraja senta*, were present in the EU Division 3M surveys but were not recorded in the catches used to delineate the fish bioturbation polygons (Figure 8). They may be present inside those polygons in catches below the 75 kg threshold that was identified to delineate the polygons.

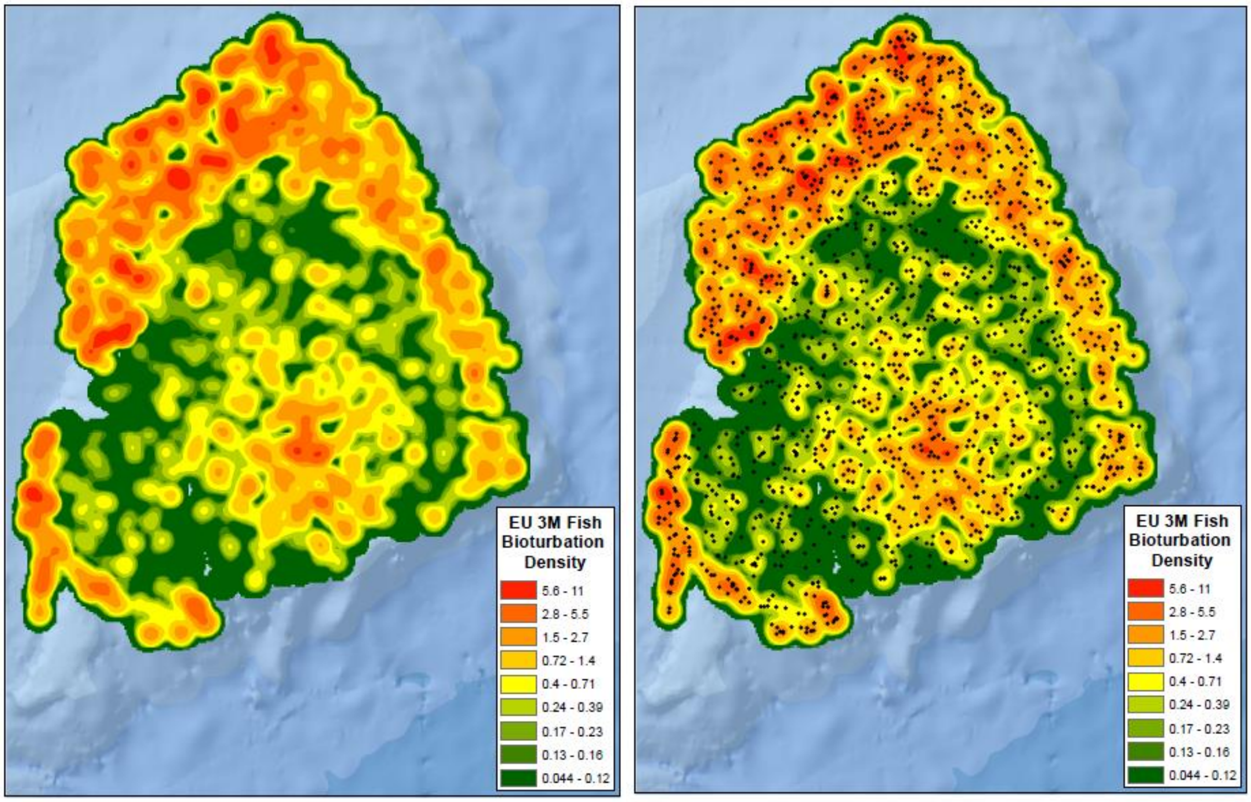

Figure 7. EU 3M Survey: Kernel density fish bioturbation biomass (kg/km^2) surface in NAFO Division 3M. Left Panel: Kernel density surface. The green areas represent low bioturbation biomass densities while the red areas indicate high densities; Right Panel: EU Flemish Cap research vessel survey data points overlain on the kernel density surface showing spatial distribution of data.

Table 6. The number of points attributing to the delineation of fish bioturbation function KDE polygons based on successively smaller research vessel bioturbator catch weight thresholds (kg) from the EU 3M Surveys. The area and number of observations used to define each polygon and the percent change in area and the number of additional observations between successive thresholds are provided. The shaded row represents the threshold used to define the bioturbation function KDE polygons.

Fish Bioturbator Catch Threshold (Kg)	Number of Observations in Polygon	Additional Observations Per Interval	Area of Polygon (km^2)	Percent Change in Area Between Successive Thresholds
150	38		1242.4	97.5
125	71	33	2454.3	107.5
100	114	43	5093.9	77.2
85	158	44	9024.7	18.3
75	201	43	10677.8	36.8
60	268	67	14604.1	14.5
50	345	77	16717.5	5.3
40	427	82	17599.6	9.2
35	490	63	19214.6	13.5
30	561	71	21800.8	16.3
25	643	82	25343.8	3.0
20	740	97	26116.4	16.9
15	849	109	30533.6	18.8
12.5	916	67	36275.0	16.1
10	998	82	42097.7	12.4
7.5	1085	87	47297.1	5.3
5	1221	136	49790.3	5.9
3.5	1325	104	52733.6	1.4
2	1428	103	53459.5	2.9
0.008	1547	119	55028.3	

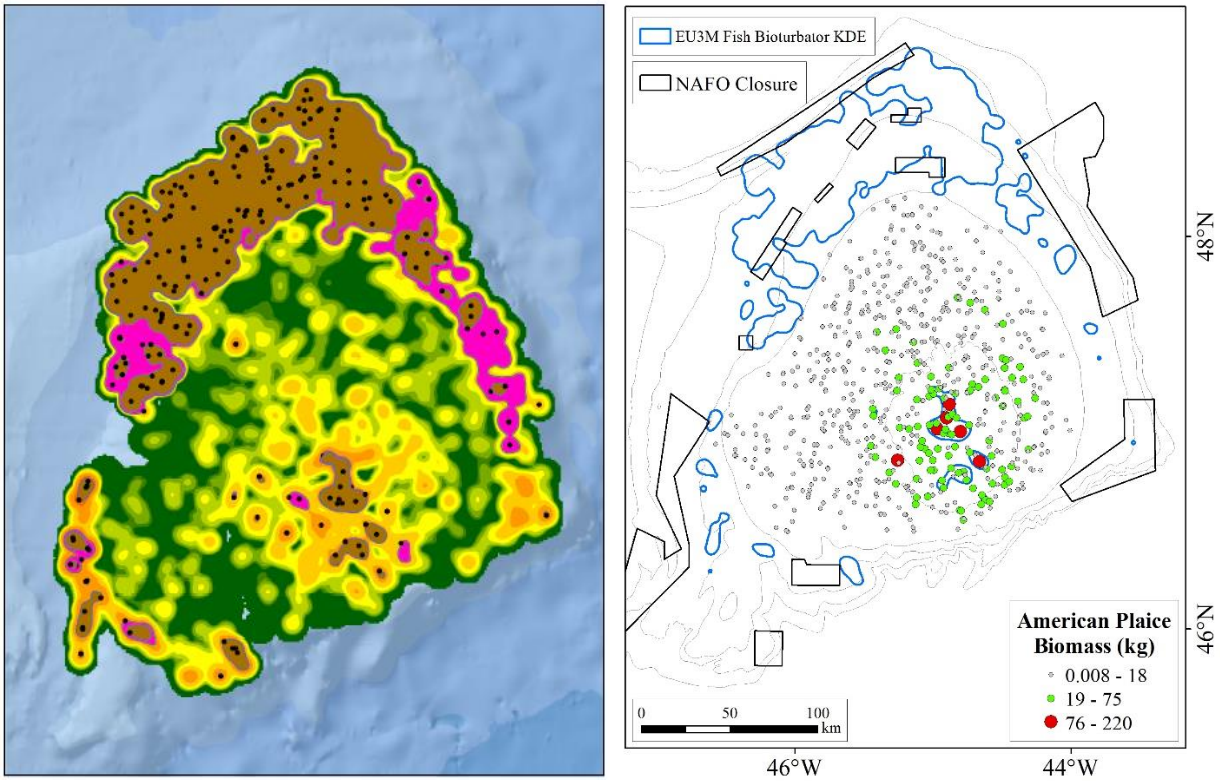

Figure 8. EU 3M Survey: Left panel: The kernel density distribution of fish bioturbation biomass in NAFO Division 3M based on analyses of the EU survey data. Comparison of the area covered by catches ≥ 75 kg (brown) and catches ≥ 60 kg (pink) showing the increase in area. Black dots indicate location of survey stations used to determine these areas. The KDE polygons encapsulating catches ≥ 75 kg (brown) are considered the KDE fish bioturbation polygons. Right panel: Biomass of American plaice (*Hippoglossoides platessoides*) from the same EU surveys of Division 3M showing the high biomass associated with the fish bioturbation KDE on the shallow portion of Flemish Cap.

Canadian Fall Surveys of Divisions 3LNO – Invertebrate Bioturbation Biomass

A kernel density surface was created using the invertebrate bioturbation biomass data collected from the Canadian research vessel surveys of NAFO Division 3LNO conducted in the fall (Table 1, Figure 3). There were 513 trawl locations in the analysis (Figure 9). KDE parameters were: Search Radius = 14.04 km; Contour Interval = 0.0002; Cell size default = 1684.3 m. These parameters are the default parameters and there was no need to increase the search radius as the default value created a sufficient surface for the analysis although there are some gaps in an area on the Tail of Grand Bank (Figure 9). Increasing the search radius to fill in those blanks was deemed not justified as it would lead to greater interpolation around the data. This would have the effect of increasing the polygon area where data is sparse (especially in the Flemish Pass area).

The KDE analyses showed areas of concentrated invertebrate bioturbator biomass on the Tail of Grand Bank, with lesser activity in Flemish Pass (Figure 9). The areas near the Southeast Shoal are near the areas assessed for the seq squirt (*Boltenia ovifera*) VMEs (Kenchington et al., 2019).

The polygons constructed around successively smaller catch thresholds showed that the area difference was increasing for the first six intervals as areas were delineated and then combined. The greatest change in area that was not well supported by a number of data points filling the gaps was between the 2 and 1 kg thresholds (Figure 10, Table 7). The ≥ 1 kg polygon (Figure 10) captured areas in Flemish Pass that were only supported by one or two data points. Consequently we identified the 2 kg threshold as the best supported to represent the invertebrate bioturbation biomass from the Canadian Fall Surveys of NAFO Divisions 3LNO.

Table 7. The number of points attributing to the delineation of bioturbation function KDE polygons based on successively smaller research vessel bioturbator catch weight thresholds (kg) from the Canadian Fall Survey of NAFO Divisions 3LNO. The area and number of observations used to define each polygon and the percent change in area and the number of additional observations between successive thresholds are provided. The shaded row represents the threshold used to define the bioturbation function KDE polygons.

Invertebrate Bioturbator Catch Threshold (Kg)	Number of Observations in Polygon	Additional Observations Per Interval	Area of Polygon (km²)	Percent Change in Area Between Successive Thresholds
25	14		1400.4	91.7
10	30	16	2684.7	60.4
7	47	17	4306.7	82.8
3	78	31	7873.6	46.8
2	98	20	11559.5	37.5
1	136	38	15890.8	7.2
0.75	157	21	17035.9	29.4
0.5	194	37	22037.9	6.7
0.4	210	16	23523.1	19.1
0.3	244	34	28017.1	20.6
0.2	282	38	33779.0	28.7
0.1	357	75	43468.6	14.0
0.008	508	151	49563.3	

Of the 44 invertebrate bioturbator taxa recorded in the Canadian surveys of NAFO Divisions 3LNO, 29 were present in the fall surveys used to run the KDE analyses and 24 of those were found in the catches greater or equal to 2 kg (Table 7) used to delineate the KDE polygons. In contrast to Division 3M the bioturbator biomass in the KDE polygons in Divisions 3LNO was dominated by holothuroids and the brittle star *Ophiura sarsii* (Appendix 5). Only one VME taxon was present, the Pennatulacea (sea pens), and they only contributed to 0.005% of the total catch weight. The sea cucumber *Cucumaria frondosa*, occurring in 73 of the 98 trawl catches (Table 7) was the most prevalent species, followed by gastropods which were present in 54 trawl catches (Appendix 5). *Cucumaria frondosa* is a surficial modifier. It slightly buries into the sediments to orient itself for suspension feeding (Sun et al., 2018) and aggregations have been observed to tumble/roll across the sea floor (Hamel et al., 2019). Sun (2019) documents three modes of locomotion: forward crawling, and passive and active rolling, all modifying surficial sediments.

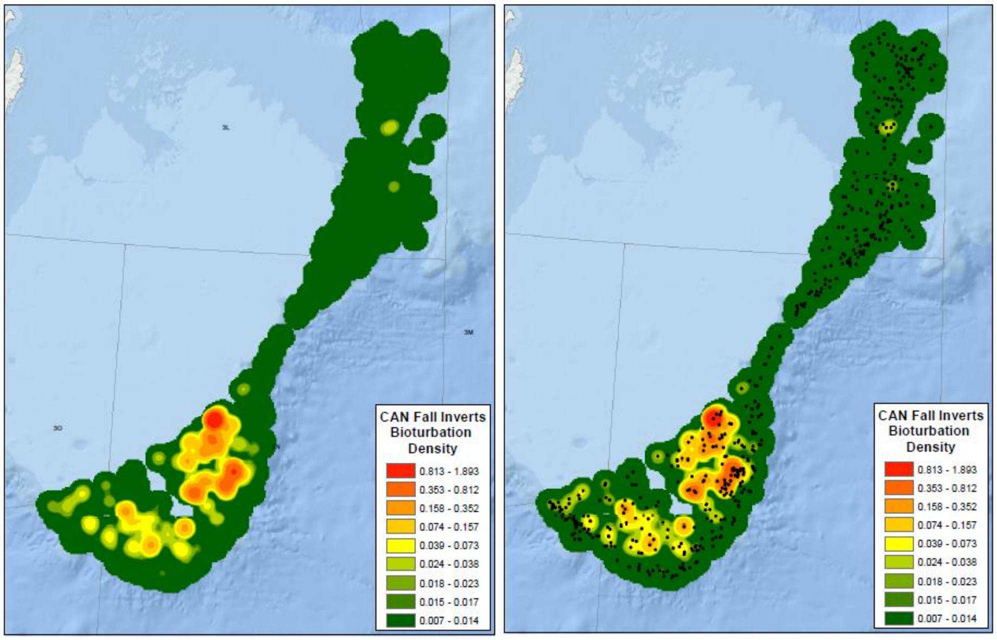

Figure 9. Canadian Fall 3LNO Survey: Kernel density invertebrate bioturbation biomass (kg/km^2) surface in NAFO Divisions 3LNO. Left Panel: Kernel density surface. The green areas represent low bioturbation biomass densities while the red areas indicate high densities; Right Panel: Canadian Fall research vessel survey data points overlain on the kernel density surface showing spatial distribution of data.

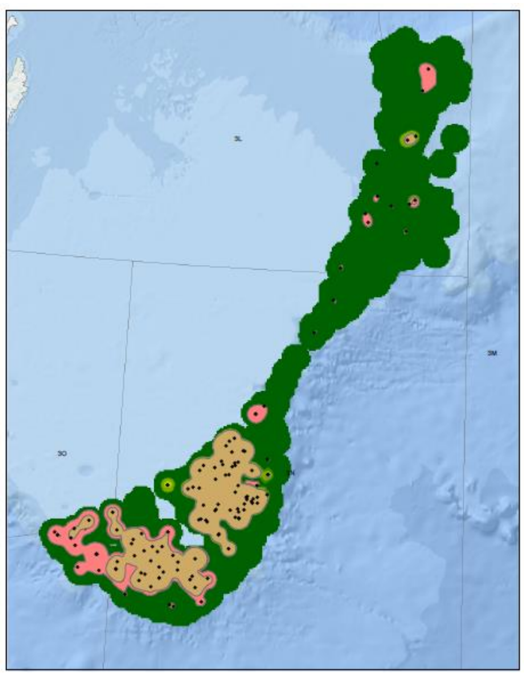

Figure 10. Canadian Fall 3LNO Survey: The kernel density distribution of invertebrate bioturbation biomass in NAFO Divisions 3LNO based on analyses of Canadian Fall Survey data. Comparison of the area covered by catches ≥ 2 kg (light brown) and catches ≥ 1 kg (salmon) showing the increase in area. Black dots indicate location of survey stations used to determine these areas. The KDE polygons encapsulating catches ≥ 2 kg (light brown) are considered the KDE invertebrate bioturbation polygons.

Canadian Spring Surveys of Divisions 3LNO – Invertebrate Bioturbation Biomass

A kernel density surface was created using the invertebrate bioturbation biomass data collected from the Canadian research vessel surveys of NAFO Divisions 3LNO conducted in the spring (Table 1, Figure 3). There were 551 trawl locations in the analysis (Figure 11). KDE parameters were: Search Radius = 13.86 km; Contour Interval = 0.0005; Cell size default = 1662.9 m. These parameters are the default parameters and there was no need to increase the search radius as the default value created a continuous surface (Figure 11). The kernel density surface is similar to that produced from the fall surveys (Figure 9) with most of the invertebrate biomass occurring on the Tail of Grand Bank and relatively less in Flemish Pass (Figure 11). The increased number of tows in these surveys gives a more continuous coverage than in the fall survey.

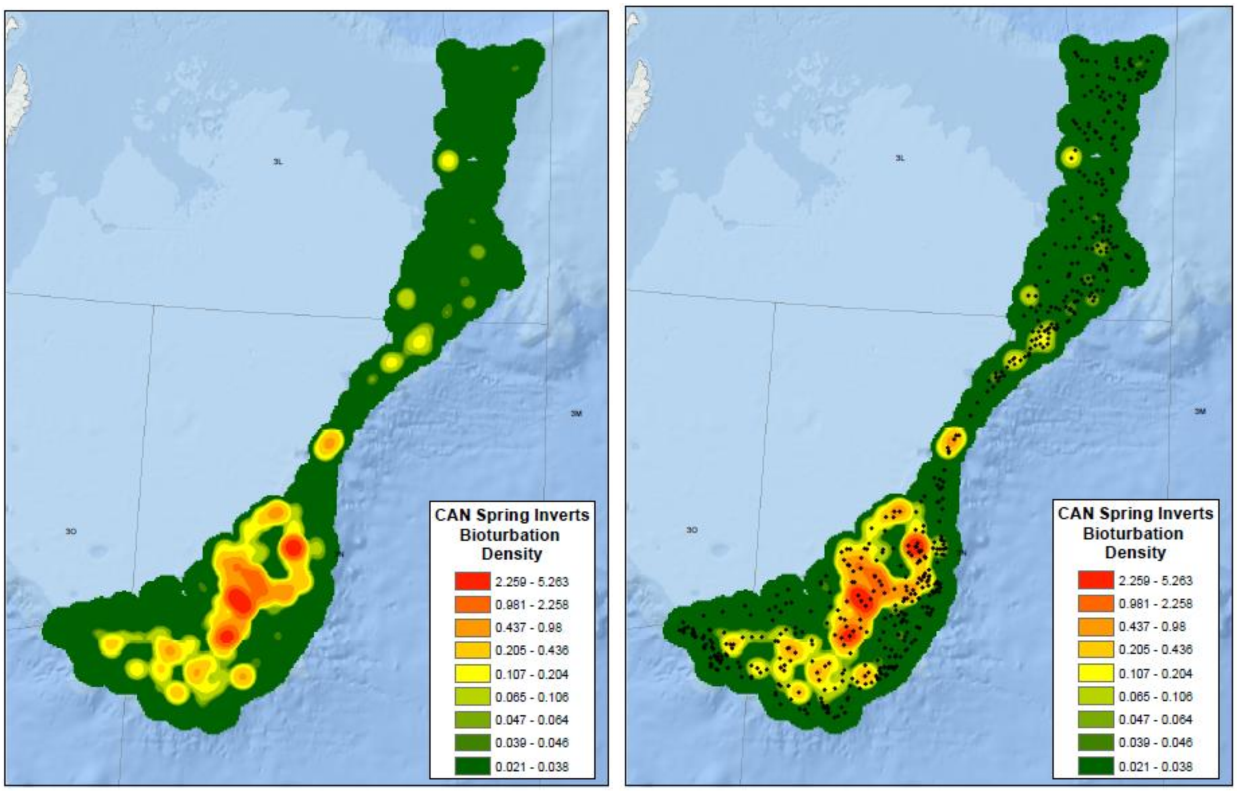

Figure 11. Canadian Spring 3LNO Survey: Kernel density invertebrate bioturbation biomass (kg/km^2) surface in NAFO Divisions 3LNO. Left Panel: Kernel density surface. The green areas represent low bioturbation biomass densities while the red areas indicate high densities; Right Panel: Canadian Spring research vessel survey data points overlain on the kernel density surface showing spatial distribution of data.

The largest catch threshold, ≥ 100 kg, identified a number of trawl locations which were near one another on the Tail of Grand Bank. From this larger starting area (Table 8), the area increased again through the identification of 3 new areas outside the initial polygons established with the 100 kg threshold. The area increased with each threshold and each new area was generally well supported by the data (data within the area and not just on the periphery). The greatest change in area that was not as well supported by a number of data points filling the gaps was between the 5 and 3 kg thresholds (Figure 12, Table 8). The 3 kg polygon (Figure 12) captured a large area along Flemish Pass that was not well supported. Consequently we identified the 5 kg threshold as the best supported to represent the invertebrate bioturbation biomass from the Canadian Fall Surveys of Divisions 3LNO.

Table 8. The number of points attributing to the delineation of bioturbation function KDE polygons based on successively smaller research vessel bioturbator catch weight thresholds (kg) from the Canadian Spring Survey of Divisions 3LNO. The area and number of observations used to define each polygon and the percent change in area and the number of additional observations between successive thresholds are provided. The shaded row represents the threshold used to define the bioturbation function KDE polygons.

Invertebrate Bioturbator Catch Threshold (Kg)	Number of Observations in Polygon	Additional Observations Per Interval	Area of Polygon (km^2)	Percent Change in Area Between Successive Thresholds
100	14		1748.0	54.0
50	29	15	2692.2	95.9
25	44	15	5274.6	87.9
15	62	18	9910.7	28.0
10	72	10	12690.0	21.4
5	108	36	15400.2	37.3
3	146	38	21147.1	22.6
2	190	44	25922.1	12.1
1.35	226	36	29065.5	16.5
1	261	35	33847.6	17.7
0.7	292	31	39846.5	2.5
0.5	327	35	40835.3	4.7
0.35	364	37	42762.6	10.5
0.25	398	34	47255.5	1.7
0.15	437	39	48046.4	4.5
0.1	551	114	50218.9	0.0
0.05	551	0	50218.9	0.0
0.008	551	0	50218.9	

The Canadian spring surveys of Divisions 3LNO contained a similar suite of bioturbator species as the fall surveys, with most taxa in common. The spring surveys had 27 bioturbator taxa present in the catches and of those 22 were present in the catches greater than or equal to 5 kg (Table 8) used to delineate the KDE bioturbation polygons (Appendix 6), with the Pennatulacea (sea pens) being the only VME Indicator taxa present and contributing only 0.013% of the total biomass. *Cucumaria frondosa*, a surficial modifier as noted above, was the top species contributing to the total biomass in the catches and this was followed by the sand dollar *Echinarachnius parma*. Both were prevalent species, being found in 89 and 76 trawl sets (Appendix 6) of the 108 used to delineate the polygons (Table 8). The sand dollars were much more prevalent in the spring surveys than in the fall (Appendix 5 vs. Appendix 6). The reason for this is unknown. In other species seasonal migratory behaviour has been observed (discussed in Yeo et al., 2012). Sand dollars are important bioturbators (Lohrer et al., 2005) and were found to modify at least a third of the total surface in a study area on Sable Island Bank (Stanley and James, 1971). The sand dollars and the brittle stars, *Ophiura sarsii*, are known to be very susceptible to damage by bottom contact fishing gears (Prena et al., 1999).

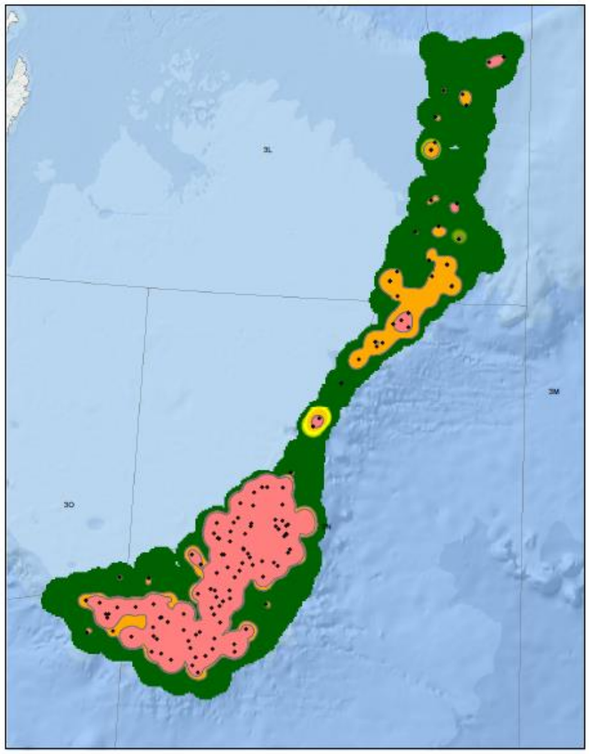

Figure 12. Canadian Spring 3LNO Survey: The kernel density distribution of invertebrate bioturbation biomass in the NAFO Regulatory Area 3LNO based on analyses of Canadian Spring Survey data. Comparison of the area covered by catches ≥ 5 kg (light brown) and catches ≥ 3 kg (salmon) showing the increase in area. Black dots indicate location of survey stations used to determine these areas. The KDE polygons encapsulating catches ≥ 5 kg (light brown) are considered the KDE invertebrate bioturbation polygons.

KDE Invertebrate Bioturbation Polygons from the Canadian Spring and Fall Surveys of 3LNO

The KDE polygons of significant concentrations of invertebrate bioturbation biomass from the fall (Figure 10) and spring (Figure 12) Canadian surveys are shown overlain on one another in Figure 13. The areas are very similar and the data gap in the analysis on the Tail of Grand Bank seen in Figure 10 in the fall survey, is nicely bridged in the polygons from the spring surveys. Therefore although there were differences in biomass and depth between the survey catches (Table 3, Figure 4), the areas identified by the KDE analyses are similar between the spring and fall surveys.

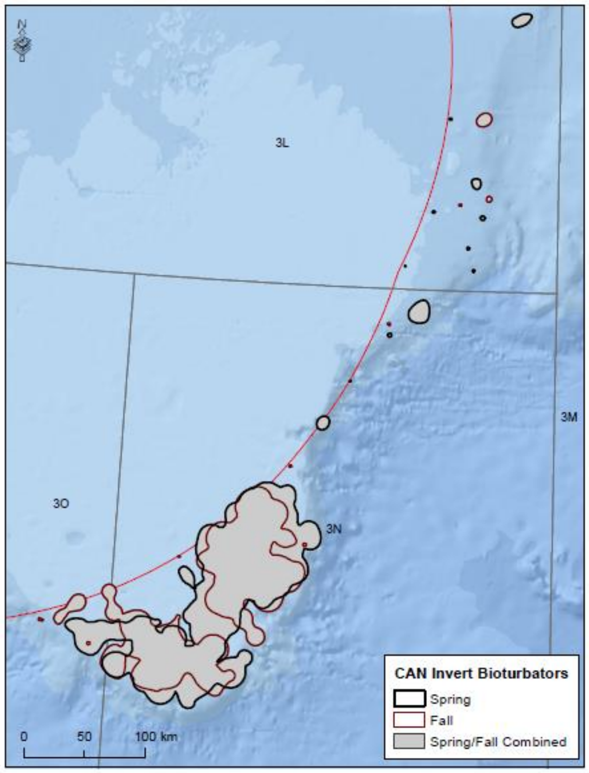

Figure 13. Canadian Spring and Fall 3LNO Surveys: The kernel density polygons of high concentrations of invertebrate bioturbation biomass in the NAFO Regulatory Area 3LNO based on analyses of Canadian Spring (black) and Fall (red) Survey data. The grey area shows the combined area from both surveys.

Canadian Surveys of Divisions 3LNO – Fish Bioturbation Biomass

A kernel density surface was created using the fish bioturbation biomass data collected from the Canadian research vessel surveys of NAFO Divisions 3LNO conducted in the spring and fall (Table 1, Figure 3). There were 1190 trawl locations used in the analyses (Figure 14). KDE parameters were: Search Radius = 14.10 km; Contour Interval = 0.01; Cell size default = 1692.3 m. These parameters are the default parameters and there was no need to increase the search radius as the default value created a continuous surface (Figure 14).

As noted in the comparison of the EU Flemish Cap surveys between fish and invertebrates, the KDE surface for the fish covers a larger area and is more diffuse than that of the invertebrates, which are less mobile than the fish over the distances covered by the trawls. There are more areas of high density bioturbating fish in Flemish Pass (Figure 14) than were seen in the invertebrates (Figures 10, 12).

Delineation of the polygon using the largest catch threshold (500 kg; Table 9) delineated a large area of 8014 km^2 on the Tail of Grand Bank. This is 8x the area first circumscribed for the invertebrate bioturbation biomass from the spring surveys (Table 8). The next threshold increased the area by 37.4% but was well supported by the spatial location of the data. No clear identification of a threshold appears until going from 100 kg to the 75 kg (Table 9, Figure 15). This increase of 42.6% is not well supported by the data and includes a large area in Flemish Pass where there is little data occupying the inner area of the polygon established with 75 kg (Figure 15). Consequently the 100 kg threshold was used to delineate the fish bioturbation biomass in NAFO Divisions 3LNO using data from the Canadian surveys.

Table 9. The number of points attributing to the delineation of fish bioturbation function KDE polygons based on successively smaller research vessel bioturbator catch weight thresholds (kg) from the Canadian Spring and Fall Surveys of NAFO Divisions 3LNO. The area and number of observations used to define each polygon and the percent change in area and the number of additional observations between successive thresholds are provided. The shaded row represents the threshold used to define the bioturbation function KDE polygons.

Fish Bioturbator Catch Threshold (Kg)	Number of Observations in Polygon	Additional Observations Per Interval	Area of Polygon (km^2)	Percent Change in Area Between Successive Thresholds
500	35		8014.0	96.4
300	98	63	15736.1	37.4
200	169	71	21620.3	16.3
125	242	73	25133.6	1.1
100	283	41	25411.2	42.6
75	345	62	36235.5	18.5
50	428	83	42950.1	0.0
40	483	55	42950.1	11.2
35	534	51	47742.1	0.0
30	589	55	47742.1	0.0
25	650	61	47742.1	0.3
20	730	80	47873.7	10.7
15	809	79	53001.5	0.1
12.5	864	55	53051.6	0.0
10	933	69	53051.6	0.0
7.5	1002	69	53051.6	0.0
5	1074	72	53058.8	0.0
2.5	1132	58	53058.8	10.2
0.02	1190	58	58481.9	

The species contributing to the fish bioturbator KDE polygons in NAFO Divisions 3LNO are listed in Appendix 7. Twenty fish bioturbators were identified in the Canadian surveys (Appendix 1), 14 of which were recorded in catches in 3LNO and 10 of those were found in the 283 catches used to create the fish bioturbator KDE polygons (Table 9). Yellowtail flounder, *Limanda ferruginea*, a commercial species was the greatest contributor to total biomass of those catches used to construct the KDE polygons and therefore heavily influenced the analyses. American plaice (*Hippoglossoides platessoides*) was the second most prominent species in terms of biomass and was the most prevalent occurring in 275 of the 283 trawl sets (Appendix 7). Unlike found in Division 3M, the sand lance, *Ammodytes dubius*, and the smooth skate, *Malacoraja senta*, were present in the catches used to delineate the fish bioturbation polygons (Figure 15). Only three skate taxa and the ordinal flatfish taxon were present in the surveys but not in those catches used to delineate the KDE polygons (Appendix 7).

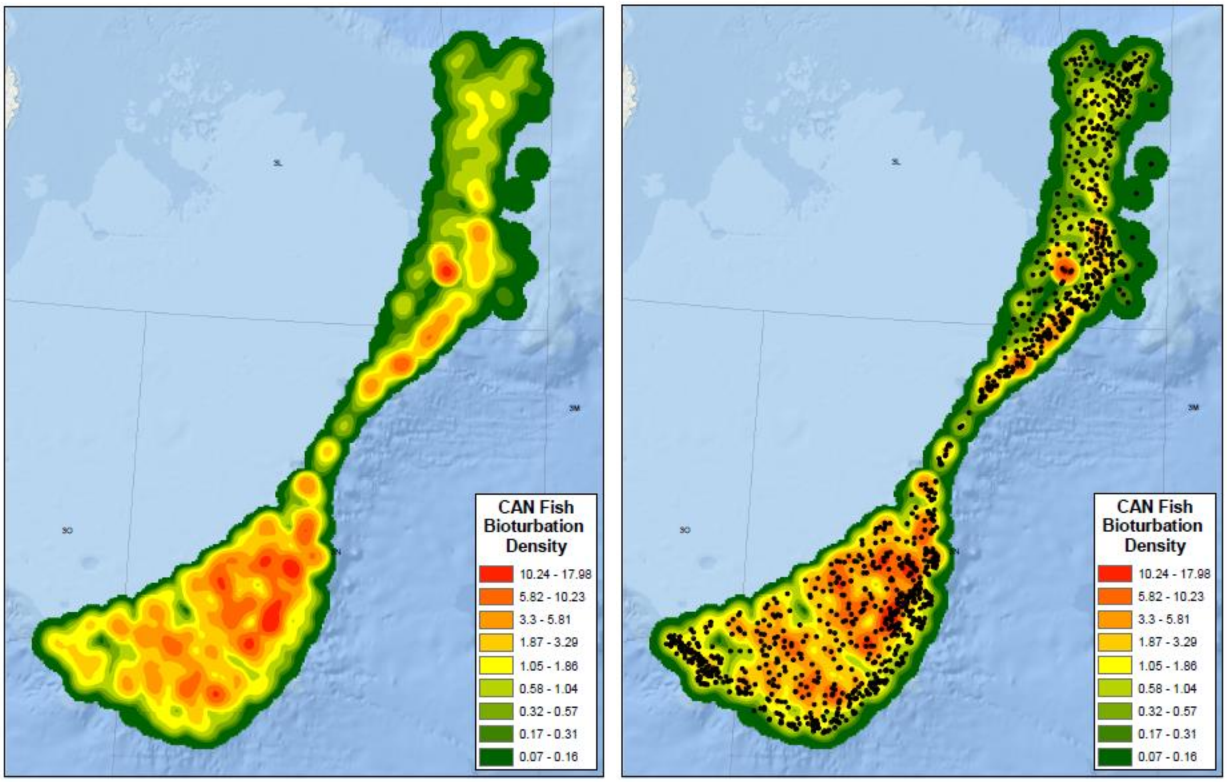

Figure 14. Canadian Spring and Fall 3LNO Surveys: Kernel density fish bioturbation biomass (kg/km^2) surface in NAFO Divisions 3LNO. Left Panel: Kernel density surface. The green areas represent low bioturbation biomass densities while the red areas indicate high densities; Right Panel: Canadian research vessel survey data points overlain on the kernel density surface showing spatial distribution of data.

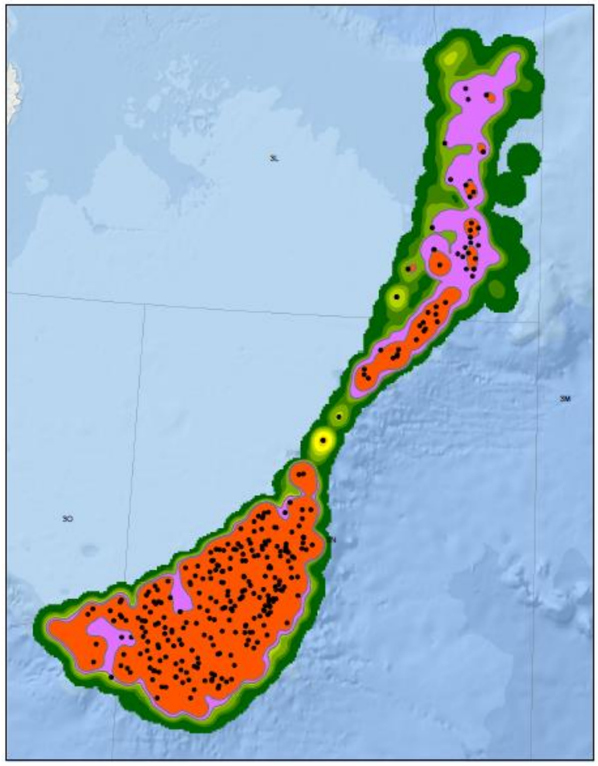

Figure 15. Canadian Spring and Fall 3LNO Surveys: The kernel density distribution of fish bioturbation biomass in NAFO Divisions 3LNO based on analyses of Canadian Spring and Fall Survey data. Comparison of the area covered by catches ≥ 100 kg (red) and catches ≥ 75 kg (purple) showing the increase in area. Black dots indicate location of survey stations used to determine these areas. The KDE polygons encapsulating catches ≥ 100 kg (red) are considered the KDE invertebrate bioturbation polygons.

EU Surveys of Divisions 3LNO – Invertebrate Bioturbation Biomass

A kernel density surface was created using the invertebrate bioturbation biomass data collected from the EU research vessel surveys of NAFO Divisions 3LNO (Table 1, Figure 3). There were 1880 trawl locations used in the analyses (Figure 16). KDE parameters were: Search Radius = 14.64 km; Contour Interval = 0.00025; Cell size default = 1757.1 m. These parameters are the default parameters and there was no need to increase the search radius as the default value created a continuous surface (Figure 16).

As for the kernel density surfaces produced from the Canadian surveys of Divisions 3LNO (Figure 13) of invertebrate bioturbation biomass, the surface produced with the EU data (Figure 16) shows high concentrations on the Tail of Grand Bank and less biomass in Flemish Pass. The highest biomass is in the Southeast Shoal area.

The areas occupied by successive catch thresholds are shown in Table 10. The highest catches are largely on the Tail of Grand Bank and the area increases consistently in that region with increasing thresholds and good data support. The first potential threshold is 10 kg where there is a 49.5% increase in area in going to the next threshold of 7 kg (Table 10). However, that change is well supported by the data and groups together high density areas on the northern part of the tail. This holds true down to the 2 kg threshold where there is a large change, not strongly supported by the data between it and the 1.5 kg threshold (Table 10, Figure 17). The new area created by the catches ≥ 1.5 kg is in Flemish Pass (Figure 17). The 2 kg threshold was selected to delineate high concentrations of invertebrate bioturbation biomass from the EU surveys of NAFO Divisions 3LNO.

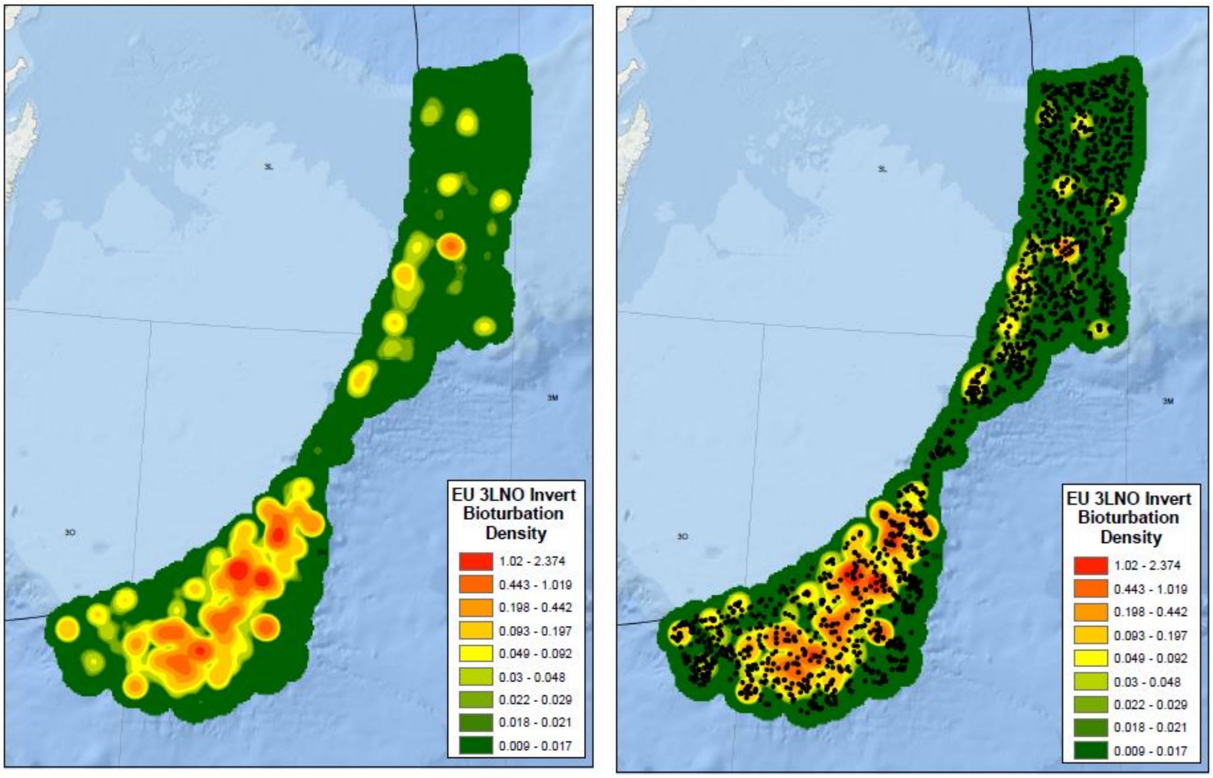

Figure 16. EU 3LNO Surveys: Kernel density invertebrate bioturbation biomass (kg/km^2) surface in NAFO Divisions 3LNO. Left Panel: Kernel density surface. The green areas represent low bioturbation biomass densities while the red areas indicate high densities; Right Panel: EU research vessel survey data points overlain on the kernel density surface showing spatial distribution of data.

Table 10. The number of points attributing to the delineation of invertebrate bioturbation function KDE polygons based on successively smaller research vessel bioturbator catch weight thresholds (kg) from the EU Surveys of NAFO Divisions 3LNO. The area and number of observations used to define each polygon and the percent change in area and the number of additional observations between successive thresholds are provided. The shaded row represents the threshold used to define the bioturbation function KDE polygons.

Invertebrate Bioturbator Catch Threshold (Kg)	Number of Observations in Polygon	Additional Observations Per Interval	Area of Polygon (km²)	Percent Change in Area Between Successive Thresholds
100	10		218.4	783.4
50	22	12	1929.3	100.4
30	37	15	3866.6	101.9
15	63	26	7806.0	13.1
10	83	20	8832.3	49.5
7	103	20	13204.4	10.8
5	138	35	14626.0	26.6
3	177	39	18520.2	28.0
2	236	59	23699.6	47.6
1.5	278	42	34991.1	25.8
1	358	80	44002.0	9.7
0.75	433	75	48262.4	0.0
0.5	521	88	48275.9	11.6
0.4	584	63	53856.6	10.1
0.3	675	91	59280.4	0.2
0.2	803	128	59424.3	1.7
0.15	921	118	60410.8	11.6
0.1	1101	180	67424.3	0.0
0.075	1241	140	67424.3	0.0
0.05	1399	158	67424.3	3.4
0.01	1772	373	69686.7	0.0
0.001	1880	108	69686.7	

The EU surveys include 123 invertebrate taxa that were identified as bioturbators (Appendix 2) and 117 of those were recorded in the surveys from Divisions 3LNO (Appendix 8). Of those 92 were found in the catches that were greater or equal to 2 kg and so used to delineate the KDE bioturbation polygons from those surveys (Table 10). Although many taxa were included in those catches, only 4 contributed to 90% of the total biomass (Appendix 8). The sea cucumber, *Cucumaria frondosa*, a slow-growing surficial modifier that is thought to live to about 10 years (Fiendel, 2002), contributed most to the biomass and was the most prevalent taxon, occurring in 161 of the 236 trawl sets included in the delineation of the polygons. This species as also the dominant taxon in the Canadian spring and fall surveys. Snow crabs, the gastropod *Euspira* and other holothuroids comprised the 90% of the biomass of the 161 sets. Sand dollars were high ranking in biomass as well, and were the second most prevalent species as was found in the Canadian Spring Surveys (Appendix 6). Eight VME indicator taxa, all sea pens, were included in catches delineating the invertebrate bioturbation polygons, together accounting for 0.005% of the total biomass, with *Anthoptilum* contributing the most to the biomass of the catches.

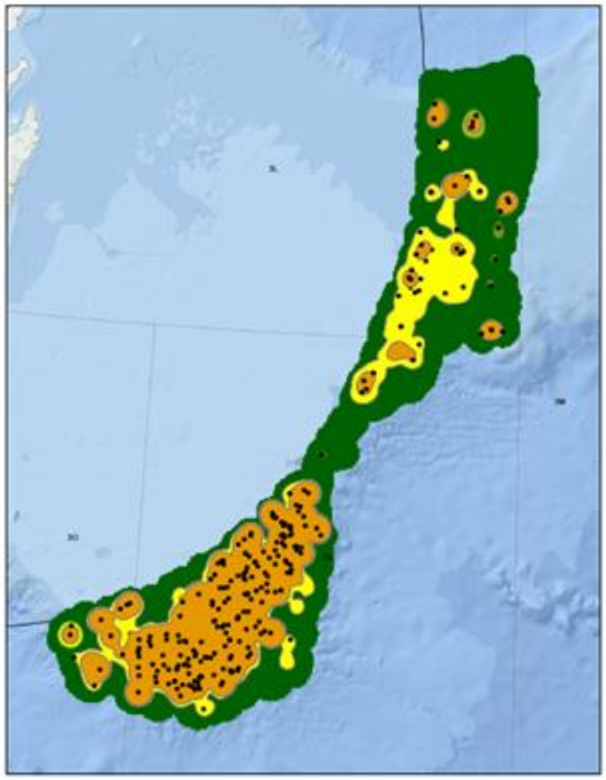

Figure 17. EU 3LNO Surveys: The kernel density distribution of invertebrate bioturbation biomass in NAFO Divisions 3LNO based on analyses of EU survey data. Comparison of the area covered by catches ≥ 2 kg (brown) and catches ≥ 1.5 kg (yellow) showing the increase in area in the Flemish Pass region. Black dots indicate location of survey stations used to determine these areas. The KDE polygons encapsulating catches ≥ 2 kg (brown) are considered the KDE invertebrate bioturbation polygons.

Figure 18 shows that the KDE polygons from the EU surveys tend to be larger than those of the Canadian surveys on the Tail of Grand Bank, extending into deeper water. This is because for the invertebrates, the EU surveys have more trawl sets in deeper water than the Canadian surveys in Divisions 3LNO, the bioturbation data from which were all less than 1333 m while EU surveys sampled to 1429 m. The depth range for the analysed data from the Canadian Fall and Spring Surveys was 36 to 1333 m and 38 to 725 m respectively, while the depth range for the EU surveys was 40 to 1429 m. There is also a depth gap in the bioturbator data set within the EU surveys between 514 and 789 m with no sets falling between those depths. Consequently in reviewing the invertebrate species composition in the deeper stations we examined EU sets greater and less than 750 m to explore potential species differences. The EU surveys had 23 trawl locations in deeper waters from 789 to 1489 m.

Compared with the shallower EU survey data, fourteen deep water taxa were found only in these 23 deeper trawl sets (Appendix 9) of the 92 taxa in the full data, however most were only found in one or two sets with small total biomass. Another six taxa had 70% or more of the sets in which they were recorded occurring below 750 m *and* 80% or more of their biomass in the deeper sets (Appendix 9). These are considered deep water taxa that were sometimes caught in shallower water (or misrecorded as occurring there). Of those, the brittle star *Ophiomusa lymani*, Maldanid polychaetes and the sea pen *Anthoptilum* was recorded in 80% of their sets below 750 m *and* 99% or more of their biomass, and had the largest total biomasses (Appendix 9). These taxa all contributed to the establishment of the KDE polygons for invertebrate bioturbators (Appendix 8). Of those taxa only found in sets below 750 m, the synallactid Paelopatides had the largest total biomass and was recorded in 5 trawl sets. This species along with the solitary cup coral, *Flabellum*, the decapod *Eualus gaimardii* and the sea pen *Pennatula aculeata*, a NAFO VME Indicator species (NAFO, 2020), had sufficient biomass to influence the delineation of the KDE polygons (Appendix 8). Other species, occurred in only the shallow sets or in both the shallower and deep sets but in differing proportions, as would be expected. Therefore the EU surveys identify some important areas of bioturbation in the deeper waters that the Canadian surveys miss, largely in the 3O 'notch', the northern slopes of the Tail of Grand Bank and the deep Flemish Pass. In terms of the bioturbators, these deeper sets do not appear to have sampled a bioturbator community that is strongly different from that sampled in the full data, however a few species are uniquely represented there and are noted as typical deep water fauna (e.g., *Paelopatides* spp.).

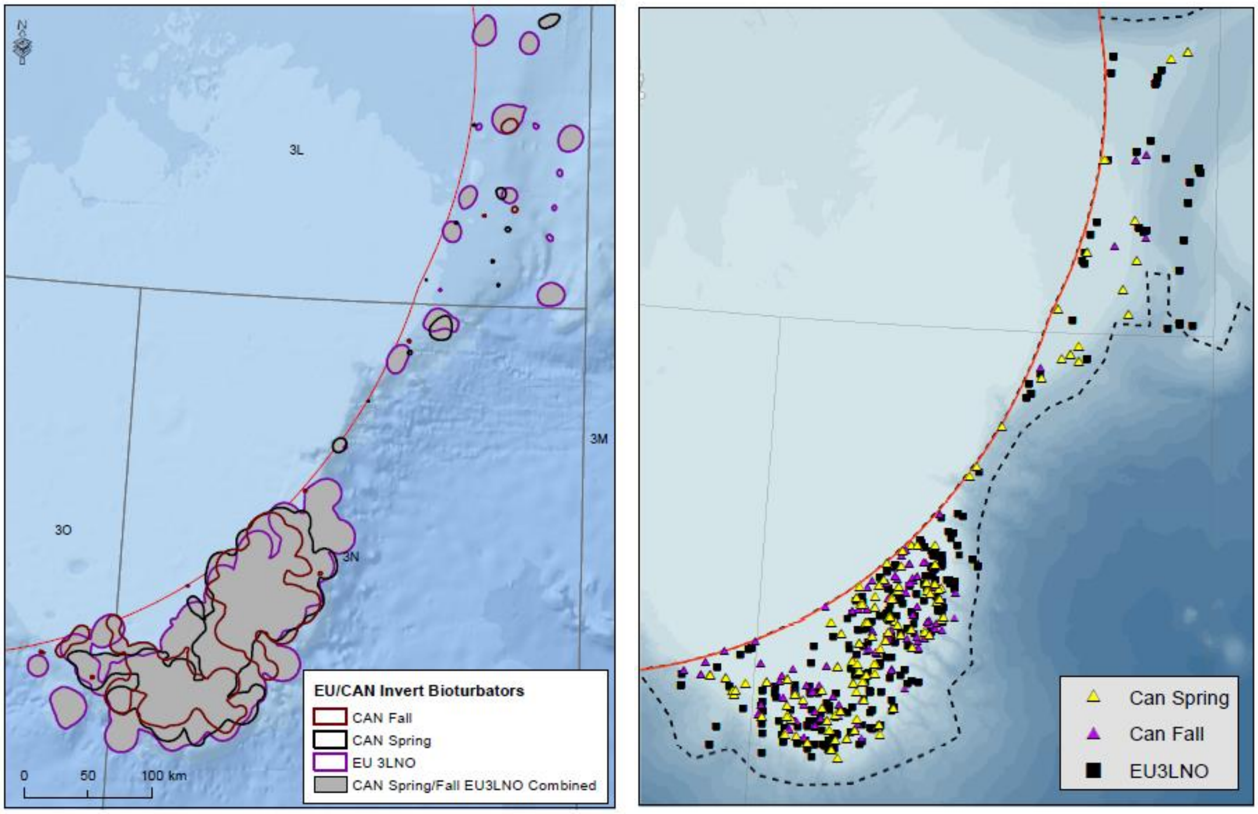

Figure 18. EU and Canadian Spring and Fall Surveys of 3LNO: Left panel: The kernel density polygons of high concentrations of invertebrate bioturbation biomass in the NAFO Regulatory Area 3LNO based on analyses of Canadian Spring (black) and Fall (red) and EU (purple) Survey data. The grey area shows the combined area from all three surveys. Right panel: The location of the trawl sets from each survey used to delineate the polygons shown in the left panel.

These differences in species composition do not affect the KDE analyses which were done separately when biomass differences were found. However they provide insight into the different benthic communities contributing to this function and would be important for analyses of nutrient and chemical cycling.

EU Surveys of Divisions 3LNO – Fish Bioturbation Biomass

A kernel density surface was created using the fish bioturbation biomass data collected from the EU research vessel surveys of NAFO Divisions 3LNO conducted (Table 1, Figure 3). There were 1952 trawl locations used in the analyses (Figure 19). KDE parameters were: Search Radius = 14.64 km; Contour Interval = 0.01; Cell size default = 1757.1 m. These parameters are the default parameters and there was no need to increase the search radius as the default value created a continuous surface (Figure 19).

As for the kernel density surfaces produced from the Canadian surveys of Divisions 3LNO (Figure 14) of fish bioturbation biomass, the surface produced with the EU data (Figure 19) shows high concentrations on the Tail of Grand Bank and less biomass in Flemish Pass.

The areas covered by successively smaller catch thresholds are provided in Table 11. A number of very large catches (over 1 mt) were spatially clumped on the Tail of the bank and so the first threshold covered a large initial area. In moving from the 200 kg threshold to the 150 kg threshold a large, poorly supported area to the north of Flemish Pass is created (Figure 20). The 200 kg threshold demarcates the KDE polygon for high concentrations of fish bioturbators in the EU surveys of Divisions 3LNO (Table 11). Figure 21 compares the location of the KDE polygons for high concentrations of fish bioturbators in both the EU and Canadian surveys of Divisions 3LNO. The areas are similar and cover a greater spatial extent than those of the invertebrates (Figure 18).

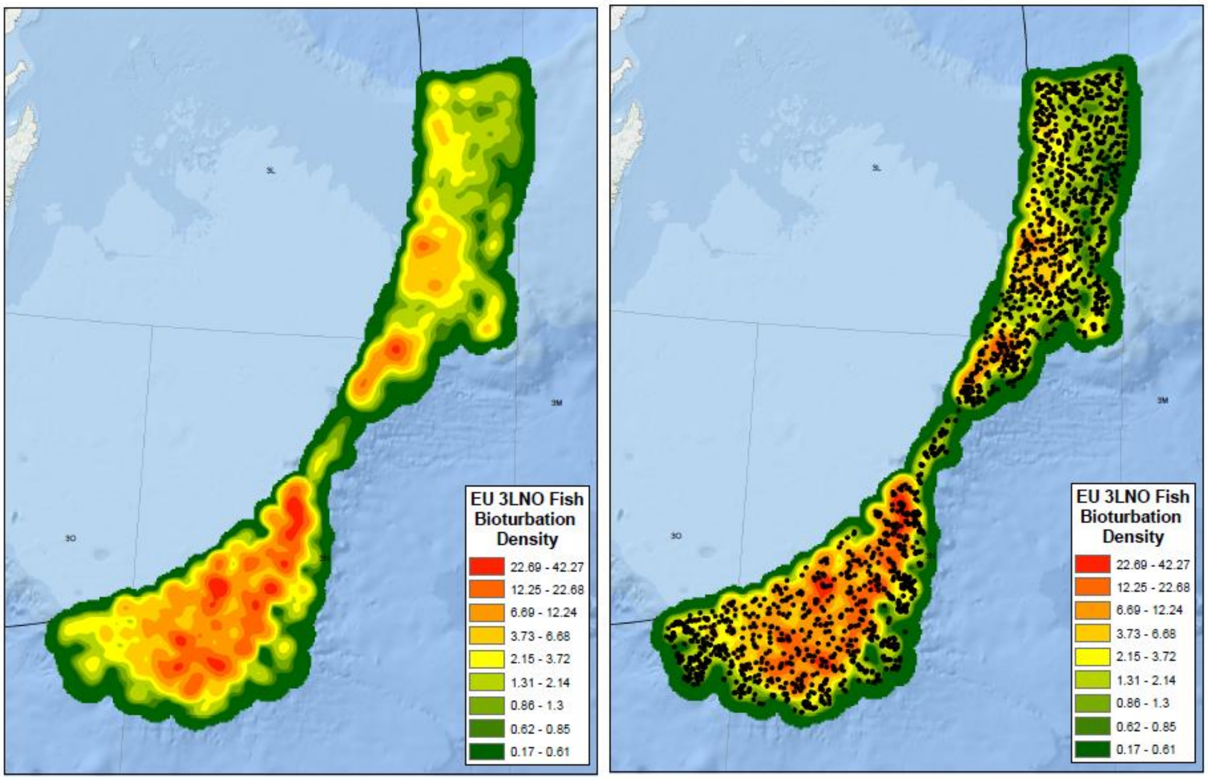

Figure 19. EU Surveys of 3LNO: Kernel density fish bioturbation biomass (kg/km^2) surface in NAFO Divisions 3LNO. Left Panel: Kernel density surface. The green areas represent low bioturbation biomass densities while the red areas indicate high densities; Right Panel: EU research vessel survey data points overlain on the kernel density surface showing spatial distribution of data.

All 17 bioturbator fish identified from the EU surveys (Appendix 2) were present in the catches analyzed from NAFO Divsions 3LNO and 12 of those were found in the 356 catches ≥ 200 kg that delineated the significant concentrations of fish bioturbation biomass (Table 11). Yellowtail flounder, *Limanda ferruginea*, contributed most to the biomass of those catches, followed by American plaice, *Hippoglossoides platessoides*, and sand lance, *Ammodytes dubius*, together accounting for 90% of the fish bioturbator biomass (Appendix 10). The results are very similar to those produced from the Canadian surveys in terms of the top species, with the relative positions of the sand lance and *Amblyraja radiata* being exchanged in the EU surveys.

Table 11. The number of points attributing to the delineation of fish bioturbation function KDE polygons based on successively smaller research vessel bioturbator catch weight thresholds (kg) from the EU Surveys of NAFO Divisions 3LNO. The area and number of observations used to define each polygon and the percent change in area and the number of additional observations between successive thresholds are provided. The shaded row represents the threshold used to define the bioturbation function KDE polygons.

Fish Bioturbator Catch Threshold (Kg)	Number of Observations in Polygon	Additional Observations Per Interval	Area of Polygon (km^2)	Percent Change in Area Between Successive Thresholds
1000	57		12049.6	65.0
500	161	104	19883.1	19.3
400	213	52	23728.9	0.0
300	284	71	23728.9	8.2
200	356	72	25671.7	54.3
150	420	64	39599.7	16.4
125	471	51	46106.8	17.0
100	541	70	53966.5	0.0
90	580	39	53966.5	1.0
80	629	49	54496.5	3.6
70	707	78	56461.3	3.1
60	797	90	58201.2	0.6
50	893	96	58529.6	1.7
40	1059	166	59499.6	2.6
35	1163	104	61026.6	1.6
30	1286	123	62002.8	0.0
25	1410	124	62002.8	0.0
20	1541	131	62002.8	0.0
15	1662	121	62002.8	3.3
10	1791	129	64033.3	9.1
5	1902	111	69885.5	0.0
0.15	1952	50	69885.5	

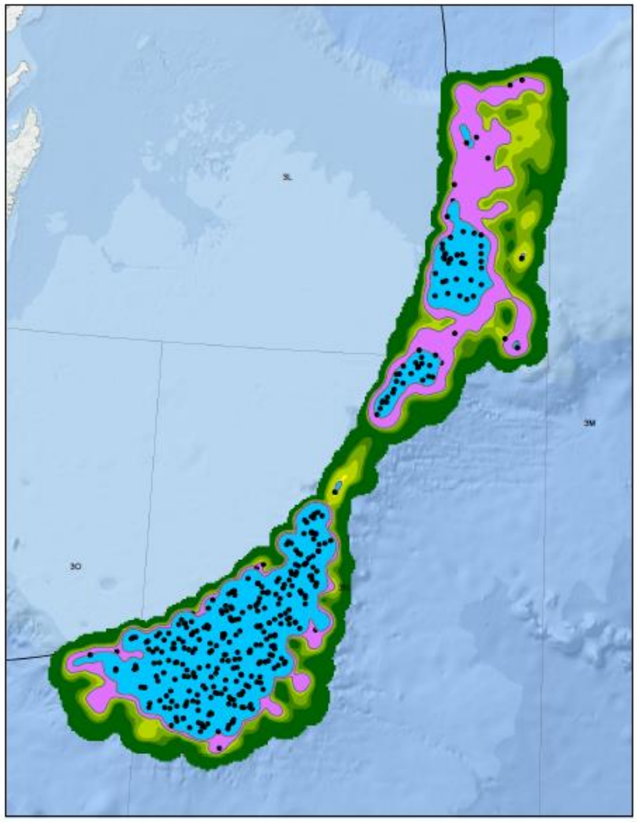

Figure 20. EU Surveys of 3LNO: The kernel density distribution of fish bioturbation biomass in NAFO Divisions 3LNO based on analyses of EU survey data. Comparison of the area covered by catches ≥ 200 kg (blue) and catches ≥ 150 kg (pink) showing the increase in area in the Flemish Pass region. Black dots indicate location of survey stations used to determine these areas. The KDE polygons encapsulating catches ≥ 200 kg (blue) are considered the KDE fish bioturbation polygons.

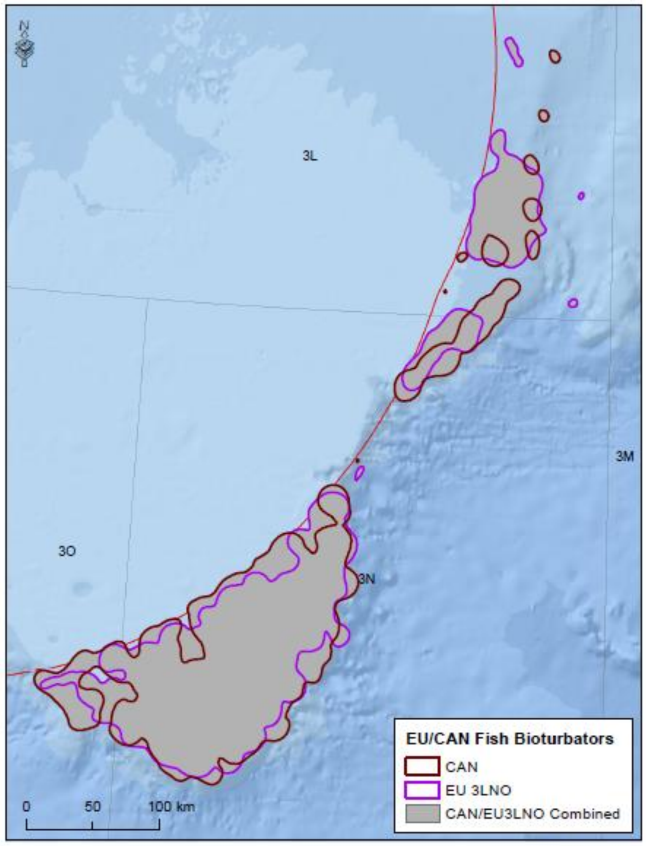

Figure 21. EU and Canadian Surveys of 3LNO: The kernel density polygons of high concentrations of fish bioturbation biomass in the NAFO Regulatory Area 3LNO based on analyses of Canadian (red) and EU (purple) Survey data. The grey area shows the combined area from both surveys.

Overview of Kernel Density Polygons of Significant Concentrations of Invertebrate and Fish Bioturbators

Figure 22 shows the combined results of the kernel density analyses for significant concentrations of invertebrate and fish bioturbation biomass in the NAFO Regulatory Area. For both EU and Canadian surveys the Tail of Grand Bank has high concentration of bioturbation biomass, indicating that this area is likely important for remineralisation and other geochemical processes. The northern slopes of Flemish Cap also have significant biomass associated with bioturbation. Although both the fish and invertebrate bioturbation biomass are in similar areas, the area covered by the fish is broader and less detailed, possibly reflecting their mobility.

For the invertebrate taxa, all three surveys in Divisions 3LNO (Canadian Spring, Fall and EU) identified the sea cucumber, *Cucumaria frondosa*, as the top species contributing to the catches which delineated the KDE polygons. The brittlestar *Ophiura sarsii*, which can live to 20 years (Ravelo et al., 2017) was common to the higher ranking taxa in all three surveys and the sand dollar *Echinarachnius parma* ranked highly in the Canadian spring surveys and the EU surveys. All three are considered surficial modifiers, causing bioturbation in the upper centimetres of the sea bed. As biomass drives these KDE analyses it appears that the differences in area between the 3LNO KDE polygons for invertebrate bioturbation are related to the location of the trawl sets rather than to large differences in species composition – although there are species that are uniquely found in the deeper sets, or are more prevalent there. This area contrasts sharply with the top ranking species on Flemish Cap, where two VME indicator sea pens, *Anthoptilum* and *Halipteris finmarchica* contribute most to the biomass and influence the delineation of the KDE invertebrate bioturbation polygons there. These results are consistent with the Flemish Cap being a unique ecosystem in terms of its benthos (Murillo et al., 2016).

A similar pattern is seen in the comparison of the top ranking bioturbating fish species. In Divisions 3LNO both Canadian and EU surveys identify the same four top ranking species, with only the relative positions of the third and fourth ranking species differing. In both, *Limanda ferruginea* is the top ranking contributor to the biomass that delineated the fish bioturbation polygons. Again, Division 3M has a different top ranking species list. *Reinhardtius hippoglossoides* dominates the biomass along with other Pleuronectidae. Most of these species are surficial modifiers, disturbing the upper surface of the sediment as they feed and camouflague. However, the burrowing sand lance, *Ammodytes dubius*, a top contributor to biomass in Divisions 3LNO, burrows in the sand to a depth of several inches (7.5 cm) (Nizinski et al., 1990).

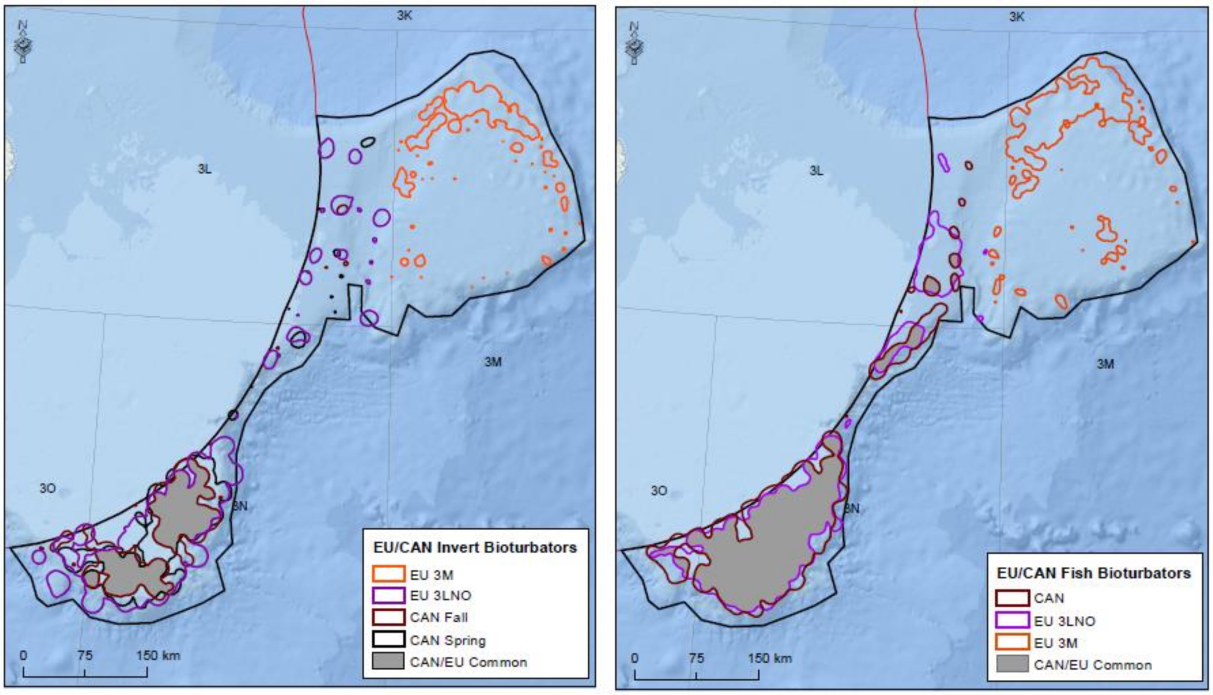

Figure 22. The kernel density polygons of high concentrations of invertebrate (left panel) and fish (right panel) bioturbation biomass in the NAFO Regulatory Area based on analyses of Canadian (red/black) and EU (orange/purple) survey data. The grey area shows the common area from the surveys in Divisions 3LNO (Canadian spring, fall and EU for invertebrates and Canadian and EU for fish).

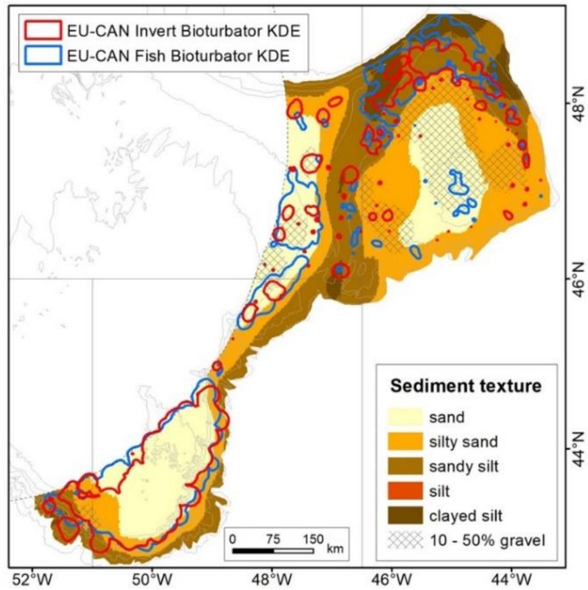

Figure 23. Sediment texture map classified according to Shepard (1954), modified from Murillo et al. (2016), with the invertebrate and fish bioturbation KDE polygons overlain.

Bioturbators in relation to bottom sediment type

Significant concentrations of invertebrate and fish bioturbation biomass in the Flemish Cap area were mostly associated with sandy-silt to clayed-silt bottoms, although the significant concentrations on top of the Cap were associated with sandy bottoms with high gravel presence (Figure 23). The concentration of bioturbation biomass on the Tail and Nose of Grand Bank was mainly associated with sandy bottoms, with a small portion located on the western corner of the Tail (Div. 3O) associated with silty-sand bottom (Figure 23). Those likely are sea pens which have been identified as having significant concentrations in that region (Kenchington et al., 2019).

Nutrient Cycling

Nutrient exchange between the productive surface waters and the benthos is effected through a number of different pathways in marine ecosystems and supports essential ecosystem functions such as energy transfer in food webs and biogeochemical cycling (Griffiths et al., 2017; Agnetta et al., 2019). Benthic species have a diversity of feeding guilds, which have been classified variously in the literature over many decades. Amongst the macrofauna, early classifications distinguished microphages (species feeding on many food items simultaneously) and macrophages (species feeding on one food item at a time). Suspension feeders, detritivores, and deposit feeders were all considered microphages, while predators, omnivores and scavengers were considered macrophages. Various schemes have been adopted, building on this early system. Macdonald et al. (2010) recognized 10 feeding 'types' in their study of taxonomic and feeding guild classification for the 2567 marine benthic macroinvertebrates of the Strait of Georgia in British Columbia, Canada:

1. Deposit feeder (ingests sediment);
2. Detritus feeder (ingests particular matter only, without sediment);
3. Suspension/Filter-feeder (strains particles from the water);
4. Predator (eats live animals only);
5. Scavenger (carrion only);
6. Suctorial parasite;
7. Chemosynthetic (with symbiotic bacteria);
8. Lignivorous (eats wood);
9. Grazer (feeds by scraping, either on algae or sessile animals); and
10. Browsing (feeds by tearing or gathering particular items).

Their goal was to use the feeding guilds to trace carbon pathways through the ecosystem. Of these groups, filter-feeding benthos (#3 above) play an important role in benthic-pelagic coupling (Rossi et al., 2017), and influence ecosystem services through their influence on benthic and pelagic food webs, filtration of vast amounts of water (Pham et al., 2019), and for some, habitat provision. Here, we have focused only on the benthic filter-feeding species found in the NAFO Regulatory Area, recognizing that there are other trophic pathways influencing nutrient cycling. There are two general categories of filter-feeders: 'passive' filter-feeders depend entirely on ambient water flow to supply particles to their feeding structures (e.g., corals); and 'active' filter-feeders create their own feeding current to enhance the local supply of suspended food particles (e.g., sponges, crustaceans, and bivalve molluscs) (Goldberg, 2018). Some others, such as some barnacles, utilize both strategies. We use the general term 'filter-feeder' unless we wish to distinguish active and passive modes.

Table 12. List of taxa where nutrient cycling through filter feeding was inferred based on congeneric, confamilial or higher order aggregations.

Taxon used for Consolidating Data	Rationale	Number of taxa affected
(P.) Porifera	All considered active filter-feeders.	22
(P.) Cnidaria	Inferred from the species present and the literature.	1
(C.) Hexanauplia	Copepods must beat their cephalic appendages to drive the feeding current.	1
(C.) Ascidiacea	Extended classification to all families and lower order taxa based on the literature.	3
(C.) Bivalvia	Extended classification to all families and lower order taxa based on the literature.	27
(O.) Euphausiacea	Extended classification to all families and lower order taxa based on the literature for *Euphausia pacifica*.	5
(O.) Alcyonacea	Extended classification to all families and lower taxa based on the literature for other members of this order.	16
(O.) Antipatharia	Extended classification to all families and lower order taxa based on the literature.	3
(O.) Pennatulacea	Extended classification to all families and lower order taxa based on the literature.	7

Murillo et al. (2020a) mapped species with the 'Active filter feeding' mode as a proxy for nutrient cycling (Figure 1). Active filter-feeders process a high volume of water, taking nutrients from the water column and making them available to the benthos. Here we also include 'Passive filter-feeders' because although the nutrient cycling rate may be slower, ultimately they also capture particles from the water column and so should be considered in this benthic compartment as well. The dominant taxa (by individual weight) in our data sets fitting these categories are the sponges (Porifera) and the bivalve molluscs. A number of data sources were examined to determine the feeding mode of the invertebrates in our data sets. Primary sources were Murillo et al. (2020a) and Macdonald et al. (2010) both of whom covered a diversity of taxa. Note that both active and passive filter-feeders were extracted from the supplementary files of Murillo et al. (2020) although they only analyzed the active filter-feeders. Further literature sources were consulted for individual species and families to support our decisions. As for the bioturbators, some inferences were made on feeding mode based on the literature (Table 12). The lists of taxa that were classified as nutrient cyclers (filter-feeders) are provided in Appendix 11 and Appendix 12 for the Canadian and EU surveys (Table 1, Figure 3) respectively. Unlike the bioturbation trait there were no fish identified in the nutrient cycling trait category.

In order to determine whether any of the data from the different surveys could be combined (Table 1), K-S tests between pairs of data and cumulative biomass distribution plots were examined. Note that the two EU surveys of 3L and 3NO were combined for these analyses. Analyses of the nutrient cycling biomass data showed significant differences between the spring and fall surveys in Canada, and with tow length and NAFO Division using the Campelen 1800 gear (Tables 13 and 14). Cumulative biomass distribution plots (Figure 24) show that the two Canadian surveys, one conducted in the spring and one in the fall in the same area with the same gear, are very similar, as was the case for the fish bioturbators, and may reflect small differences due to season and depth (Table 1). Consequently the Canadian data for the nutrient cyclers were combined for the KDE analyses and the other surveys were kept separate. This produced the following data sets for KDE analyses:

1. Canadian data 3LNO, 15 min tow length, depth range 36-1379 m;
2. EU surveys data 3LNO, 30 min tow length, depth range 43-1462 m;
3. EU surveys data 3M, 30 min tow length, depth range 132-1460 m.

Table 13. K-S Tests for similarity of group biomass of the nutrient cycling data from the Canadian (DFO) surveys by season (Spring/Fall).

Groups Tested	K-S Test
Same gear and area, by seasons with different depths (Table 1)	
DFO NL Multi-species Spring vs. Fall Surveys (DFO)	K-S= 0.051; P<0.008

Table 14. K-S Tests for similarity of group biomass among subsets of nutrient cycling data from the EU surveys, and between Canadian and EU surveys.

Groups Tested	K-S Test
Different gear and area	
Campelen 1800 3LNO EU vs Lofoten 3M EU	K-S= 0.113; P<0.0001
Same gear and area, by tow length	
Campelen 1800 3LNO EU and Cdn 15 min vs. 30 min	K-S= 0.094; P<0.0001

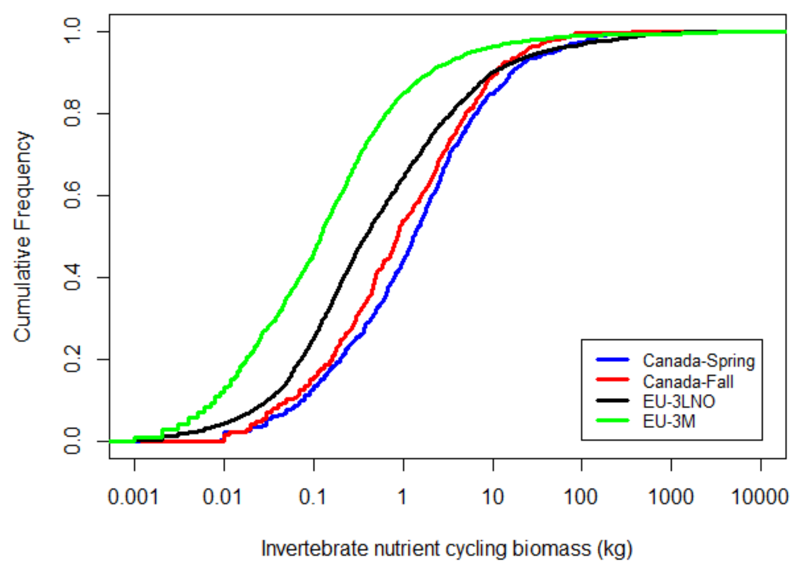

Figure 24. Cumulative nutrient cycling biomass distribution for invertebrates for each of the four surveys from which data were collected (Table 1).

Kernel Density Analyses

Canadian Surveys of Divisions 3LNO – Invertebrate Nutrient Cycling Biomass

A kernel density surface was created using the invertebrate nutrient cycling biomass data collected from the Canadian research vessel surveys of NAFO Divisions 3LNO conducted in the spring and fall (Table 1, Figure 3). There were 1078 trawl locations used in the analyses (Figure 25). KDE parameters were: Search Radius = 14.103 km; Contour Interval = 0.005; Cell size default = 1692.3 m. These parameters are the default parameters and there was no need to increase the search radius as the default value created a continuous surface (Figure 25).

The areas covered by successively smaller catch thresholds are provided in Table 15. The area increases steadily in going from 100 kg to 15 kg (Table 15). Changes in area are smaller in moving to the 6 kg threshold but small new areas are introduced with each threshold. In going from 6 to 4.5 kg thresholds the area changes by 24.4% but there is less support for the area expansion (Figure 26). Consequently the 6 kg threshold was used to delineate the KDE polygon for significant concentrations of invertebrate nutrient cycling biomass.

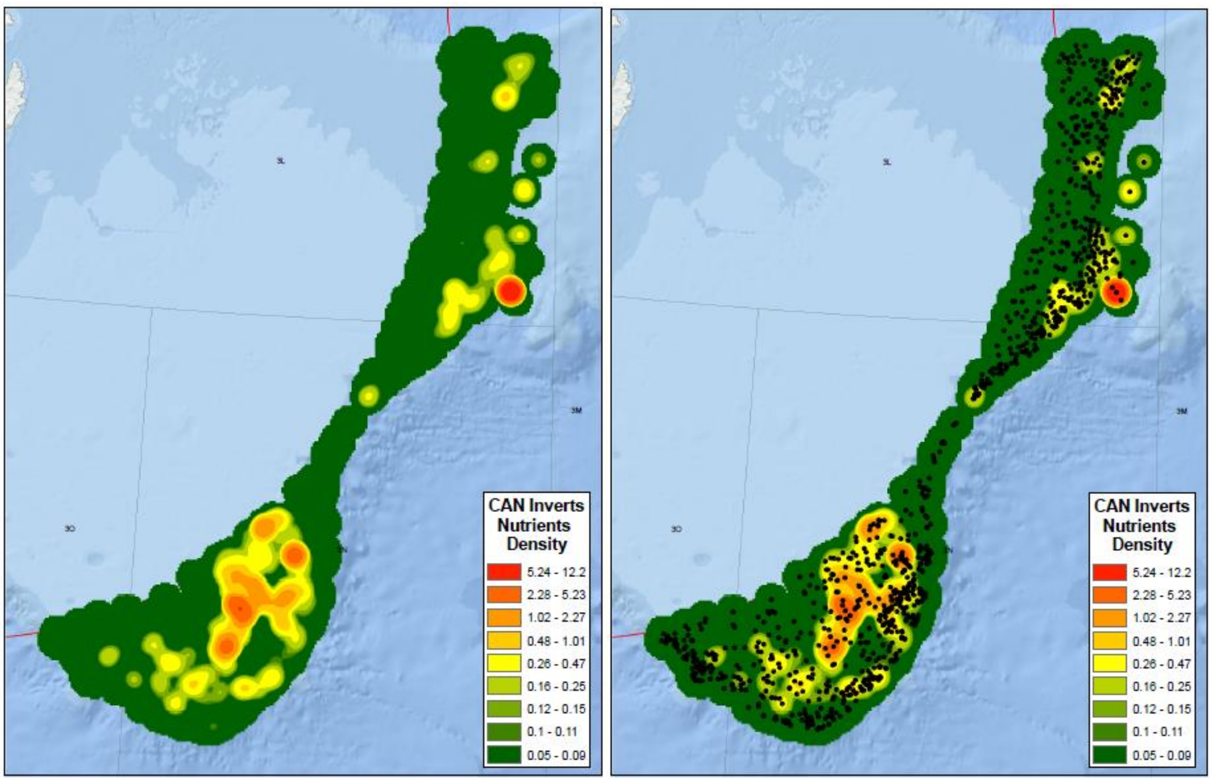

Figure 25. Canadian Spring and Fall Surveys of 3LNO: Kernel density invertebrate nutrient cycling biomass (kg/km^2) surface in NAFO Divisions 3LNO. Left Panel: Kernel density surface. The green areas represent low nutrient cycling biomass densities while the red areas indicate high densities; Right Panel: Canadian research vessel survey data points overlain on the kernel density surface showing spatial distribution of data.

There were 29 taxa that were classed as nutrient cyclers, important in benthic pelagic coupling, from the Canadian surveys (Appendix 11) and of those, 27 were present in the 3LNO trawl sets and 25 of those were present in the catches used to delineate the significant concentrations of nutrient cyclers (Appendix 13). The biomass of those 214 trawl sets (Table 15) were dominated by the sea cucumber *Cucumaria frondosa* and the sponges (recorded only as Porifera) with both taxa being prevalent in the catches being found in 118 and 101 trawl sets respectively (Appendix 13). The Porifera include species that are NAFO VME Indicators but not all sponges are VME Indicators (NAFO, 2020) and so they are not highlighted as VMEs. The same is true for the Cnidaria as a taxon, however the sea pens (Pennatulacea) and *Boltenia* are NAFO VME Indicators. Together, they contributed 1.15% of the total biomass of the 214 trawl sets used to delineate the nutrient cycling KDE polygons from the Canadian survey data.

Table 15. The number of points attributing to the delineation of invertebrate nutrient cycling function KDE polygons based on successively smaller research vessel bioturbator catch weight thresholds (kg) from the Canadian Spring and Fall Surveys of NAFO Divisions 3LNO. The area and number of observations used to define each polygon and the percent change in area and the number of additional observations between successive thresholds are provided. The shaded row represents the threshold used to define the nutrient cycling function KDE polygons.

Invertebrate Nutrient Cycling Catch Threshold (Kg)	Number of Observations in Polygon	Additional Observations Per Interval	Area of Polygon (km^2)	Percent Change in Area Between Successive Thresholds
100	17		2039.0	61.5
50	38	21	3293.5	148.2
25	61	23	8173.9	93.5
15	102	41	15819.0	20.9
10	141	39	19131.9	5.8
8	167	26	20242.1	8.2
6	214	47	21902.7	24.4
4.5	256	42	27257.9	10.9
3	332	76	30241.3	21.6
2	419	87	36774.7	2.1
1.5	481	62	37558.4	16.2
1	553	72	43661.4	3.1
0.75	621	68	45005.0	1.3
0.5	689	68	45569.4	4.0
0.3	777	88	47384.3	0.0
0.1	913	136	47384.3	0.0
0.05	970	57	47384.3	3.1
0.008	1054	84	48876.7	

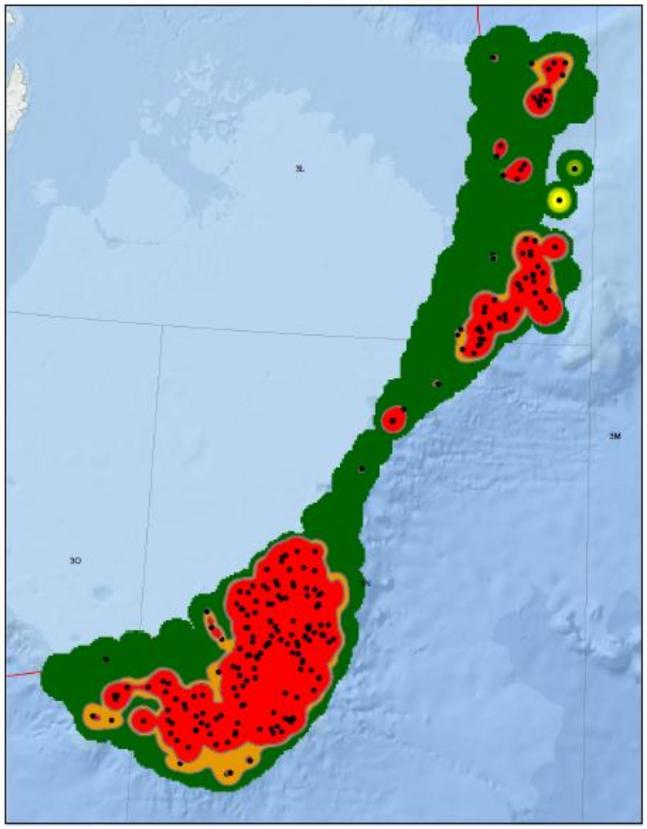

Figure 26. Canadian Spring and Fall Surveys of 3LNO: The kernel density distribution of invertebrate nutrient cycling biomass in NAFO Divisions 3LNO based on analyses of Canadian Spring and Fall Survey data. Comparison of the area covered by catches ≥ 6 kg (red) and catches ≥ 4.5 kg (brown) showing the increase in area on the Tail of Grand Bank. Black dots indicate location of survey stations used to determine these areas. The KDE polygons encapsulating catches ≥ 6 kg (red) are considered the KDE invertebrate nutrient cycling polygons.

EU Surveys of Divisions 3LNO – Invertebrate Nutrient Cycling Biomass

A kernel density surface was created using the invertebrate nutrient cycling biomass data collected from the EU research vessel surveys of NAFO Divisions 3LNO (Table 1, Figure 3). There were 1880 trawl locations used in the analyses (Figure 27). KDE parameters were: Search Radius = 14.642 km; Contour Interval = 0.0025; Cell size default = 1757.0 m. These parameters are the default parameters and there was no need to increase the search radius as the default value created a continuous surface (Figure 27).

The areas covered by successively smaller catch thresholds are provided in Table 16. The area increases with each threshold and is well supported by the data until the 2.5 kg threshold (Figure 28, Table 16) where a large area on the Tail of Grand Bank is created with only a few data points. Similarly there is little support for the increase in area in some of the Flemish Pass polygons (Figure 28). Consequently the 3.5 kg threshold is considered the best choice for delineation of the invertebrate nutrient cycling KDE biomass polygons.

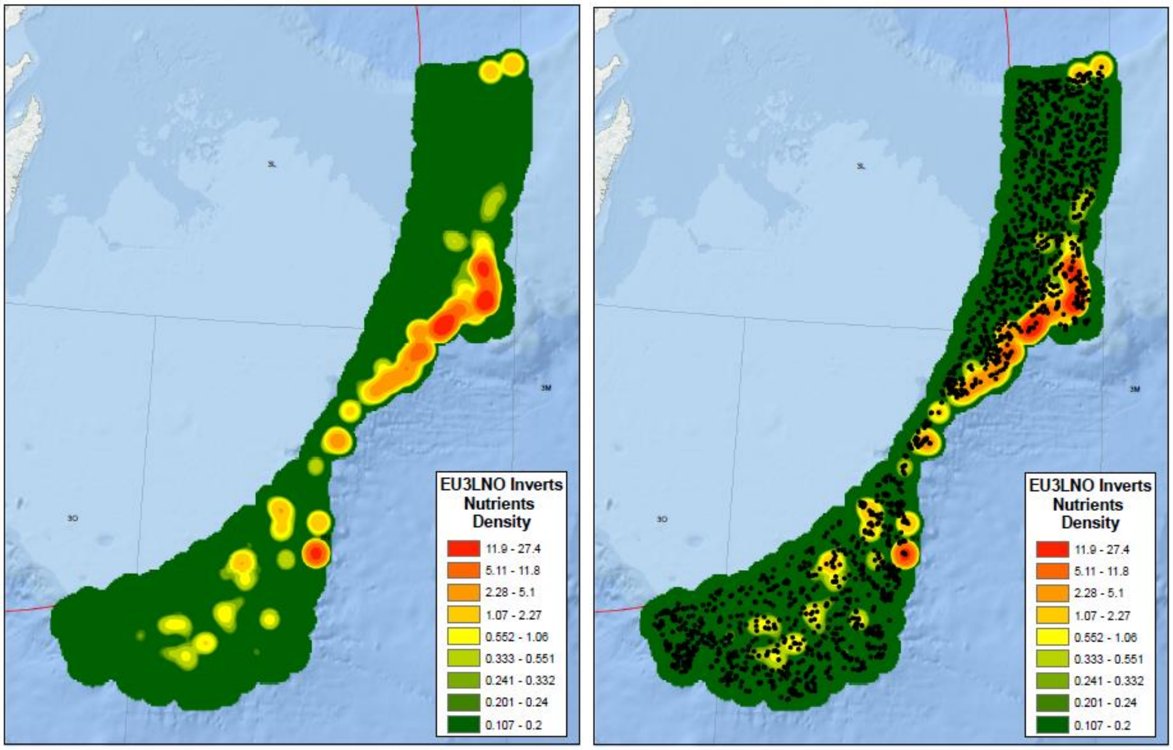

Figure 27. EU Surveys of 3LNO: Kernel density invertebrate nutrient cycling biomass (kg/km^2) surface in NAFO Divisions 3LNO. Left Panel: Kernel density surface. The green areas represent low nutrient cycling biomass densities while the red areas indicate high densities; Right Panel: EU research vessel survey data points overlain on the kernel density surface showing spatial distribution of data.

The EU surveys record 176 taxa that we have classified as nutrient cyclers (Appendix 12) and 168 taxa were recorded in catches from Divisions 3LNO (Appendix 14) and of those 134 were found in the 373 catches used to delineate the KDE polygons (Table 16). As was found in the Canadian surveys (Appendix 13), large-sized sponges and the sea cucumber *Cucumaria frondosa* dominated the biomass of those catches (Appendix 14). Forty VME Indicator taxa were identified (NAFO, 2020) and accounted for 77.9% of the total biomass in these catches (Appendix 14). This represents a more accurate representation of the relative VME biomass in the nutrient cycling KDE polygons in Divisions 3LNO, as sponges were only recorded as Porifera in the Canadian surveys and so it was not possible to include them as a VME Indicator there as many sponges caught in the surveys have not been classed as VME Indicators. Even in the EU surveys Porifera were recorded in 262 of the 373 traw sets above the 3.5 kg threshold (Table 16) with 5242 kg recorded (Appendix 14). After those Porifera records, Hydrozoa and the soft coral *Duva florida* were the most prevalent in the surveys, being present in 244 and 242 trawl sets, respectively (Appendix 14).

Table 16. The number of points attributing to the delineation of invertebrate nutrient cycling function KDE polygons based on successively smaller research vessel bioturbator catch weight thresholds (kg) from the EU Surveys of NAFO Divisions 3LNO. The area and number of observations used to define each polygon and the percent change in area and the number of additional observations between successive thresholds are provided. The shaded row represents the threshold used to define the nutrient cycling function KDE polygons.

Invertebrate Nutrient Cycling Catch Threshold (Kg)	Number of Observations in Polygon	Additional Observations Per Interval	Area of Polygon (km²)	Percent Change in Area Between Successive Thresholds
500	18		1062.7	256.0
200	43	25	3782.8	55.3
100	61	18	5875.2	13.9
50	81	20	6691.9	62.3
30	104	23	10860.3	55.3
15	150	46	16866.4	15.2
10	187	37	19423.7	33.5
7.5	232	45	25937.2	24.1
5	307	75	32190.1	7.9
3.5	373	66	34724.7	34.5
2.5	436	63	46688.2	16.9
1.5	567	131	54577.9	6.1
1	669	102	57900.7	5.9
0.8	734	65	61322.3	0.0
0.6	810	76	61322.3	0.0
0.45	887	77	61322.3	6.6
0.35	963	76	65383.8	0.0
0.3	1012	49	65383.8	0.0
0.25	1084	72	65383.8	0.0
0.2	1158	74	65383.8	0.0
0.15	1270	112	65383.8	0.0
0.1	1405	135	65383.8	0.0
0.075	1491	86	65383.8	0.0
0.05	1601	110	65383.8	0.0
0.025	1704	103	65383.8	0.0
0.01	1787	83	65383.8	0.0
0.001	1860	73	65383.8	

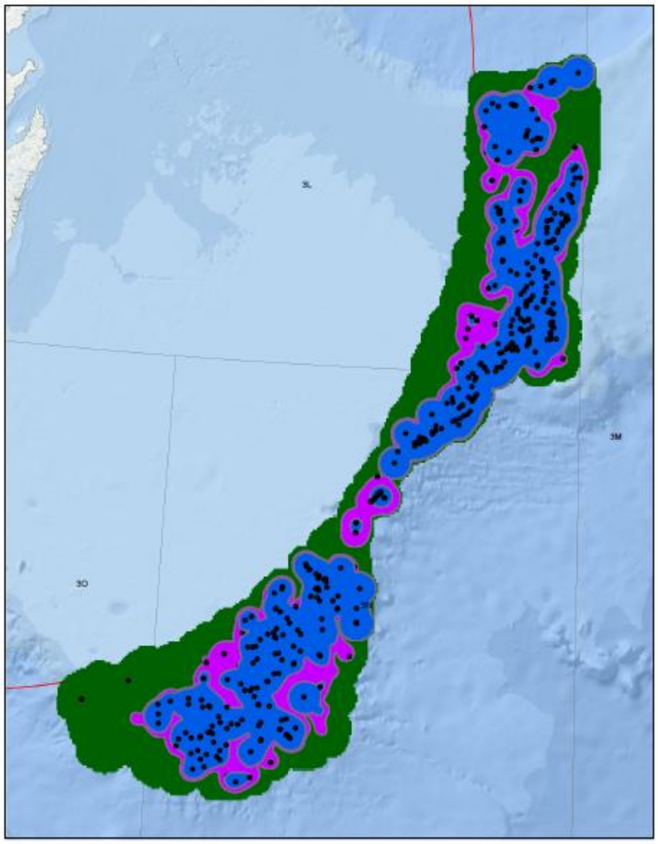

Figure 28. EU Surveys of 3LNO: The kernel density distribution of invertebrate nutrient cycling biomass in NAFO Divisions 3LNO based on analyses of EU survey data. Comparison of the area covered by catches ≥ 3.5 kg (blue) and catches ≥ 2.5 kg (pink) showing the increase in area. Black dots indicate location of survey stations used to determine these areas. The KDE polygons encapsulating catches ≥ 3.5 kg (blue) are considered the KDE invertebrate nutrient cycling polygons.

EU Surveys of Division 3M – Invertebrate Nutrient Cycling Biomass

A kernel density surface was created using the invertebrate nutrient cycling biomass data collected from the EU research vessel surveys of NAFO Division 3M (Table 1, Figure 3). The peak biomass is found on the eastern and southeastern slopes of Flemish Cap and coincides with the large biomass of sponges found on the sponge grounds. The sponges are all active filter-feeders. There were 1502 trawl locations used in the analyses (Figure 29), although this was reduced to 1047 within the .004 contour polygons (Table 17). The 455 points not included had catches that ranged from 0.001 kg to 0.558 kg (mean ± standard deviation: 0.041 ± 0.052 kg) and so would not have influenced the selection of the high concentration polygons. KDE parameters were: Search Radius = 8.203 km; Contour Interval = 0.004; Cell size default = 984.4 m. These parameters are the default parameters and there was no need to increase the search radius as the default value created a continuous surface (Figure 29).

The first two thresholds (50 and 10 kg, Table 17) capture the highest biomass locations along the eastern and southeastern slopes of Flemish Cap (Figure 29). The 5 kg threshold identifies new areas on the northern upper slope of the Cap and the 3 kg threshold links some of these areas together with good data support. This continues until the large change in area (139.1%) between the area covered by catches ≥ 0.75 kg and that covered by catches ≥ 0.5 kg. The large increase in area leaves data gaps within the polygons (Figure 30) and so the 0.75 kg threshold was selected as the best for delineating areas of high nutrient cycling biomass in Division 3M.

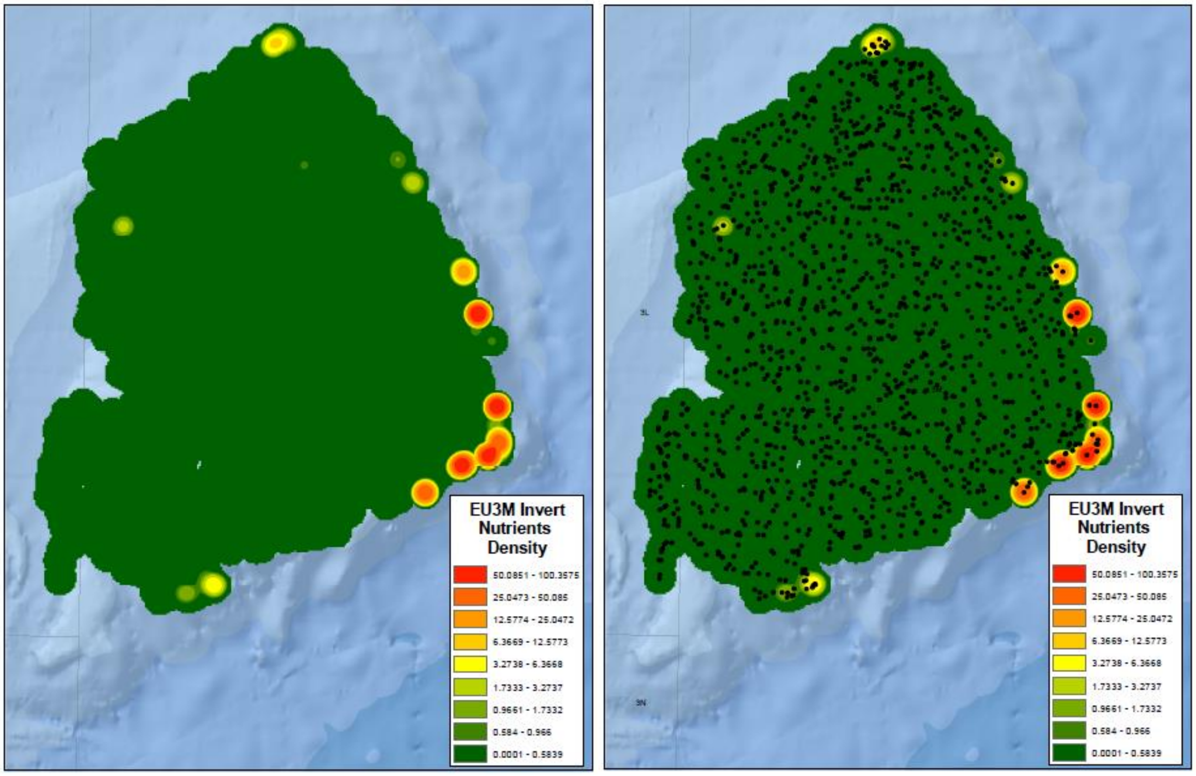

Figure 29. EU Surveys of 3M: Kernel density invertebrate nutrient cycling biomass (kg/km^2) surface in NAFO Division 3M. Left Panel: Kernel density surface. The green areas represent low nutrient cycling biomass densities while the red areas indicate high densities; Right Panel: EU research vessel survey data points overlain on the kernel density surface showing spatial distribution of data.

Of the 176 taxa identified as nutrient cyclers from the EU surveys species lists (Appendix 12) only 64 were recorded from Flemish Cap, Division 3M (Appendix 15) and of those taxa, 62 were recorded in the 277 catches that were used to delineate the nutrient cycling KDE polygons on Flemish Cap (Table 17). The top 90% of the biomass was found in the massive sponges (Geodiidae/Astrophorina) with Porifera ranking third and the most prevalent in the records, being identified in 226 of the 277 trawl sets (Appendix 15). The soft coral *Duva florida* and the sea pen *Anthoptilum* were also prevalent, being recorded in 158 and 135 trawl sets respectively. Twenty-five VME Indicator taxa accounted for 92.67% of the total biomass in the 277 trawl sets.

Table 17. The number of points attributing to the delineation of invertebrate nutrient cycling function KDE polygons based on successively smaller research vessel bioturbator catch weight thresholds (kg) from the EU Surveys of NAFO Division 3M. The area and number of observations used to define each polygon and the percent change in area and the number of additional observations between successive thresholds are provided. The shaded row represents the threshold used to define the nutrient cycling function KDE polygons.

Invertebrate Nutrient Cycling Catch Threshold (Kg)	Number of Observations in Polygon	Additional Observations Per Interval	Area of Polygon (km^2)	Percent Change in Area Between Successive Thresholds
50	22		720.1	116.9
10	55	33	1562.0	77.7
5	85	30	2775.3	36.6
3	119	34	3789.7	90.0
1.5	178	59	7199.4	29.6
1	226	48	9327.7	28.5
0.75	277	51	11986.6	139.1
0.5	358	81	28662.6	4.1
0.4	402	44	29840.0	1.5
0.3	482	80	30279.3	3.1
0.25	529	47	31223.4	1.3
0.2	595	66	31633.3	0.5
0.15	659	64	31796.8	0.0
0.1	762	103	31808.2	0.1
0.075	809	47	31850.3	0.6
0.05	856	47	32028.1	1.0
0.04	886	30	32341.5	0.0
0.03	907	21	32341.5	0.0
0.02	947	40	32341.5	0.0
0.01	998	51	32341.5	0.0
0.005	1027	29	32341.5	0.0
0.001	1047	20	32341.5	

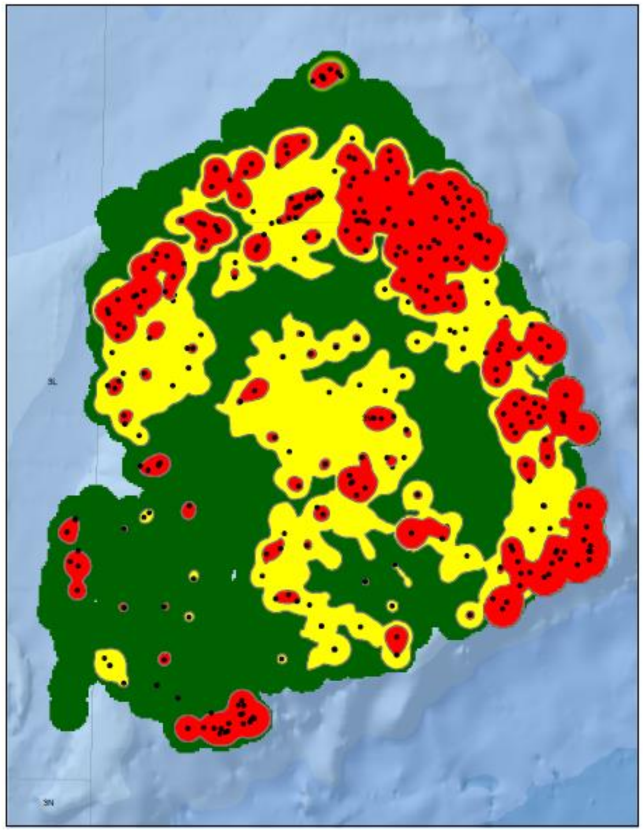

Figure 30. EU Surveys of 3M: The kernel density distribution of invertebrate nutrient cycling biomass in NAFO Division 3M based on analyses of EU survey data. Comparison of the area covered by catches ≥ 0.75 kg (red) and catches ≥ 0.5 kg (yellow) showing the increase in area in the Flemish Cap region. Black dots indicate location of survey stations used to determine these areas. The KDE polygons encapsulating catches ≥ 0.75 kg (red) are considered the KDE invertebrate nutrient cycling polygons.

Overview of Kernel Density Polygons of Significant Concentrations of Invertebrate Nutrient Cyclers

Figure 31 shows the combined results of the kernel density analyses for significant concentrations of invertebrate nutrient cycling biomass in the NAFO Regulatory Area. This activity is widespread throughout the NRA, indicating that many areas are important for benthic-pelagic coupling. Where the bioturbation activity is restricted to soft bottoms, nutrient cycling occurs on both soft and hard bottoms and so has a broader potential occupancy extent.

Both the Canadian and EU surveys of NAFO Divisions 3LNO identified the large-sized, massive, sponges (all active filter-feeders) and the sea cucumber, *Cucumaria frondosa* (a passive filter-feeder), as comprising the top 90% of the biomass in the catches that were used to delineate the KDE polygons. The Canadian surveys recorded the sponges only as 'Porifera' while the EU surveys identified *Geodia* spp., and other Astrophorids as the taxa involved. The VME Indicator taxon, *Boltenia ovifera*, ranked high in biomass in both surveys (Appendices 13, 14) which, given that it does not have a high individual weight, suggests that it is abundant in some areas.

A similar result was found on Flemish Cap (Division 3M), where these same sponge taxa dominated the biomass (Appendix 15), although there, some sea pens were highly ranked as well. Unlike the

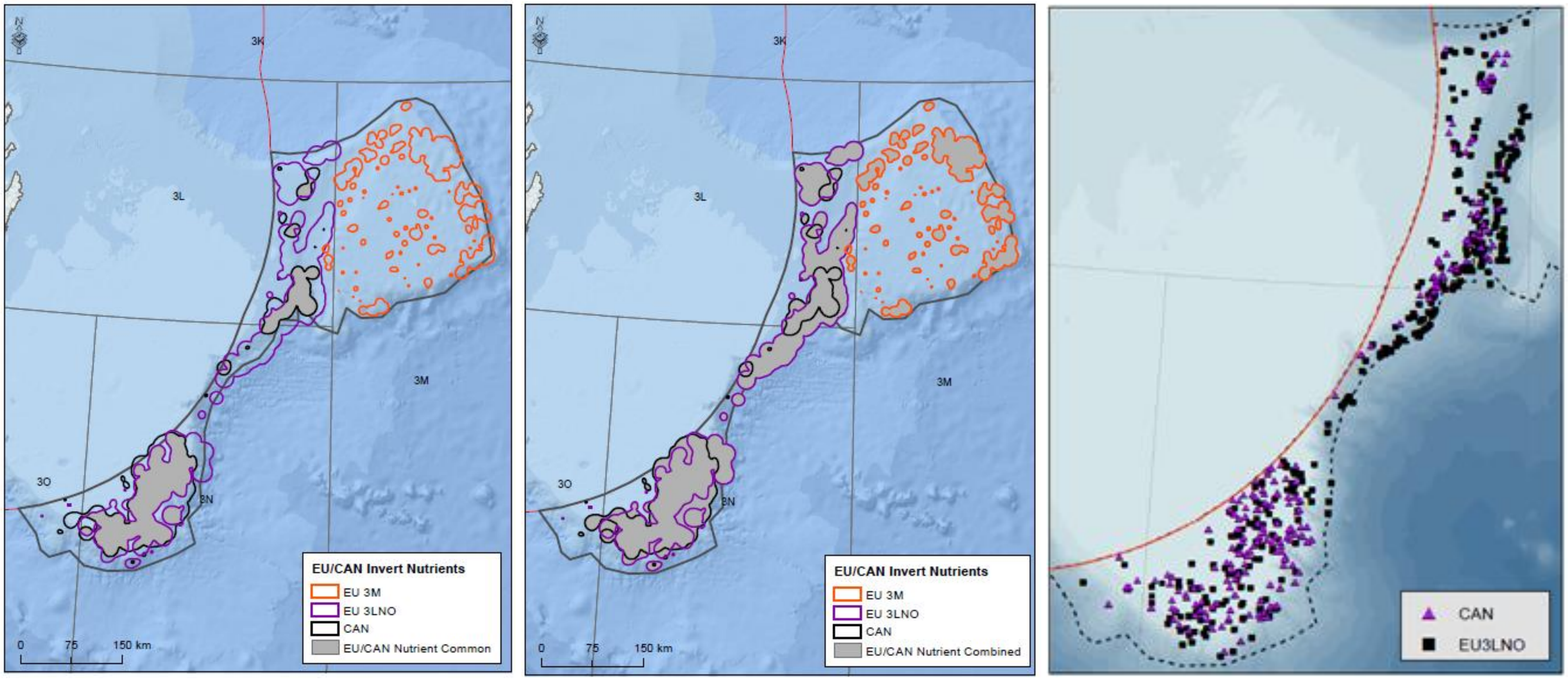

Figure 31. The kernel density polygons of high concentrations of invertebrate nutrient cycling biomass in the NAFO Regulatory Area based on analyses of Canadian (black) and EU (orange/purple) survey data. Left panel: The grey area shows the common area from both Canadian and EU surveys in Divisions 3LNO. Middle panel: The grey area shows the full area of high concentration of nutrient cycling in the NRA from the three surveys combined. The fishing footprint perimeter is shown as a solid grey line and approximates 2000 m. Right panel: The location of the trawl sets from the Canadian and EU surveys in Divisions 3LNO used in the KDE analysis to delineate the polygons shown in the left and middle panels.

bioturbators, nutrient cyclers are heavily dominated by VME Indicator taxa accounting for at least 77% of the biomass in the catches above the threshold established in 3LNO and 93% of that in 3M.

As noted for the bioturbation KDE polygons, the polygons created from data collected by the EU Surveys in Divisions 3LNO include trawl sets in deeper water and so provide valuable data for those areas (Figure 31). In this case the depth ranges are similar for both surveys (36-1379 m for Canadian surveys and 43-1462 m for EU surveys) but there were only 7 trawl sets greater than 750 m in the Canadian data set and 161 trawl sets in the EU survey data set. There were no depth gaps in the EU survey, with sets recorded in every 100 m depth bin within the depth range. In the Canadian surveys there were no stations in the nutrient data set that fell between 800-900 m and between 1000-1100 m. As the KDE analyses were done on the total biomass, irrespective of species, these differences highlight areas where future surveys may alter the current polygons, especially for stations along the peripheries.

As noted, the species compositions are not directly comparable between EU and Canadian surveys in Divisions 3LNO, as the EU species list is more detailed. Of the two dominant taxa reported in each (Appendices 13, 14), sponges and the sea cucumber *Cucumaria frondosa*, the Canadian surveys record Porifera at all sampled depth ranges (n=101 sets), while the EU surveys record Porifera across the depth range (47-1462 m, n=262 sets) but the *Geodia* (n=38 sets), Geodidae (n=49 sets) and Astrophorida (n=52 sets) are all deeper living (649-1462 m, 790-1399 m, and 657-1399 m respectively). The greater number of deep water sets in the EU surveys, largely in the deep Flemish Pass (Figure 31), will mean that the KDE polygons covering those areas will have a predominance of the *Geodia*-type massive sponges.

In contrast, *Cucumaria frondosa* was recorded at all sampled depth ranges in the Canadian surveys between 39 and 684 m (n= 118 sets). In the EU surveys this species was only recorded between 43 and 271 m (n=117 sets). Therefore the common area on the Tail of Grand Bank between these surveys (Figure 31) would have a greater influence of this species in the Canadian data between 271 and 684 m. None of this affects the analyses but rather helps to understand what is driving the KDE results.

Habitat Provision

Marine biogenic habitats, such as cold-water coral gardens and sponge grounds are created by living organisms that form three-dimensional structures that create niches for other species and thereby locally enhance biodiversity. The United Nations General Assembly resolutions calling for the protection of Vulnerable Marine Ecosystems highlight the biodiversity that such areas contain. For a VME indicator to qualify as a VME, it should be present in significant concentrations (habitat forming), or in the case of uniqueness or rarity, be associated with an area or ecosystem whose loss could not be compensated for by similar areas or ecosystems elsewhere (FAO, 2009). Identification of what species/habitats qualify as VME indicators is based on five criteria established by FAO in 2009:

1. Uniqueness or rarity;
2. Functional significance of the habitat;
3. Fragility;
4. Life history traits of the component species that make recovery difficult;
5. Structural complexity.

The VME indicator species in NAFO (NAFO, 2020b) were mostly identified on the basis of the 5th criterion, structural complexity (Murillo et al., 2011), and so would meet our definition of habitat provision applied herein.

Murillo et al. (2020a) assessed the habitat provision function of taxa based on a combination of trait modalities. Habitat provision was confirmed if taxa met trait categories of 'medium' and 'large' for 'maximum adult size', 'sessile' for 'motility', and 'patchy' and 'highly aggregated' for 'degree of contagion' (excluding the Orders Actiniaria, Brisingida, and Euryalida). Here we have followed that general approach, excluding motile, solitary and small-sized species, and have included the NAFO VME indicator taxa. We have also reviewed the literature for inclusion of other species. All sponges were included as even if the species does not form dense aggregations, the spicules that are shed on dying form important habitats for other species (Barrio Froján et al., 2012). For some others, the classification was inferred based on the literature for closely related species (Table 18). For all species that were classified as habitat providers we reviewed the literature to find supporting evidence that the habitats they formed enhanced biodiversity. Taxa that demonstrated that function but may have not been included based on size, for example, were reinstated. The lists of taxa that were classified as important habitat providers are provided in Appendix 16 and Appendix 17 for the Canadian and EU surveys (Table 1, Figure 3) respectively. There were no fish identified in the habitat provision trait category.

Table 18. List of taxa where habitat provision was inferred based on congeneric, confamilial or higher order aggregations.

Taxon used for Consolidating Data	Rationale	Number of taxa affected
(P.) Porifera	All considered to provide habitat through living individuals and through spicule mats generated after death.	11
(P.) Bryozoa	Inferred from *Eucratea loricata*.	1
(O.) Leptothecata	Extended classification to all families and lower order taxa based on the literature and to the superior category Hydrozoa.	11
(O.) Alcyonacea	Extended classification to all lower order taxa not otherwise identified except for Alcyoniidae.	8
(O.) Pennatulacea	Extended classification to all lower order taxa not otherwise identified.	6
(F.) Pyuridae	Classification inferred from confamilial species.	1
(F.) Mytilidae	Extended classification to lower order taxa based on the literature.	2

In order to determine whether any of the data from the different surveys could be combined (Table 1), K-S tests between pairs of data and cumulative biomass distribution plots were examined. Note that the two EU surveys of 3L and 3NO were combined for these analyses. Analyses of the habitat provision biomass data showed no significant differences between the spring and fall surveys in Canada, and so those two surveys of Divisions 3LNO were combined (Table 19). This is supported by the cumulative biomass curves for those two surveys (Figure 32). Significant differences were found with tow length and NAFO Division using the Campelen 1800 gear (Table 20). Cumulative biomass distribution plots (Figure 32) show that the two EU surveys are different from each other and from the Canadian surveys. Consequently the Canadian data were combined for the KDE analyses and the other surveys were kept separate. This produced the following data sets for KDE analyses:

1. Canadian data 3LNO, 15 min tow length, depth range 39-1333 m;
2. EU surveys data 3LNO, 30 min tow length, depth range 42-1433 m;
3. EU surveys data 3M, 30 min tow length, depth range 132-1460 m.

Table 19. K-S Tests for similarity of group biomass of the habitat provision data from the Canadian (DFO) surveys by season (Spring/Fall).

Groups Tested	K-S Test
Same gear and area, by seasons with different depths (Table 1)	
DFO NL Multi-species Spring vs. Fall Surveys (DFO) Species	K-S= 0.025; P<0.609

Table 20. K-S Tests for similarity of group biomass among subsets of habitat provision data from the EU surveys, and between Canadian and EU surveys.

Groups Tested	K-S Test
Different gear and area	
Campelen 1800 3LNO EU vs Lofoten 3M EU	K-S= 0.062; P<0.0001
Same gear and area, by tow length	
Campelen 1800 3LNO EU and Cdn 15 min vs. 30 min	K-S= 0.079; P<0.0001

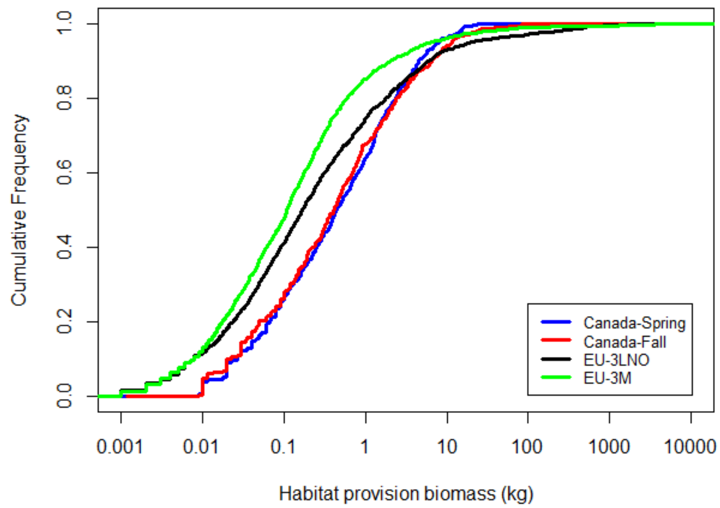

Figure 32. Cumulative habitat provision biomass distribution for invertebrates for each of the four surveys from which data were collected (Table 1).

EU Surveys of Divisions 3LNO – Invertebrate Habitat Provision Biomass

A kernel density surface was created using the invertebrate habitat provision biomass data collected from the EU research vessel surveys of NAFO Divisions 3LNO (Table 1, Figure 3). The peak biomass is found on the slopes of Flemish Pass and coincides with the large biomass of sponges found on the sponge grounds there (Figure 33). There were 1767 trawl locations used in the analyses (Figure 33), although this was reduced to 1658 within the .002 kg contour polygons (Table 21) to reduce run time. The 109 points not included had catches that ranged from 0.001 kg to 0.414 kg (mean ± standard deviation: 0.043 ± 0.060 kg) and so would not have influenced the selection of the high concentration polygons. KDE parameters were: Search Radius = 14.642 km; Contour Interval = 0.002; Cell size default = 1757.0 m. These parameters are the default parameters and there was no need to increase the search radius as the default value created a continuous surface (Figure 33).

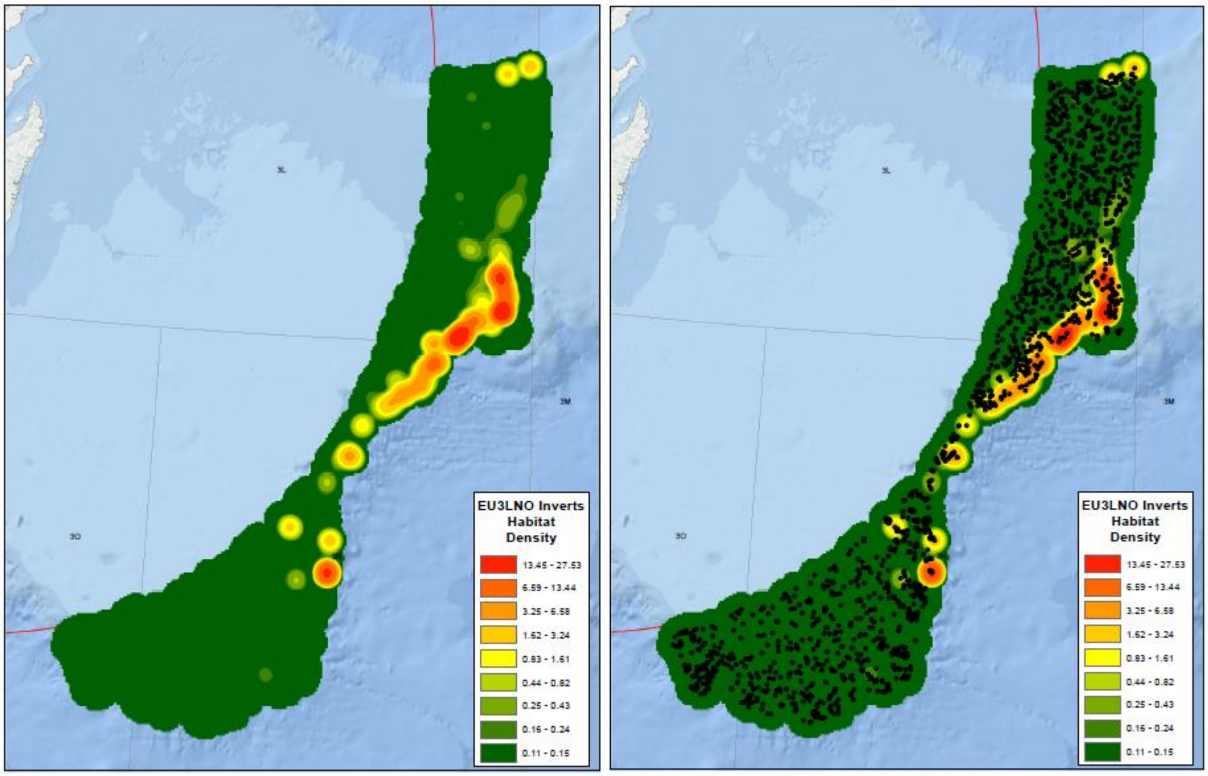

Figure 33. EU Surveys of 3LNO: Kernel density invertebrate habitat provision biomass (kg/km^2) surface in NAFO Divisions 3LNO. Left Panel: Kernel density surface. The green areas represent low habitat provision biomass densities while the red areas indicate high densities; Right Panel: EU research vessel survey data points overlain on the kernel density surface showing spatial distribution of data.

The increase in area associated with successively smaller catch thresholds from the KDE analyses is shown in Table 21. The area increases as new concentrations of the different habitat providers are delineated through to the 1 kg threshold. The increase in area of 20.4% going from polygons capturing catches ≥ 1 kg and those capturing ≥ 0.8 kg (Table 21) is the first increase in area where there are not a lot of data to support some of the expansion (Figure 34). Therefore the 1 kg threshold was used to delineate the high concentrations of habitat provider biomass in NAFO Division 3LNO from the EU surveys.

Of the 95 taxa that were classed as habitat providers from the EU Surveys (Appendix 17), 89 were recorded in the catches from Divisions 3LNO. Of those, 76 were recorded in the 451 trawl sets that were used to delineate the habitat provision KDE polygons (Appendix 18). Ninety percent of the total biomass of those catches was comprised of sponges, *Geodia* and other Astrophorids with unidentified Porifera. The latter was the most prevalent taxon, occurring in 397 trawl sets (Appendix 18). Glass sponges (*Asconema* and Pheronematidae) ranked high in terms of contribution to the total biomass, as did the sea squirt *Boltenia ovifera*. The majority of the biomass, 84.43%, was comprised of VME Indicator taxa as would be expected, and this is likely much higher as the unidentified Porifera likely contained many VME Indicator taxa.

Table 21. The number of points attributing to the delineation of invertebrate habitat provision function KDE polygons based on successively smaller research vessel habitat provision catch weight thresholds (kg) from the EU Surveys of NAFO Divisions 3LNO. The area and number of observations used to define each polygon and the percent change in area and the number of additional observations between successive thresholds are provided. The shaded row represents the threshold used to define the habitat provision function KDE polygons.

Invertebrate Habitat Provision Catch Threshold (Kg)	Number of Observations in Polygon	Additional Observations Per Interval	Area of Polygon (km^2)	Percent Change in Area Between Successive Thresholds
500	18		1059.4	
100	53	35	5398.1	44.8
30	78	25	7817.2	23.1
15	104	26	9624.9	23.9
8	142	38	11929.1	24.8
6	178	36	14893.4	36.5
4	235	57	20327.8	29.6
2.5	298	63	26340.9	6.7
2	336	38	28108.9	19.0
1.5	385	49	33458.4	19.9
1	451	66	40103.3	20.4
0.8	500	49	48286.4	0.8
0.6	568	68	48690.3	16.0
0.45	624	56	56466.8	0.6
0.35	682	58	56818.0	0.0
0.3	718	36	56818.0	0.0
0.25	767	49	56818.0	0.0
0.2	832	65	56818.0	0.0
0.16	898	66	56818.0	0.0
0.13	955	57	56818.0	0.0
0.11	997	42	56818.0	0.0
0.095	1040	43	56818.0	0.0
0.08	1088	48	56818.0	0.0
0.06	1159	71	56818.0	0.0
0.05	1202	43	56818.0	0.0
0.04	1255	53	56818.0	0.0
0.03	1324	69	56818.0	0.0
0.02	1398	74	56818.0	0.0
0.01	1488	90	56818.0	0.0
0.005	1571	83	56818.0	0.0
0.001	1658		56818.0	0.0

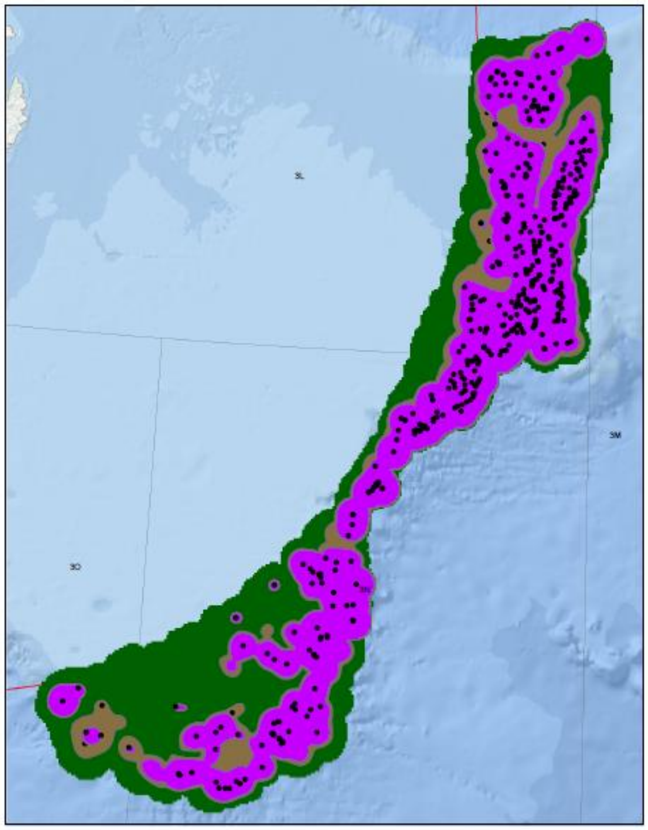

Figure 34. EU Surveys of 3LNO: The kernel density distribution of invertebrate habitat provision biomass in NAFO Division 3LNO based on analyses of EU survey data. Comparison of the area covered by catches ≥ 1 kg (purple) and catches ≥ 0.8 kg (brown) showing the increase in area on the Tail of Grand Bank with data gaps. Black dots indicate location of survey stations used to determine these areas. The KDE polygons encapsulating catches ≥ 1 kg (purple) are considered the KDE invertebrate habitat provision polygons.

Canadian Surveys of Divisions 3LNO – Invertebrate Habitat Provision Biomass

A kernel density surface was created using the invertebrate habitat provision biomass data collected from the Canadian research vessel surveys of NAFO Divisions 3LNO conducted in the spring and fall (Table 1, Figure 3). There were 933 trawl locations used in the analyses (Figure 35) although this was reduced to 911 within the .00075 kg contour polygons (Table 17) to reduce computer run time. The 22 points not included had catches that ranged from 0.00889 kg to 0.08 kg (mean ± standard deviation: 0.031 ± 0.021 kg) and so would not have influenced the selection of the high concentration polygons. KDE parameters were: Search Radius = 14.103 km; Contour Interval = 0.00075; Cell size default = 1692.3 m. These parameters are the default parameters and there was no need to increase the search radius as the default value created a continuous surface (Figure 35).

The areas covered by successively smaller catch thresholds are provided in Table 22. The area increases steadily in going from 15 kg to 3 kg (Table 22). Changes in area are smaller in moving to the 1 kg threshold but small new areas are introduced with each threshold. In going from 0.6 to 0.5 kg thresholds the area changes by 25.6% and there is less support for the area expansion (Figure 36). This is the largest increase in area after the concentrations are mapped out. Consequently the 0.6 kg threshold was used to delineate the KDE polygon for significant concentrations of invertebrate habitat provision biomass. These polygons appear to capture areas of the VME polygons for sea pens, sponges and large gorgonian corals (Kenchington et al., 2019).

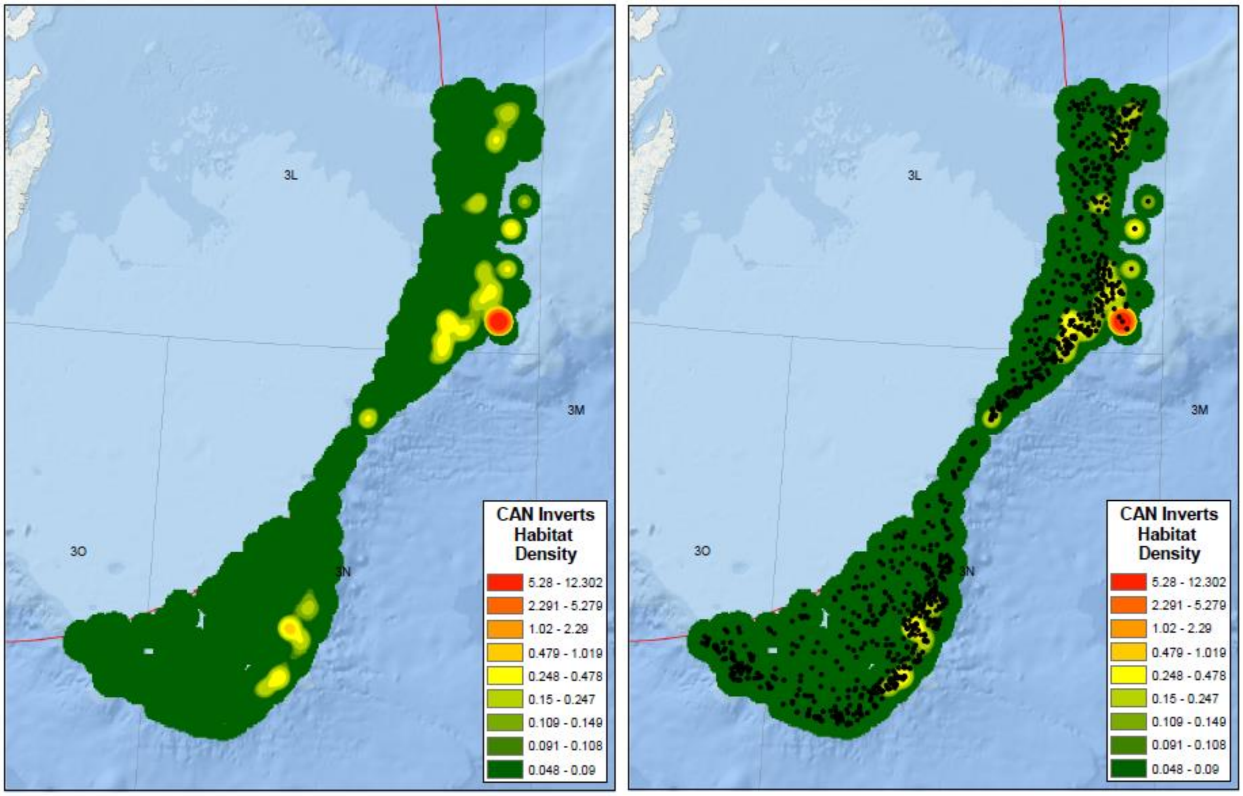

Figure 35. Canadian Spring and Fall Surveys of 3LNO: Kernel density invertebrate habitat provision biomass (kg/km^2) surface in NAFO Divisions 3LNO. Left Panel: Kernel density surface. The green areas represent low habitat provision biomass densities while the red areas indicate high densities; Right Panel: Canadian research vessel survey data points overlain on the kernel density surface showing spatial distribution of data.

The Canadian surveys do not record the invertebrates to the same degree of taxonomic resolution as is done in the EU surveys. As a result only 10 taxa were classified as habitat providers in the Canadian surveys (Appendix 17) and all 10 were present in the survey data from Divisions 3LNO, and all 10 were present in the subset of 408 trawl sets that were used to delineate the KDE polygons for high concentrations of habitat providers from the Canadian surveys (Appendix 19). Porifera was the top ranking taxon, accounting for more than 90% of the total biomass in those 408 trawl sets, and occurring in 349 of them. Soft corals (Nephtheidae) and *Boltenia* were the second and third ranking in terms of biomass. The coarser taxonomic resolution also meant that VME Indicator taxa could not be separated out from the higher level classifications such as Porifera. As a result only 4.13% of the habitat provision biomass in the catches delineating the KDE polygons, could be attributed to VME Indicator taxa (Appendix 19).

Table 22. The number of points attributing to the delineation of invertebrate habitat provision function KDE polygons based on successively smaller research vessel habitat provision catch weight thresholds (kg) from the Canadian Spring and Fall Surveys of NAFO Divisions 3LNO. The area and number of observations used to define each polygon and the percent change in area and the number of additional observations between successive thresholds are provided. The shaded row represents the threshold used to define the habitat provision function KDE polygons.

Invertebrate Habitat Provision Catch Threshold (Kg)	Number of Observations in Polygon	Additional Observations Per Interval	Area of Polygon (km^2)	Percent Change in Area Between Successive Thresholds
15	25		1933.3	
10	47	22	4754.1	60.1
6	87	40	7610.2	28.2
4	124	37	9759.8	26.2
3	159	35	12312.0	44.6
2	213	54	17807.6	4.9
1.5	255	42	18686.4	2.8
1.25	293	38	19204.2	3.8
1	320	27	19940.2	20.6
0.8	362	42	24040.4	11.8
0.6	408	46	26868.4	25.6
0.5	437	29	33750.2	1.8
0.4	481	44	34352.0	6.9
0.3	528	47	36715.5	23.3
0.25	556	28	45255.3	0.0
0.2	588	32	45255.3	0.4
0.15	635	47	45439.3	0.0
0.1	690	55	45439.3	1.2
0.07	734	44	45984.3	0.0
0.05	768	34	45984.3	0.0
0.03	820	52	45984.3	0.0
0.02	861	41	45984.3	0.0
0.008	911	50	45984.3	

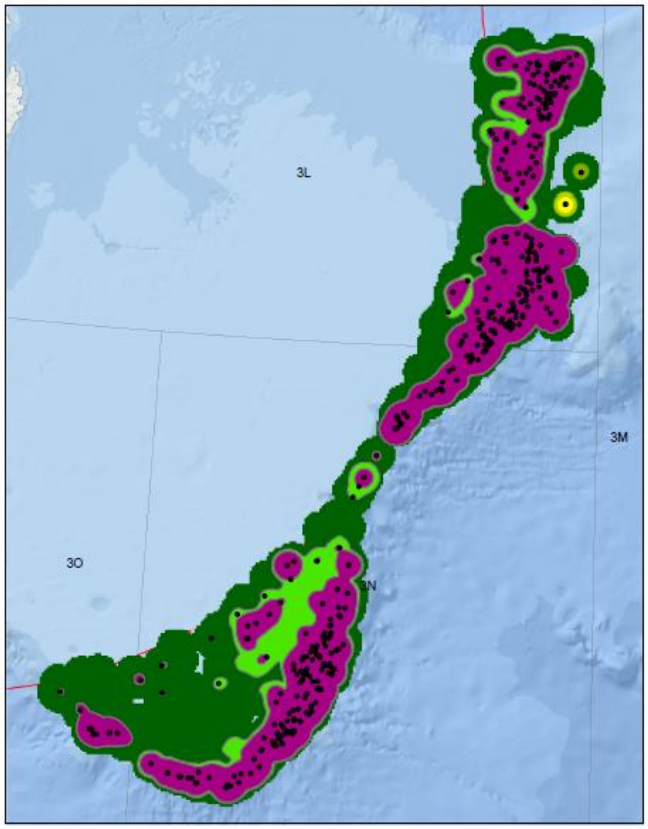

Figure 36. Canadian Spring and Fall Surveys of 3LNO: The kernel density distribution of invertebrate habitat provision biomass in NAFO Divisions 3LNO based on analyses of Canadian Spring and Fall Survey data. Comparison of the area covered by catches ≥ 0.6 kg (purple) and catches ≥ 0.5 kg (light green) showing the increase in area on the Tail of Grand Bank with data gaps. Black dots indicate location of survey stations used to determine these areas. The KDE polygons encapsulating catches ≥ 0.6 kg (purple) are considered the KDE invertebrate habitat provision polygons.

EU Surveys of Division 3M – Invertebrate Habitat Provision Biomass

A kernel density surface was created using the invertebrate habitat provision biomass data collected from the EU research vessel surveys of NAFO Division 3M (Table 1, Figure 3). The peak biomass is found on the eastern and southeastern slopes of Flemish Cap and coincides with the large biomass of sponges found on the sponge grounds there (Figure 37). There were 1405 trawl locations used in the analyses (Figure 37), although this was reduced to 1405 within the .004 kg contour polygons (Table 23) to reduce the computer run time. The 459 points not included had catches that ranged from 0.001 kg to 0.555 kg (mean ± standard deviation: 0.043 ± 0.052 kg) and so would not have influenced the selection of the high concentration polygons. KDE parameters were: Search Radius = 8.203 km; Contour Interval = 0.004; Cell size default = 984.4 m. These parameters are the default parameters and there was no need to increase the search radius as the default value created a continuous surface (Figure 37).

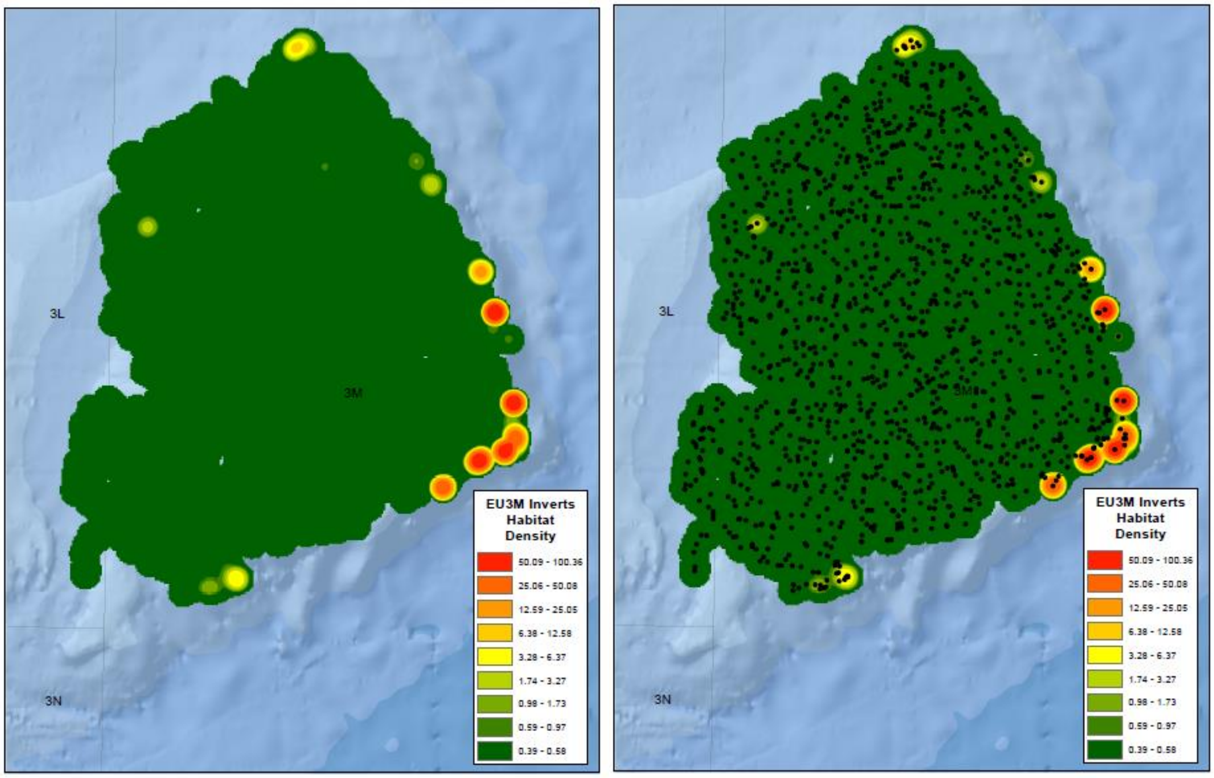

Figure 37. EU Surveys of 3M: Kernel density invertebrate habitat provision biomass (kg/km^2) surface in NAFO Divisios 3M. Left Panel: Kernel density surface. The green areas represent low habitat provision biomass densities while the red areas indicate high densities; Right Panel: EU research vessel survey data points overlain on the kernel density surface showing spatial distribution of data.

The areas covered by successively smaller catch thresholds are provided in Table 23. The 50 kg, 15 kg and 5 kg thresholds identify different *Geodia*-dominated sponge grounds on the slopes of Flemish Cap. These have the largest biomass and so are delineated first. The 2.5 and 1.5 kg thresholds pick up the sea pen VMEs in the shallower water and the 1 kg thresholds delineates some polygons on the shallowest part of the Cap, likely areas where the glass sponge *Asconema foliatum* is found (Murillo et al., 2020b). Those areas are further delineated through to the 0.5 kg threshold. In going to the 0.4 kg threshold the area changes by 67.1% and there is less data to support the area expansion (Figure 38). This is the largest increase in area after the concentrations are mapped out. Consequently the 0.5 kg threshold was used to delineate the KDE polygon for significant concentrations of invertebrate habitat provision biomass in NAFO Division 3M.

There were 95 taxa classified as habitat providers from the EU surveys, and 38 of those were recorded in Division 3M. Of those 38, 37 were included in the 310 trawl sets that were used to define the habitat provision KDE habitats on Flemish Cap (Appendix 20). As indicated by the KDE surfaces, the Geodiid sponges dominated the catch biomass with the soft coral *Duva florida* and the sea pen *Anthoptilum* the highest ranking non-sponge taxa with respect to total biomass (Appendix 20). VME Indicator taxa comprised 92.77% of the catch biomass in the catches used to delineate the KDE polygons (Appendix 20).

Table 23. The number of points attributing to the delineation of invertebrate habitat provision function KDE polygons based on successively smaller research vessel habitat provision catch weight thresholds (kg) from the EU surveys of NAFO Division 3M. The area and number of observations used to define each polygon and the percent change in area and the number of additional observations between successive thresholds are provided. The shaded row represents the threshold used to define the habitat provision function KDE polygons.

Invertebrate Habitat Provision Catch Threshold (Kg)	Number of Observations in Polygon	Additional Observations Per Interval	Area of Polygon (km²)	Percent Change in Area Between Successive Thresholds
50	22		720.2	
15	44	22	1281.2	112.1
5	82	38	2717.5	41.4
2.5	125	43	3842.0	77.5
1.5	165	40	6819.6	27.8
1	208	43	8713.1	31.1
0.75	246	38	11427.0	26.5
0.6	283	37	14454.0	10.4
0.5	310	27	15959.1	67.1
0.4	352	42	26660.6	0.7
0.35	388	36	26851.2	0.9
0.3	429	41	27085.6	2.6
0.25	472	43	27783.6	1.7
0.2	533	61	28248.4	0.8
0.175	556	23	28470.1	0.3
0.15	590	34	28562.1	0.0
0.125	621	31	28562.1	0.0
0.1	675	54	28562.1	0.1
0.08	702	27	28604.3	0.2
0.07	721	19	28673.1	0.0
0.06	738	17	28673.1	0.3
0.05	761	23	28772.9	0.0
0.04	786	25	28772.9	1.1
0.03	813	27	29084.5	0.0
0.02	855	42	29084.5	0.0
0.015	876	21	29084.5	0.0
0.01	900	24	29084.5	0.0
0.007	913	13	29084.5	0.0
0.004	930	17	29084.5	0.0
0.002	942	12	29084.5	0.0
0.001	946	4	29084.5	

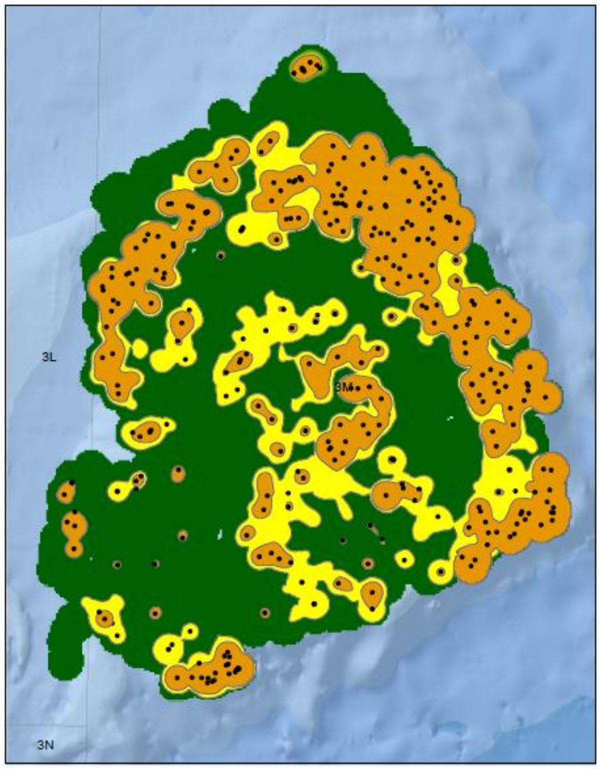

Figure 38. EU Surveys of 3M: The kernel density distribution of invertebrate habitat provision biomass in NAFO Division 3M based on analyses of EU survey data. Comparison of the area covered by catches ≥ 0.5 kg (brown) and catches ≥ 0.4 kg (yellow) showing the increase in area with few data to support the expansions. Black dots indicate location of survey stations used to determine these areas. The KDE polygons encapsulating catches ≥ 0.5 kg (purple) are considered the KDE invertebrate habitat provision polygons.

Overview of Kernel Density Polygons of Significant Concentrations of Invertebrate Habitat Providers

Figure 39 shows the combined results of the kernel density analyses for significant concentrations of invertebrate habitat provision biomass in the NAFO Regulatory Area. The concentrations are found along the slopes of Grand Bank and Flemish Pass as well as on the Flemish Cap. In all three surveys, the catches which delineated the KDE polygons were dominated by large-sized sponges – *Geodia* spp. and other Astrophorids, as well as unidentified Porifera. In Divisions 3LNO, the sea squirt *Boltenia ovifera* and the soft coral *Duva florida* comprised the highest biomass for non-sponge taxa in both Canadian and EU surveys, while in Division 3M, *Duva florida*, the sea pen *Anthoptilum* and the large gorgonian corals *Paragorgia* were among the highest ranking non-sponge biomass. Because the VME Indicator taxa were part of the selection criteria for this trait, they dominate the biomass in the habitat provision KDE polygons. As for the other traits, the EU surveys in Divisions 3LNO are more frequent in deeper water (Figure 39), particularly in the deep Flemish Pass, and the deep slopes of Grand Bank. The depth range of the EU Surveys was 44-1462 m for the trawl locations used to delineate the KDE polygons, and sets were found in every 100 m depth bin. Of those, 219 were in water greater than 750 m. Whereas the Canadian survey data also covered a range of 40 – 1333 m (with gaps between 800-900 m and 1000-1100 m depth bins), only 9 tows were in water greater than 750 m. Porifera was recorded in Canadian and EU sets

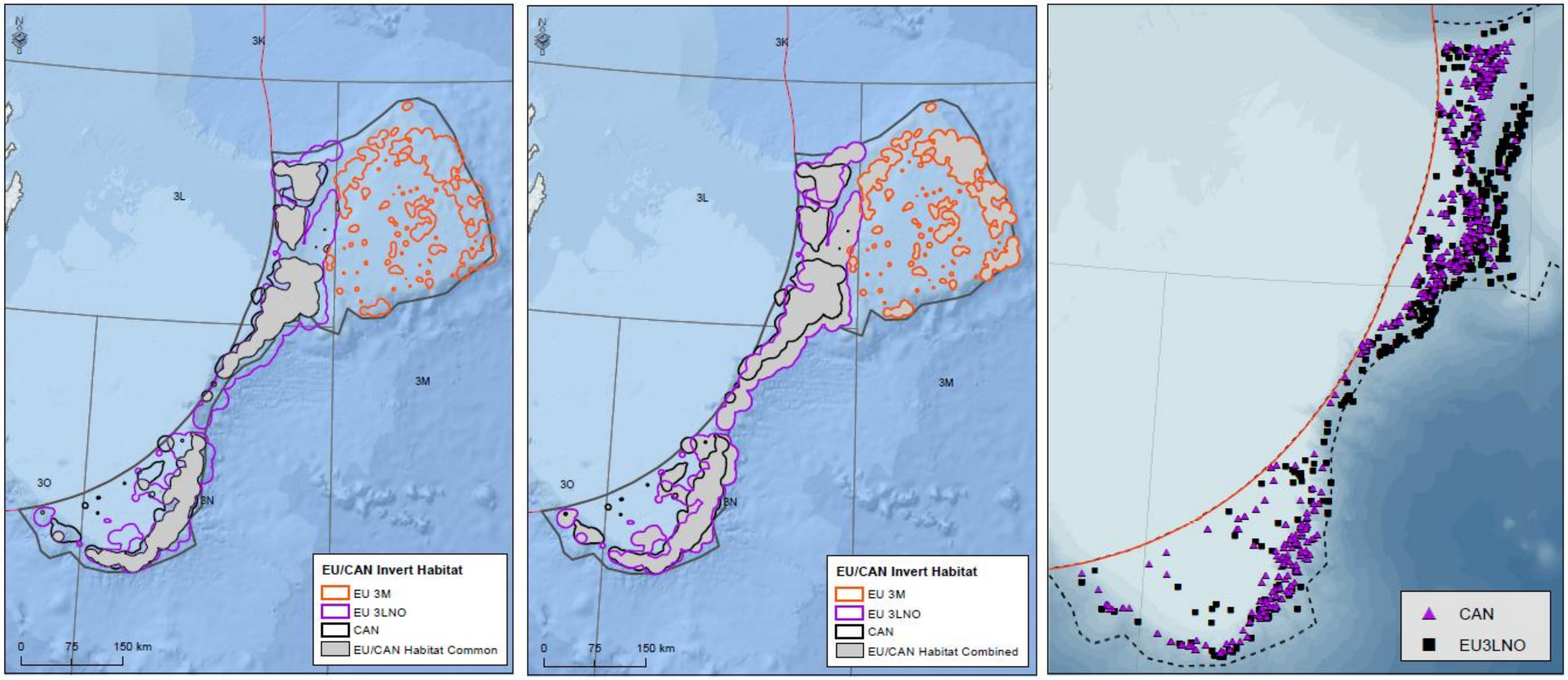

Figure 39. Left panel: The kernel density polygons of high concentrations of invertebrate habitat provider biomass in the NAFO Regulatory Area based on analyses of Canadian (black) and EU (orange/purple) survey data. The grey area shows the common areas of high concentration of habitat provision in the NRA (mostly in Divisions 3LNO) from the three surveys. Middle panel: KDE polygons as for the left panel. The grey area shows the full area of high concentration of habitat provision in the NRA from the three surveys combined. The fishing footprint perimeter is shown as a solid grey line and approximates 2000 m. Right panel: Location of the EU and Canadian trawl sets used to delineate the KDE polygons in Division 3LNO in the left panel.

through out the full depth range of each survey (n=349 sets and n=397 sets, respectively), and so there was no strong bias in species composition between them. However, the EU surveys recorded *Geodia* and Astrophorina only in the deeper sets below 649 and 458 m respectively, along with the sea pens and large and small gorgonian corals. The EU surveys consequently identify important areas of habitat provision, largely in sponge dominated areas and sea pen fields, in deeper water (Figure 39).

Functional Diversity

To quantify functional diversity (FD), Murillo et al. (2020a) calculated two metrics for each sampling location using the 'FD' package (Laliberté et al., 2015) from the statistical computing software R 3.5.1 (R Core Team, 2018). They calculated functional richness (FRic; Villéger et al., 2008), recommended when the total functional range covered by the community is desired (Legras et al., 2018).

In order to quantify functional diversity it is desirable to code multiple traits and modalities. Due to time limitations we were not able to complete that for the 2020 meeting of WG-ESA. However we have extracted the FRic values for each of the 175 stations of Murillo et al. (2020a) and performed a KDE analyses on those data to trial the approach. As noted in the Introduction, Murillo et al. (2020a) only undertook their analysis in NAFO Division 3M, using the EU research vessel survey data from 2007 (see Figure 2).

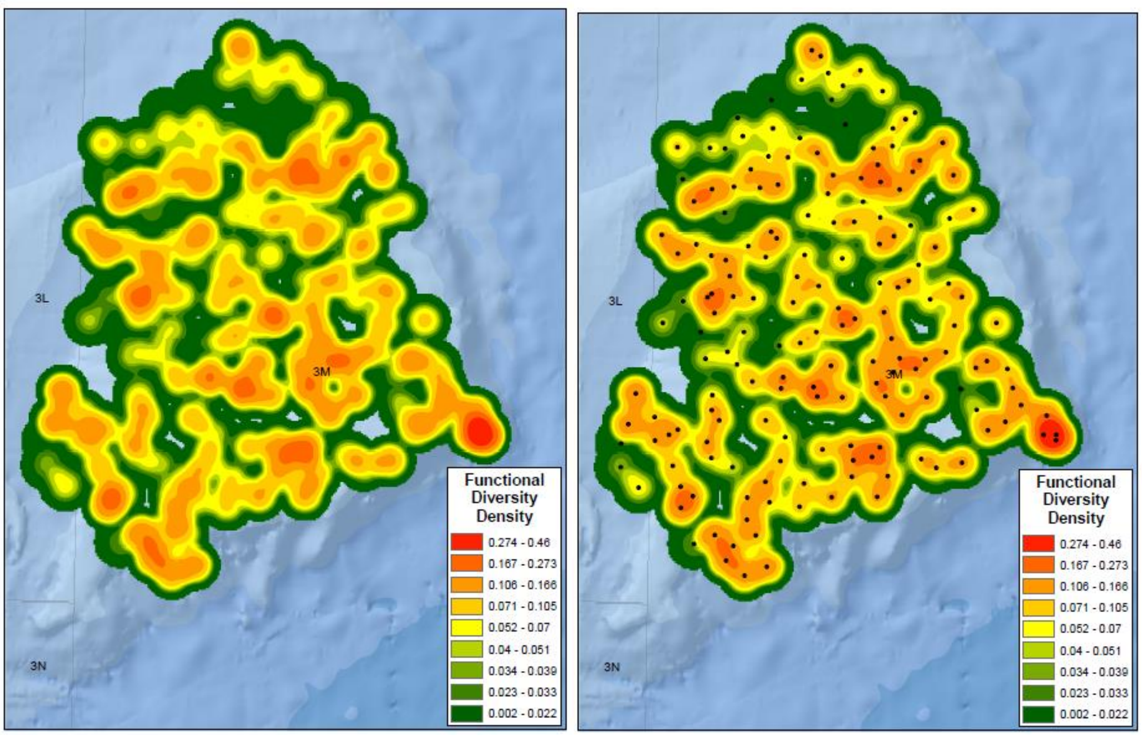

Figure 40. 2007 EU Survey of 3M: Kernel density functional diversity biomass (kg/km^2) surface in NAFO Divisios 3M. Left Panel: Kernel density surface. The green areas represent low functional diversity biomass densities while the red areas indicate high densities; Right Panel: EU 2007 research vessel survey data points overlain on the kernel density surface showing spatial distribution of data.

A kernel density surface was created using the FRic data collected from the EU research vessel surveys of NAFO Division 3M (Table 1, Figure 3). There were 175 trawl locations used in the analyses (Figure 40). KDE parameters were: Search Radius = 15.0 km; Contour Interval = 0.001; Cell size default = 1016.6 m. The search radius was increased to 15 km from the default 8.471 in order to create a more continuous surface (Figure 40). Functional diversity ranged from 1.507 to 39.710 with a mean of 19.300 and standard deviation of 8.467. We feel that this analysis would be improved in future by adding more survey years to the data set analyzed. The random sampled depth-stratified survey design means that in any one year the survey stations are not likely to be highly aggregated (Figure 40). There was insufficient time to score the full trait suite (Murillo et al., 2020a) required to do that for this year but that will be considered in future work.

The kernel density surface (Figure 40) showed high functional richness at various locations on Flemish Cap with the highest values in the sponge grounds on the southeast slope. The FRic values were not highly aggregated and so the KDE analyses did not perform as well as for the other traits based on biomass, in the sense that the area increase was steady and it was more difficult to determine the threshold (Table 24). However in going from FRic values greater or equal to 13 to 10, the polygon area increased by 41.6% and there were data gaps in the large area created in the central part of the Cap (Figure 41). Other increases in area were better supported and so we chose the FRic threshold of 13 to identify the significant concentrations of functional diversity on Flemish Cap (Figure 41).

Table 24. The number of points attributing to the delineation of invertebrate functional diversity (FRic) KDE polygons based on successively smaller thresholds from the 2007 EU survey of NAFO Division 3M. The area and number of observations used to define each polygon and the percent change in area and the number of additional observations between successive thresholds are provided. The shaded row represents the threshold used to define the functional diversity KDE polygons.

Invertebrate Functional Diversity Threshold	Number of Observations in Polygon	Additional Observations Per Interval	Area of Polygon (km²)	Percent Change in Area Between Successive Thresholds
35	7		537.3	
30	21	14	1205.8	81.6
27.5	33	12	2190.0	58.5
25	47	14	3471.3	50.4
22.5	64	17	5222.2	33.0
20	81	17	6947.0	38.1
17.5	98	17	9593.3	64.3
15	119	21	15761.6	16.2
13	133	14	18317.7	41.6
10	151	18	25934.5	55.5
7.5	162	11	40329.6	10.3
4.5	167	5	44493.2	12.4
1.5	175	8	50026.3	

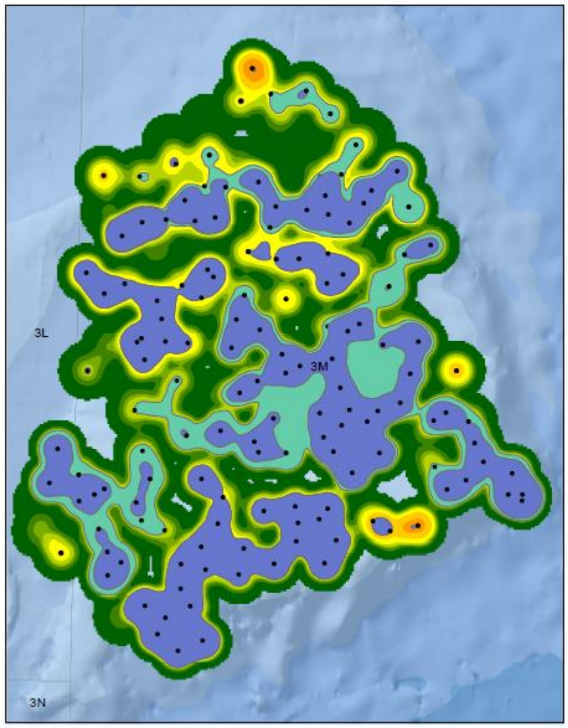

Figure 41. 2007 EU Survey of 3M: The kernel density distribution of invertebrate functional diversity in NAFO Division 3M based on analyses of EU survey data. Comparison of the area covered by values ≥ 13 (blue) and values ≥ 10 (green) showing the increase in area with few data (FRic) to support the expansions. Black dots indicate location of survey stations used to determine these areas. The KDE polygons encapsulating values ≥ 13 (blue) are considered the KDE invertebrate functional divesity polygons.

Discussion

Our analyses used biomass, rather than abundance, as the variable for the kernel density analyses for bioturbation, nutrient cycling and habitat provision as it may represent functionality more accurately than abundance (Saint-Germain et al., 2007). Biomass captures the energy flow through the system, which can be disrupted by changes in biomass (Maureaud et al., 2017), and further enables calculations of biosequestered carbon (Pham et al., 2019). It is the standard variable used for modeling biogeochemical cycles (Bar-On et al., 2018; Maldonado et al., 2020).

Energy flow through an ecosystem is linked to individual metabolic rate which determines both the uptake of resources from the environment and the allocation of resources by the organism to movement, growth and reproduction etc. Consequently, metabolic rate controls ecological processes at all levels of organization, and metabolism is scaled to body mass to the exponent 0.75 (Brown et al., 2004). In contrast, abundance only indirectly influences energy flow through correlation with biomass (Saint-Germain et al., 2007), and that correlation may not always be very strong. When working with species whose body masses range across several orders of magnitude, as is the case in this study, analysis of abundance data without consideration of body mass, would assume that abundant small-sized species have a greater ecological function in the system than larger less abundant species, and that two individuals of different body mass have the same ecological impact and influence in the analyses (Saint-Germain et al., 2007). For most applications this is not a reasonable assumption, although small benthic filter-feeders such as hydrozoans, which make only a minor contribution to benthic community biomass, may play an important role in transferring energy from pelagic to benthic ecosystems (Gili et al., 1998). Belley and Snelgrove (2016) also showed that some species can affect benthic flux rates disproportionately relative to their abundance. Where so little is known about the ecosystem functions of many of the species in our analyses, further exploration of the role of species with small individual biomass is warranted. However, in our data sets abundance is not always recorded for each taxon, particularly for the invertebrates, and for some, such as colonial or encrusting organisms, it can be difficult to quantify. Running KDE analyses using the biomass of different size classes of organisms, an unintended consequence of our analyses for the invertebrates and fish for bioturbation, could be one way of examining how well the KDE polygons constructed here capture areas important to organisms with smaller biomass given these issues with abundance data. However, KDE is a spatial analysis and so aspects of abundance correlated to the area occupied may be captured in addition to correlations with biomass. Nevertheless, abundance can be very important for other aspects of ecosystem functioning, such as population dynamics, and KDE analyses using that variable for selected taxa is something that can be explored in future work.

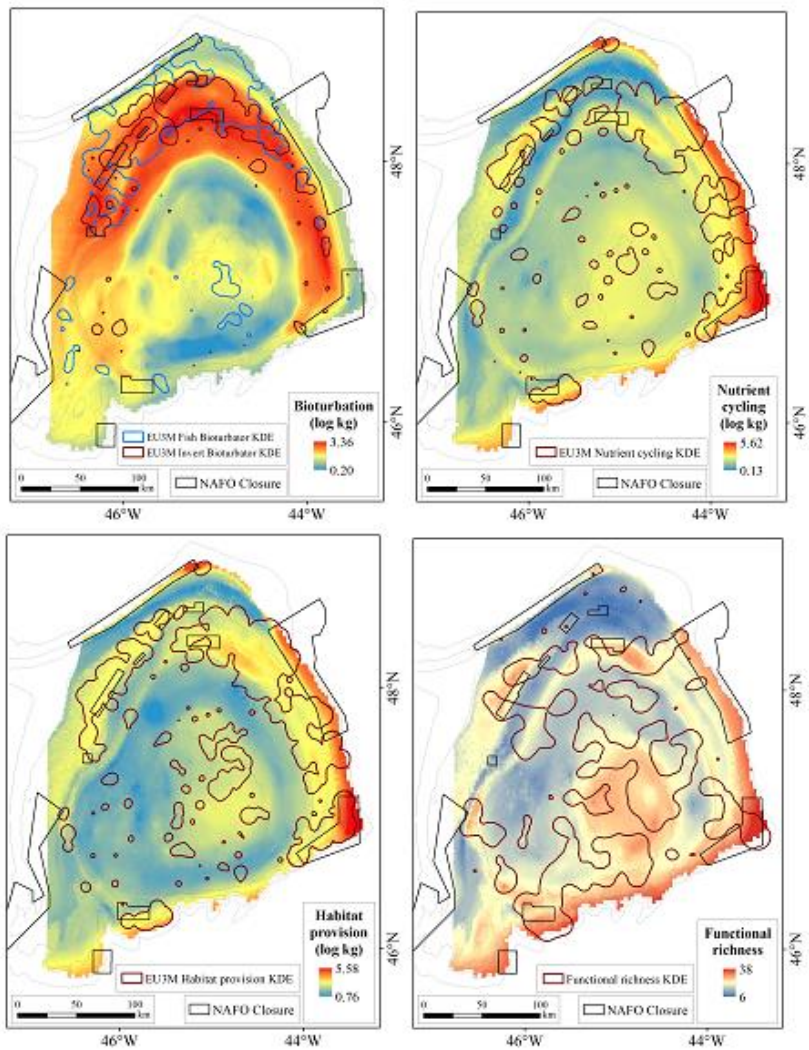

Figure 42. KDE Polygons for bioturbation, nutrient cycling, habitat provisions and functional richness (FRic) for NAFO Division 3M overlain on the random forest models for those traits from Murillo et al. (2020a).

Here, our purpose was to identify significant concentrations of the biomass for each ecosystem function so that the KDE polygons created for the VMEs (Kenchington et al., 2019) could be overlain and the relative area occupied compared. For that reason too, biomass had to be used to render the areas comparable.

The kernel density analyses appears to have performed well when applied to the catch biomass of the various taxa that contributed to each of the ecosystem functions assessed (bioturbation, nutrient cycling and habitat provision). For Division 3M we were able to directly compare our results with those of Murillo et al. (2020) (Figure 42) and there is a good correlation between the areas identified using both methods (KDE vs. SDM), despite the difference in time frame over which the data were collected (9 years vs. 1 year). Functional richness, FRic, did not perform well in the KDE analyses, likely due to the spatial configuration of the single year of data; in that application the trait data were the same (one year, 2007) and only the analyses differed. Mapping of the functional trait diversity in the NAFO Regulatory Area facilitates the mainstreaming of ecosystem services into policy and decision making (Maes et al., 2012). Here we have produced maps of key areas (KDE polygons) for three ecosystem services (Figure 42). These maps can be used to contextualize the impacts of bottom contact fishing gear on VMEs which contribute to all three ecosystem services examined.

The KDE polygons were similarly situated in Divisions 3LNO between those constructed from the Canadian and EU surveys, however the EU surveys had a greater number of stations in deeper water in the subsets of the data analyzed, and so allowed for improved delineation below 700 m over the Canadian surveys. Taxonomic resolution was higher in the EU surveys than in the Canadian surveys as well, however this does not affect the analysis as the resolution of the Canadian data was generally sufficient to classify the constituent taxa by their traits. For example, although the knowledge of the species composition of the Porifera was valuable for interpreting the data, all sponges were classified as nutrient cyclers and habitat providers. This would not be possible to do with FRic calculations, where information on a range of traits/modalities are required and which would differ within the phylum; further work with FRic should be focussed on the EU data sets. Where the Canadian data required further resolution, it was possible to get expert opinion from at-sea personnel and to later cross compare with the EU data from the same areas. We have documented the species and taxa that contributed to the deeper sets, many of which are VME indicators. However, the inclusion of species/taxa in each analysis was made on the basis of their functions *a priori*, and so while species composition will vary locally within each KDE polygon, inclusion of the deeper sets and their resident species only affects the spatial extent of the analyses at those locations. There were no cases where the EU data sets included taxa that would not be recorded in the Canadian data sets; albeit at a higher level of organization.

The diverse array of species and taxa included in the analysis has created relatively large KDE polygons for each of the areas assessed. It appeared that as new areas were delineated that these were capturing different species groups (for example see Figure 8) and so contributing to the large areas delineated. This is a positive outcome as it means that where species with a smaller biomass were situationally separated from the taxa that dominated the highest biomass, they were captured in the delineation. We noted that where the fish were assessed they had larger KDE polygons delineated than those for invertebrates in the same areas. This we attribute to the scale of mobility of the fish, and potentially to weaker response to environmental filters over the scales examined.

Bioturbation Function

Bioturbation activites which deliver oxygen and organic matter at the sediment-water interface are critical to geochemical processes (Shull et al., 2009; Snelgrove et al., 2018). Many bioturbating organisms live below the sediments where their galleries and burrows contribute to solute exchange, and those species will not be represented in this data set which was collected by bottom trawl gears. Our data set is largely comprised of 'surficial modifiers', that is species whose activities are restricted to the surficial layer (0–2 cm) of the sediment profile (Solan, 2000 in Oug et al., 2018). Also present are upward conveyors such as Maldanidae that are 'head-down feeders' that actively transport sediment to the sediment surface, downward conveyers such as *Echiura* (spoon worms) that actively bring sediment downwards from the sediment surface, and biodiffusors such as *Eunice norvegica* that facilitate a random diffusive transport of particles over short distances in the sediment (Solan, 2000 in Oug et al., 2018). The sea cucumber *Cucumaria frondosa* is classed as a surficial modifier. Due to its abundance and individual weight, this species dominated the sets in the KDE polygons in Divisions 3LNO. In general, surficial modifiers have a low impact on bioturbation compared with the other functional groups (Queirós et al., 2013; Belley and Snelgrove, 2018), however when present in high abundance such species can impact effluxes of nutrients (Belley and Snelgrove, 2018). Benthic and demersal fish can also directly influence bioturbation processes (Hall, 1994) through turnover of the sediment while feeding, and through reworking of sediments for concealment (Fleeger et al., 2006). The identification of key areas for invertebrate activities could be further explored by size-based evaluations as noted earlier, given that many of the species which influence bioturbation may be poorly represented in the present analyses due to their relatively small collective biomass.

However it should be noted that many annelids and arthropods contributed to the sets inside the invertebrate KDE polygons (e.g., Appendix 3), with some, such as the Sabellidae ranking high in terms of total biomass. Therefore such analyses would likely only highlight areas of high biomass for such species within the current KDE polygons.

Nutrient Cycling Function

Our list of nutrient cyclers includes active and passive filter-feeders. Such species play key roles in benthic–pelagic coupling processes mediated by living organisms. Sponges were the top contributers to nutrient cycling biomass in our data sets. As sponges are active and efficient filter-feeders (Kahn et al., 2015; Pham et al., 2019) that utilize a wide range of particulate and dissolved food (Bart et al., 2020), the KDE polygons likely reflect the key areas for this function. Our analyses includes sponges that are VME Indicators as well as other sponge species, creating larger polygons than those produced for the VME sponges alone (Kenchington et al., 2019).

Habitat Provision Function

The list of habitat providers draws heavily on the VME Indicator taxa for this area. However by focusing on function and not just the life history characteristics associated with vulnerability (FAO, 2009) our data includes a number of habitat-forming Nephtheids, polychaetes, hydrozoans and molluscs. As for the nutrient cyclers, sponges dominated the biomass of catches inside the KDE polygons, however all of the taxa were present in the delineated areas. Sponges are known to locally enhance biodiversity in the NAFO Regulatory Area (Beazley et al., 2013; Beazley et al., 2015) and the KDE polygons guided by their distribution are a good match for this function.

Other Comments and Considerations

In examining the species lists and data from the surveys we noted very few records that could be erroneous. Two anomalous species observations that we feel should be examined further are the 11 records of *Lophelia pertusa* (*Desmophyllum pertusum*) and the single record of Pheronematidae recorded from the EU surveys of 3NO conducted in 2014. As these are VME indicator taxa we suspect that these are misidentifications as they were not reported previously in the survey summaries to WG-ESA. However as they are VME Indicator taxa some follow up is warranted. Other records associated with the weights of some taxa may also be erroneous. For example while it is not impossible to collect 57 kg of the brittlestar *Ophiomusium lymani*, it would be good to validate such catches with photos if available. In this example, another set recorded 19 kg of this species, so this species does occur in high biomass in the NRA. None of these issues would have a detectable effect on the analyses.

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Appendix 1. Species Classified as Bioturbators from the Canadian (DFO-NL) Surveys (see Table 1).

Phylum	Class	Order	Family	Genus	Scientific Name (WoRMS)	Reference	Notes
Annelida	Polychaeta				Polychaeta		Values based on the largest biomass of annelids (Sabellids) from EU surveys.
Arthropoda	Malacostraca	Amphipoda			Amphipoda	[1]	
Arthropoda	Malacostraca	Decapoda	Crangonidae	Argis	Argis dentata	[1]	
Arthropoda	Malacostraca	Decapoda	Crangonidae	Crangon	Crangon	[2]	
Arthropoda	Malacostraca	Decapoda	Crangonidae	Metacrangon	Metacrangon jacqueti	[2]	
Arthropoda	Malacostraca	Decapoda	Crangonidae	Pontophilus	Pontophilus norvegicus	[2]	
Arthropoda	Malacostraca	Decapoda	Crangonidae	Sabinea	Sabinea septemcarinata	[2]	
Arthropoda	Malacostraca	Decapoda	Crangonidae	Sabinea	Sabinea sarsii	[2]	
Arthropoda	Malacostraca	Decapoda	Crangonidae	Sabinea	Sabinea hystrix	[2]	
Arthropoda	Malacostraca	Decapoda	Crangonidae	Sclerocrangon	Sclerocrangon boreas	[2]	
Arthropoda	Malacostraca	Decapoda	Crangonidae	Sclerocrangon	Sclerocrangon ferox	[2]	
Arthropoda	Malacostraca	Decapoda	Oregoniidae	Chionoecetes	Chionoecetes opilio	[3]	
Arthropoda	Malacostraca	Decapoda	Paguridae		Paguridae	[4]	
Arthropoda	Malacostraca	Decapoda	Thoridae	Eualus	Eualus fabricii	[2]	Bioturbation: Surficial modifier
Arthropoda	Malacostraca	Decapoda	Thoridae	Eualus	Eualus macilentus	[2]	Bioturbation: Surficial modifier
Arthropoda	Malacostraca	Decapoda	Thoridae	Eualus	Eualus gaimardii	[2]	Bioturbation: Surficial modifier
Arthropoda	Malacostraca	Decapoda	Thoridae	Eualus	Eualus belcheri	[2]	Bioturbation: Surficial modifier
Arthropoda	Pycnogonida				Pycnogonida		Inferred from the designation for the known taxa in the region.
Chordata	Actinopterygii	Perciformes	Ammodytidae	Ammodytes	Ammodytes dubius	[5]	
Chordata	Actinopterygii	Pleuronectiformes	Pleuronectidae	Glyptocephalus	Glyptocephalus cynoglossus		
Chordata	Actinopterygii	Pleuronectiformes	Pleuronectidae	Hippoglossoides	Hippoglossoides platessoides	[6]	

Chordata	Actinopterygii	Pleuronectiformes	Pleuronectidae	Hippoglossus	Hippoglossus hippoglossus		
Chordata	Actinopterygii	Pleuronectiformes	Pleuronectidae	Limanda	Limanda ferruginea		
Chordata	Actinopterygii	Pleuronectiformes	Pleuronectidae	Pseudopleuronectes	Pseudopleuronectes americanus		
Chordata	Actinopterygii	Pleuronectiformes	Pleuronectidae	Reinhardtius	Reinhardtius hippoglossoides		
Chordata	Actinopterygii	Pleuronectiformes			Pleuronectiformes		
Chordata	Elasmobranchii	Rajiformes	Arhynchobatidae	Bathyraja	Bathyraja spinicauda	[7]	
Chordata	Elasmobranchii	Rajiformes	Rajidae	Amblyraja	Amblyraja radiata	[7]	
Chordata	Elasmobranchii	Rajiformes	Rajidae	Amblyraja	Amblyraja jenseni		
Chordata	Elasmobranchii	Rajiformes	Rajidae	Dipturus	Dipturus laevis		
Chordata	Elasmobranchii	Rajiformes	Rajidae	Dipturus	Dipturus linteus	[7]	
Chordata	Elasmobranchii	Rajiformes	Rajidae	Leucoraja	Leucoraja erinacea		
Chordata	Elasmobranchii	Rajiformes	Rajidae	Leucoraja	Leucoraja ocellata		
Chordata	Elasmobranchii	Rajiformes	Rajidae	Malacoraja	Malacoraja senta	[7]	
Chordata	Elasmobranchii	Rajiformes	Rajidae	Malacoraja	Malacoraja spinacidermis	[7]	
Chordata	Elasmobranchii	Rajiformes	Rajidae	Raja	Raja	[7]	
Chordata	Elasmobranchii	Rajiformes	Rajidae	Rajella	Rajella bathyphila	[7]	
Chordata	Elasmobranchii	Rajiformes	Rajidae	Rajella	Rajella fyllae	[7]	
Cnidaria	Anthozoa	Pennatulacea			Pennatulacea		
Echinodermata	Asteroidea	Forcipulatida	Asteriidae	Asterias	Asterias rubens		
Echinodermata	Asteroidea	Forcipulatida	Asteriidae	Leptasterias	Leptasterias	[1]	
Echinodermata	Asteroidea	Forcipulatida	Asteriidae	Urasterias	Urasterias lincki		
Echinodermata	Asteroidea	Paxillosida	Ctenodiscidae	Ctenodiscus	Ctenodiscus	[1]	
Echinodermata	Asteroidea	Velatida	Pterasteridae	Diplopteraster	Diplopteraster multipes	[8]	
Echinodermata	Asteroidea	Velatida	Pterasteridae	Pteraster	Pteraster militaris	[8]	
Echinodermata	Asteroidea	Velatida	Pterasteridae	Pteraster	Pteraster pulvillus	[8]	
Echinodermata	Echinoidea	Clypeasteroida	Echinarachniidae	Echinarachnius	Echinarachnius parma	[1]	
Echinodermata	Echinoidea	Spatangoida			Spatangoida		Heart urchins are infaunal deposit feeders
Echinodermata	Holothuroidea	Dendrochirotida	Cucumariidae	Cucumaria	Cucumaria frondosa	[13]	
Echinodermata	Holothuroidea	Dendrochirotida	Psolidae	Psolus	Psolus	[1]	

Echinodermata	Holothuroidea				Holothuroidea	[1]	
Echinodermata	Ophiuroidea	Ophiurida	Ophiuridae	Ophiura	Ophiura sarsii	[10]	
Echinodermata	Ophiuroidea				Ophiuroidea	[11]	Likely *O. sarsii* so given a 1 in the Canadian data but not in the EU data where most taxa are not bioturbators.
Mollusca	Bivalvia	Pectinida	Pectinidae	Chlamys	Chlamys islandica		
Mollusca	Bivalvia	Pectinida	Pectinidae	Placopecten	Placopecten magellanicus	[12]	Seen partially buried in sand in photos from the Eastern Shore Islands.
Mollusca	Bivalvia	Venerida	Mactridae	Spisula	Spisula	[14]	
Mollusca	Bivalvia				Bivalvia		
Mollusca	Gastropoda	Littorinimorpha	Naticidae		Naticidae	[2]	Bioturbation: Surficial modifier
Mollusca	Gastropoda	Nudibranchia			Nudibranchia		
Mollusca	Gastropoda				Gastropoda	[1]	
Nemertia	Hoplonemertea	Polystilifera			Reptantia	[2]	Bioturbation: Biodiffusor
Phoronida					Phoronida	[2]	Bioturbation: Surficial modifier
Platyhelminthes					Platyhelminthes	[2]	Bioturbation: Surficial modifier
Sipuncula					Sipuncula	[9]	

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Appendix 2. Species Classified as Bioturbators from the EU Surveys (see Table 1).

Phylum	Class	Order	Family	Genus	Scientific Name (WoRMS)	References	Notes
Annelida	Polychaeta	Amphinomida	Euphrosinidae	Euphrosine	Euphrosine	[1]	Bioturbation: surficial modifiers, updward and downward conveyers.
Annelida	Polychaeta	Eunicida	Eunicidae	Eunice	Eunice norvegica	[1]	Bioturbation: Biodiffusor
Annelida	Polychaeta	Eunicida	Eunicidae		Eunicidae	[1]	Bioturbation: Biodiffusor
Annelida	Polychaeta	Eunicida	Onuphidae	Nothria	Nothria	[1]	Bioturbation: Surficial modifier, upward and downward conveyors
Annelida	Polychaeta	Phyllodocida	Aphroditidae	Aphrodita	Aphrodita	[1]	Bioturbation: Biodiffusor; upward and downward conveyors
Annelida	Polychaeta	Phyllodocida	Aphroditidae	Laetmonice	Laetmonice	[2] as *Laetmonice filicornis*	
Annelida	Polychaeta	Phyllodocida	Nephtyidae		Nephtyidae	[1]	All are free-living burrowers which may periodically form poorly agglutinated burrows. Bioturbation: Biodiffusor; upward and downward conveyors
Annelida	Polychaeta	Phyllodocida	Polynoidae		Polynoidae	[1]	Bioturbation: Biodiffusor; upward and downward conveyors
Annelida	Polychaeta	Sabellida	Sabellidae		Sabellidae	[1]	The species present in the NRA

							(*Potamilla*) does not form reefs, but has tubes that get into the sediment. Bioturbation: Surficial modifier (Queros et al. 2013).
Annelida	Polychaeta	Terebellida	Terebellidae		Terebellidae	[1]	Bioturbation: Most species downward conveyers.
Annelida	Polychaeta		Maldanidae		Maldanidae	[1], [2]	Most of these are burrowers. The most common species in Flemish Cap/Pass is *Maldane sarsi*. Maldanids are upward conveyers.
Annelida	Polychaeta				Echiura	[1], [3]	Bioturbation: downard conveyer
Annelida	Polychaeta				Polychaeta		Values based on the largest biomass of polychaetes (Sabellids).
Annelida					Annelida		Values based on the largest biomass of annelids (Sabellids).
Arthropoda	Malacostraca	Amphipoda	Caprellidae		Caprellidae	[1]	Bioturbation: surficial modifiers
Arthropoda	Malacostraca	Decapoda	Crangonidae	Argis	Argis dentata	[4]	
Arthropoda	Malacostraca	Decapoda	Crangonidae	Metacrangon	Metacrangon jacqueti	[1]	
Arthropoda	Malacostraca	Decapoda	Crangonidae	Pontophilus	Pontophilus norvegicus	[1]	
Arthropoda	Malacostraca	Decapoda	Crangonidae	Sabinea	Sabinea hystrix	[1]	
Arthropoda	Malacostraca	Decapoda	Crangonidae	Sabinea	Sabinea sarsii	[1]	
Arthropoda	Malacostraca	Decapoda	Crangonidae	Sabinea	Sabinea septemcarinata	[1]	
Arthropoda	Malacostraca	Decapoda	Crangonidae	Sclerocrangon	Sclerocrangon boreas	[1]	

Arthropoda	Malacostraca	Decapoda	Crangonidae	Sclerocrangon	Sclerocrangon ferox	[1]	
Arthropoda	Malacostraca	Decapoda	Galatheidae	Galathea	Galathea	[1]	Bioturbation: Biodiffusor; upward and downward conveyors
Arthropoda	Malacostraca	Decapoda	Oregoniidae	Chionoecetes	Chionoecetes	[5]	Alaska snow crabs may burrow into soft substrate to avoid predation.
Arthropoda	Malacostraca	Decapoda	Oregoniidae	Chionoecetes	Chionoecetes opilio	[5]	Alaska snow crabs may burrow into soft substrate to avoid predation.
Arthropoda	Malacostraca	Decapoda	Paguridae	Pagurus	Pagurus arcuatus	[6]	
Arthropoda	Malacostraca	Decapoda	Paguridae		Paguridae	[6]	
Arthropoda	Malacostraca	Decapoda	Thoridae	Eualus	Eualus	[1]	Bioturbation: Surficial modifier
Arthropoda	Malacostraca	Decapoda	Thoridae	Eualus	Eualus belcheri		
Arthropoda	Malacostraca	Decapoda	Thoridae	Eualus	Eualus fabricii		
Arthropoda	Malacostraca	Decapoda	Thoridae	Eualus	Eualus gaimardii		
Arthropoda	Malacostraca	Decapoda	Thoridae	Eualus	Eualus macilentus		
Arthropoda	Ostracoda				Ostracoda	[1]	Bioturbation: Surficial modifier for some species
Arthropoda	Pycnogonida	Pantopoda	Colossendeidae	Colossendeis	Colossendeis	[7]	Inferred from detritivore designation for family.
Arthropoda	Pycnogonida	Pantopoda	Colossendeidae	Colossendeis	Colossendeis colossea	[7]	Inferred from detritivore designation for family.
Arthropoda	Pycnogonida	Pantopoda	Colossendeidae		Colossendeidae	[7]	Inferred from detritivore designation for family.
Arthropoda	Pycnogonida	Pantopoda	Nymphonidae	Nymphon	Nymphon	[1]	Bioturbation: Surficial modifier

Arthropoda	Pycnogonida	Pantopoda	Pycnogonidae	Pycnogonum	Pycnogonum	[7]	Inferred from detritivore designation for family.
Arthropoda	Pycnogonida				Pycnogonida		Inferred from the designation for the known taxa in the region.
Chordata	Actinopterygii	Perciformes	Ammodytidae	Ammodytes	Ammodytes dubius	[8]	
Chordata	Actinopterygii	Pleuronectiformes	Achiropsettidae	Mancopsetta	Mancopsetta maculata		
Chordata	Actinopterygii	Pleuronectiformes	Pleuronectidae	Glyptocephalus	Glyptocephalus cynoglossus		
Chordata	Actinopterygii	Pleuronectiformes	Pleuronectidae	Hippoglossoides	Hippoglossoides platessoides	[9]	
Chordata	Actinopterygii	Pleuronectiformes	Pleuronectidae	Hippoglossus	Hippoglossus hippoglossus		
Chordata	Actinopterygii	Pleuronectiformes	Pleuronectidae	Limanda	Limanda ferruginea		
Chordata	Actinopterygii	Pleuronectiformes	Pleuronectidae	Reinhardtius	Reinhardtius hippoglossoides		
Chordata	Actinopterygii	Pleuronectiformes	Pleuronectidae		Pleuronectidae		
Chordata	Elasmobranchii	Rajiformes	Arhynchobatidae	Bathyraja	Bathyraja spinicauda	[10]	Bioturbation: Surface modifiers; all Rajidae are benthic species spending time on the seabed
Chordata	Elasmobranchii	Rajiformes	Rajidae	Amblyraja	Amblyraja hyperborea	[10]	Bioturbation: Surface modifiers; all Rajidae are benthic species spending time on the seabed
Chordata	Elasmobranchii	Rajiformes	Rajidae	Amblyraja	Amblyraja radiata	[10]	Bioturbation: Surface modifiers; all Rajidae are benthic species spending time on the seabed
Chordata	Elasmobranchii	Rajiformes	Rajidae	Dipturus	Dipturus linteus	[10]	Bioturbation: Surface modifiers; all Rajidae are benthic species spending time on the seabed

Chordata	Elasmobranchii	Rajiformes	Rajidae	Malacoraja	Malacoraja senta	[10]	Bioturbation: Surface modifiers; all Rajidae are benthic species spending time on the seabed
Chordata	Elasmobranchii	Rajiformes	Rajidae	Malacoraja	Malacoraja spinacidermis	[10]	Bioturbation: Surface modifiers; all Rajidae are benthic species spending time on the seabed
Chordata	Elasmobranchii	Rajiformes	Rajidae	Raja	Raja	[10]	Bioturbation: Surface modifiers; all Rajidae are benthic species spending time on the seabed
Chordata	Elasmobranchii	Rajiformes	Rajidae	Rajella	Rajella bathyphila	[10]	Bioturbation: Surface modifiers; all Rajidae are benthic species spending time on the seabed
Chordata	Elasmobranchii	Rajiformes	Rajidae	Rajella	Rajella fyllae	[10]	Bioturbation: Surface modifiers; all Rajidae are benthic species spending time on the seabed
Cnidaria	Anthozoa	Alcyonacea	Nephtheidae	Gersemia	Gersemia fruticosa	[11]	*Gersemia fruticosa* can be anchored into soft bottom through its basal disc.
Cnidaria	Anthozoa	Pennatulacea	Anthoptilidae	Anthoptilum	Anthoptilum		Bioturbation: Surficial modifiers
Cnidaria	Anthozoa	Pennatulacea	Funiculinidae	Funiculina	Funiculina		Bioturbation: Surficial modifiers
Cnidaria	Anthozoa	Pennatulacea	Funiculinidae	Funiculina	Funiculina quadrangularis	[2]	Bioturbation: Surficial modifiers
Cnidaria	Anthozoa	Pennatulacea	Halipteridae	Halipteris	Halipteris christii	[2]	Bioturbation: Surficial modifiers

Cnidaria	Anthozoa	Pennatulacea	Halipteridae	Halipteris	Halipteris finmarchica	[2]	Bioturbation: Surficial modifiers
Cnidaria	Anthozoa	Pennatulacea	Halipteridae		Halipteridae		Bioturbation: Surficial modifiers
Cnidaria	Anthozoa	Pennatulacea	Kophobelemnidae	Kophobelemnon	Kophobelemnon stelliferum	[2]	Bioturbation: Surficial modifiers
Cnidaria	Anthozoa	Pennatulacea	Pennatulidae	Pennatula	Pennatula	[12]	Bioturbation: Surficial modifiers
Cnidaria	Anthozoa	Pennatulacea	Pennatulidae	Pennatula	Pennatula aculeata	[2]	Bioturbation: Surficial modifiers
Cnidaria	Anthozoa	Pennatulacea	Pennatulidae	Pennatula	Ptilella grandis	[2] as *Pennatula grandis*	Bioturbation: Surficial modifiers
Cnidaria	Anthozoa	Pennatulacea	Protoptilidae	Distichoptilum	Distichoptilum		Bioturbation: Surficial modifiers
Cnidaria	Anthozoa	Pennatulacea	Protoptilidae	Distichoptilum	Distichoptilum gracile	[2]	Bioturbation: Surficial modifiers
Cnidaria	Anthozoa	Pennatulacea	Umbellulidae	Umbellula	Umbellula	[2]	Bioturbation: Surficial modifiers
Cnidaria	Anthozoa	Pennatulacea			Pennatulacea		Bioturbation: Surficial modifiers
“	Anthozoa	Scleractinia	Flabellidae	Flabellum	Flabellum	[13]	Bioturbation: Surficial modifiers
Cnidaria	Anthozoa	Scleractinia	Flabellidae	Flabellum	Flabellum (Ulocyathus) alabastrum	[13]	Bioturbation: Surficial modifiers
Echinodermata	Asteroidea	Forcipulatida	Asteriidae	Leptasterias	Leptasterias	[4]	
Echinodermata	Asteroidea	Forcipulatida	Asteriidae	Stephanasterias	Stephanasterias albula		
Echinodermata	Asteroidea	Forcipulatida	Asteriidae		Asteriidae		
Echinodermata	Asteroidea	Notomyotida	Benthopectinidae		Benthopectinidae		They are all deposit feeders. EOL: “deposit feeder - acquires nutrients either by ingesting sediment or collecting organic matter from sediment”. Inferred from Notomyotida.
Echinodermata	Asteroidea	Paxillosida	Ctenodiscidae	Ctenodiscus	Ctenodiscus crispatus	[4], [14]	This is a deposit-feeding species.

Echinodermata	Asteroidea	Velatida	Pterasteridae	Pteraster	Pteraster pulvillus	[15]	
Echinodermata	Asteroidea	Velatida	Pterasteridae		Pterasteridae		
Echinodermata	Echinoidea	Clypeasteroida	Echinarachniidae	Echinarachnius	Echinarachnius parma	[4]	
Echinodermata	Echinoidea	Spatangoida	Schizasteridae	Brisaster	Brisaster fragilis	[2]	
Echinodermata	Holothuroidea	Dendrochirotida	Cucumariidae	Cucumaria	Cucumaria frondosa	[25]	Bioturbation: Surficial modifiers
Echinodermata	Holothuroidea	Dendrochirotida	Cucumariidae	Stereoderma	Stereoderma		Bioturbation: Surficial modifiers
Echinodermata	Holothuroidea	Dendrochirotida	Psolidae	Psolus	Psolus	[4]	Bioturbation: Surficial modifiers
Echinodermata	Holothuroidea	Elasipodida	Laetmogonidae		Laetmogonidae		Bioturbation: Surficial modifiers; epifaunal deposit feeder-detritivores
Echinodermata	Holothuroidea	Elasipodida	Psychropotidae	Benthodytes	Benthodytes	[29], [30]	Bioturbation: Surficial modifiers
Echinodermata	Holothuroidea	Molpadida	Caudinidae	Caudina	Caudina	[16]	Bioturbation: Surficial modifiers
Echinodermata	Holothuroidea	Molpadiida			Molpadida	[17]	Bioturbation: Surficial modifiers
Echinodermata	Holothuroidea	Synallactida	Synallactidae	Paelopatides	Paelopatides	[30]	Bioturbation: Surficial modifiers
Echinodermata	Holothuroidea				Holothuroidea	[4]	Bioturbation: Surficial modifiers
Echinodermata	Ophiuroidea	Ophiurida	Ophiosphalmidae	Ophiomusium	Ophiomusa lymani	[18]	
Echinodermata	Ophiuroidea	Ophiurida	Ophiuridae	Homophiura	Ophioplinthus		
Echinodermata	Ophiuroidea	Ophiurida	Ophiuridae	Ophiura	Ophiura sarsii	[19]	Bioturbation: Surficial modifiers
Mollusca	Bivalvia	Adapedonta	Hiatellidae	Cyrtodaria	Cyrtodaria siliqua		
Mollusca	Bivalvia	Adapedonta	Hiatellidae	Hiatella	Hiatella arctica	[20]	Infaunal species.
Mollusca	Bivalvia	Adapedonta	Pharidae	Siliqua	Siliqua costata		
Mollusca	Bivalvia	Arcida	Arcidae	Bathyarca	Bathyarca	[21]	
Mollusca	Bivalvia	Cardiida	Cardiidae		Cardiidae	[1]	Bioturbation: Surficial modifier
Mollusca	Bivalvia	Carditida	Astartidae	Astarte	Astarte	[1], [26]	Bioturbation: Surficial modifier
Mollusca	Bivalvia	Carditida	Carditidae		Carditidae	[1]	Bioturbation: Surficial modifier

Mollusca	Bivalvia	Myida	Myidae	Mya	Mya arenaria	[1], [26]	Bioturbation: Surficial modifier
Mollusca	Bivalvia	Nuculanida	Nuculanidae	Nuculana	Nuculana	[1], [26]	Bioturbation: Surficial modifier
Mollusca	Bivalvia	Nuculanida	Yoldiidae	Megayoldia	Megayoldia thraciaeformis	[1]	Bioturbation: Surficial modifier
Mollusca	Bivalvia	Pectinida	Pectinidae	Chlamys	Chlamys islandica		Bioturbation: Surficial modifier
Mollusca	Bivalvia	Solemyida	Solemyidae	Solemya	Solemya borealis	[22]	
Mollusca	Bivalvia	Venerida	Arcticidae	Arctica	Arctica islandica	[27]	
Mollusca	Bivalvia	Venerida	Mactridae	Mactromeris	Mactromeris polynyma	[28]	
Mollusca	Bivalvia	Venerida	Mesodesmatidae	Mesodesma	Mesodesma arctatum	[23]	
Mollusca	Bivalvia	Venerida	Mesodesmatidae	Mesodesma	Mesodesma deauratum	[23]	
Mollusca	Bivalvia		Cuspidariidae	Cuspidaria	Cuspidaria	[1]	Bioturbation: Upward and downward conveyors
Mollusca	Bivalvia		Verticordiidae	Halicardia	Halicardia flexuosa	[24]	
Mollusca	Bivalvia				Bivalvia		
Mollusca	Gastropoda	Cephalaspidea	Scaphandridae	Scaphander	Scaphander punctostriatus	[1]	Bioturbation: Surficial modifier
Mollusca	Gastropoda	Littorinimorpha	Aporrhaidae	Aporrhais	Arrhoges occidentalis	[1]	Bioturbation: Surficial modifier
Mollusca	Gastropoda	Littorinimorpha	Aporrhaidae	Arrhoges	Arrhoges	[1]	
Mollusca	Gastropoda	Littorinimorpha	Naticidae	Euspira	Euspira	[1]	Bioturbation: Surficial modifier
Mollusca	Gastropoda	Littorinimorpha	Naticidae		Naticidae	[1]	Bioturbation: Surficial modifier
Mollusca	Gastropoda	Neogastropoda	Buccinidae	Beringius	Beringius turtoni		
Mollusca	Gastropoda	Neogastropoda	Buccinidae	Buccinum	Buccinum	[1], [4]	Bioturbation: Surficial modifier
Mollusca	Gastropoda	Neogastropoda	Buccinidae	Colus	Colus	[4]	
Mollusca	Gastropoda	Neogastropoda	Buccinidae	Colus	Colus islandicus		Inferred from [4]
Mollusca	Gastropoda	Neogastropoda	Buccinidae	Colus	Colus pubescens		Inferred from [4]
Mollusca	Gastropoda	Neogastropoda	Buccinidae	Colus	Colus stimpsoni		Inferred from [4]
Mollusca	Gastropoda	Neogastropoda	Buccinidae	Neptunea	Neptunea despecta	[1]	Bioturbation: Surficial modifier

Mollusca	Gastropoda	Neogastropoda	Buccinidae	Turrisipho	Turrisipho		
Mollusca	Gastropoda	Neogastropoda	Buccinidae	Volutopsius	Volutopsius norwegicus		
Mollusca	Gastropoda	Neogastropoda	Buccinidae		Buccinidae		
Mollusca	Gastropoda	Neogastropoda	Muricidae	Boreotrophon	Boreotrophon		
Mollusca	Gastropoda	Neogastropoda	Turridae		Turridae		
Mollusca	Gastropoda	Neogastropoda	Volutomitridae	Volutomitra	Volutomitra groenlandica		
Mollusca	Gastropoda	Nudibranchia	Tritoniidae	Tritonia	Tritonia	[26]	
Mollusca	Gastropoda	Nudibranchia			Nudibranchia		
Mollusca	Gastropoda				Gastropoda	[4]	
Mollusca	Gastropoda				Opisthobranchia	[4]	
Mollusca	Scaphopoda				Scaphopoda	[1]	Inferred based on the 3 species of tusk shells listed in the citation. These are infaunal species.
Nemertea					Nemertea	[1]	
Platyhelminthes	Turbellaria				Turbellaria	[1]	Bioturbation: Surficial modifier
Sipuncula					Sipuncula	[2]	

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Appendix 3. Invertebrate species Classified as Bioturbators from the EU Surveys of NAFO Division 3M (see Table 1) with Associated Total Biomass, Number of Trawl Records and Mean Biomass/Trawl, ordered by Total Biomass. Row outlined in red indicates the last taxon contributing to 90% of the cumulative biomass in the catches. NAFO VME Indicator taxa are shaded in grey. Taxa in red at the bottom of the table were present in the survey but not present in the catches creating the KDE polygons for invertebrate bioturbation.

Phylum	Class	Order	Family	Genus	Scientific Name (WoRMS)	Total Biomass (Kg)	Number of Trawl Records	Mean Biomass per Trawl (Kg)
Cnidaria	Anthozoa	Pennatulacea	Anthoptilidae	Anthoptilum	Anthoptilum	64.487	137	0.471
Cnidaria	Anthozoa	Pennatulacea	Halipteridae	Halipteris	Halipteris finmarchica	12.173	108	0.113
Echinodermata	Asteroidea	Paxillosida	Ctenodiscidae	Ctenodiscus	Ctenodiscus crispatus	7.121	14	0.509
Echinodermata	Asteroidea	Notomyotida	Benthopectinidae		Benthopectinidae	4.643	29	0.160
Cnidaria	Anthozoa	Scleractinia	Flabellidae	Flabellum	Flabellum (Ulocyathus) alabastrum	2.824	88	0.032
Echinodermata	Ophiuroidea	Ophiurida	Ophiosphalmidae	Ophiomusium	Ophiomusa lymani	1.765	13	0.136
Echinodermata	Asteroidea	Velatida	Pterasteridae		Pterasteridae	1.763	17	0.104
Echinodermata	Echinoidea	Spatangoida	Schizasteridae	Brisaster	Brisaster fragilis	1.656	20	0.083
Echinodermata	Ophiuroidea	Ophiurida	Ophiuridae	Ophiura	Ophiura sarsii	1.313	21	0.063
Mollusca	Gastropoda	Neogastropoda	Buccinidae	Neptunea	Neptunea despecta	1.250	9	0.139
Cnidaria	Anthozoa	Pennatulacea	Funiculinidae	Funiculina	Funiculina quadrangularis	1.180	44	0.027
Mollusca	Bivalvia	Carditida	Astartidae	Astarte	Astarte	1.017	35	0.029
Annelida	Polychaeta	Sabellida	Sabellidae		Sabellidae	0.934	10	0.093
Mollusca	Gastropoda	Neogastropoda	Buccinidae	Colus	Colus	0.907	11	0.082
Cnidaria	Anthozoa	Pennatulacea	Pennatulidae	Pennatula	Pennatula	0.491	11	0.045
Mollusca	Gastropoda	Neogastropoda	Buccinidae	Buccinum	Buccinum	0.430	18	0.024
Annelida	Polychaeta	Phyllodocida	Aphroditidae	Laetmonice	Laetmonice	0.401	14	0.029
Annelida	Polychaeta				Polychaeta	0.374	18	0.021
Cnidaria	Anthozoa	Pennatulacea	Umbellulidae	Umbellula	Umbellula	0.275	21	0.013
Arthropoda	Malacostraca	Decapoda	Crangonidae	Sabinea	Sabinea hystrix	0.262	19	0.014
Echinodermata	Asteroidea	Forcipulatida	Asteriidae	Stephanasterias	Stephanasterias albula	0.261	3	0.087
Cnidaria	Anthozoa	Pennatulacea			Pennatulacea	0.248	3	0.083
Mollusca	Gastropoda				Gastropoda	0.163	6	0.027

Mollusca	Gastropoda	Neogastropoda	Buccinidae	Beringius	Beringius turtoni	0.163	2	0.082
Annelida	Polychaeta	Phyllodocida	Polynoidae		Polynoidae	0.157	13	0.012
Mollusca	Gastropoda	Nudibranchia			Nudibranchia	0.135	10	0.014
Arthropoda	Pycnogonida				Pycnogonida	0.127	21	0.006
Arthropoda	Malacostraca	Decapoda	Crangonidae	Pontophilus	Pontophilus norvegicus	0.120	39	0.003
Cnidaria	Anthozoa	Pennatulacea	Halipteridae	Halipteris	Halipteris christii	0.112	3	0.037
Mollusca	Gastropoda	Cephalaspidea	Scaphandridae	Scaphander	Scaphander punctostriatus	0.095	8	0.012
Mollusca	Bivalvia				Bivalvia	0.090	4	0.023
Mollusca	Gastropoda	Littorinimorpha	Aporrhaidae	Arrhoges	Arrhoges occidentalis	0.082	6	0.014
Mollusca	Gastropoda	Neogastropoda	Buccinidae		Buccinidae	0.070	3	0.023
Cnidaria	Anthozoa	Pennatulacea	Pennatulidae	Pennatula	Ptilella grandis	0.064	4	0.016
Sipuncula					Sipuncula	0.062	3	0.021
Arthropoda	Malacostraca	Decapoda	Crangonidae	Sabinea	Sabinea sarsii	0.022	2	0.011
Mollusca	Gastropoda	Neogastropoda	Buccinidae	Turrisipho	Turrisipho	0.020	3	0.007
Echinodermata	Ophiuroidea	Ophiurida	Ophiuridae	Homophiura	Ophioplinthus	0.018	2	0.009
Cnidaria	Anthozoa	Pennatulacea	Pennatulidae	Pennatula	Pennatula aculeata	0.015	4	0.004
Cnidaria	Anthozoa	Pennatulacea	Protoptilidae	Distichoptilum	Distichoptilum gracile	0.012	5	0.002
Arthropoda	Pycnogonida	Pantopoda	Colossendeidae		Colossendeidae	0.005	4	0.001
Arthropoda	Malacostraca	Decapoda	Paguridae		Paguridae	0.004	1	0.004
Cnidaria	Anthozoa	Pennatulacea	Kophobelemnidae	Kophobelemnon	Kophobelemnon stelliferum	0.001	1	0.001
Nemertea					Nemertea	0.001	1	0.001
Annelida	Polychaeta	Phyllodocida	Aphroditidae	Aphrodita	Aphrodita			
Arthropoda	Malacostraca	Decapoda	Oregoniidae	Chionoecetes	Chionoecetes opilio			
Echinodermata	Holothuroidea				Holothuroidea			
Mollusca	Gastropoda	Neogastropoda	Muricidae	Boreotrophon	Boreotrophon			
Mollusca	Bivalvia	Pectinida	Pectinidae	Chlamys	Chlamys islandica			
Mollusca	Scaphopoda				Scaphopoda			
Arthropoda	Malacostraca	Decapoda	Crangonidae	Argis	Argis dentata			

Appendix 4. Fish species Classified as Bioturbators from the EU Surveys of NAFO Division 3M (see Table 1) with Associated Total Biomass, Number of Trawl Records and Mean Biomass/Trawl, ordered by Total Biomass. Row outlined in red indicates the last taxon contributing to 90% of the cumulative biomass in the catches. Taxa in red at the bottom of the table were present in the survey but not present in the catches creating the KDE polygons for fish bioturbation.

Phylum	Class	Order	Family	Genus	Scientific Name (WoRMS)	Total Biomass (Kg)	Number of Trawl Records	Mean Biomass per Trawl (Kg)
Chordata	Actinopterygii	Pleuronectiformes	Pleuronectidae	Reinhardtius	Reinhardtius hippoglossoides	22382.828	182	122.983
Chordata	Actinopterygii	Pleuronectiformes	Pleuronectidae	Hippoglossoides	Hippoglossoides platessoides	1328.773	19	69.935
Chordata	Actinopterygii	Pleuronectiformes	Pleuronectidae	Glyptocephalus	Glyptocephalus cynoglossus	700.478	66	10.613
Chordata	Actinopterygii	Pleuronectiformes	Pleuronectidae	Hippoglossus	Hippoglossus hippoglossus	287.460	9	31.940
Chordata	Elasmobranchii	Rajiformes	Arhynchobatidae	Bathyraja	Bathyraja spinicauda	117.500	8	14.688
Chordata	Elasmobranchii	Rajiformes	Rajidae	Amblyraja	Amblyraja hyperborea	113.313	22	5.151
Chordata	Elasmobranchii	Rajiformes	Rajidae	Rajella	Rajella bathyphila	27.500	14	1.964
Chordata	Elasmobranchii	Rajiformes	Rajidae	Amblyraja	Amblyraja radiata	20.192	8	2.524
Chordata	Elasmobranchii	Rajiformes	Rajidae	Dipturus	Dipturus linteus	3.050	3	1.017
Chordata	Elasmobranchii	Rajiformes	Rajidae	Malacoraja	Malacoraja spinacidermis	0.255	2	0.128
Chordata	Elasmobranchii	Rajiformes	Rajidae	Rajella	Rajella fyllae	0.023	2	0.012
Chordata	Elasmobranchii	Rajiformes	Rajidae	Raja	Raja	0.007	1	0.007
Chordata	Actinopterygii	Perciformes	Ammodytidae	Ammodytes	Ammodytes dubius			
Chordata	Elasmobranchii	Rajiformes	Rajidae	Malacoraja	Malacoraja senta			

Appendix 5. Invertebrate species Classified as Bioturbators from the Canadian Fall Surveys of NAFO Division 3LNO (see Table 1) with Associated Total Biomass, Number of Trawl Records and Mean Biomass/Trawl, ordered by Total Biomass. Row outlined in red indicates the last taxon contributing to 90% of the cumulative biomass in the catches. NAFO VME Indicator taxa are shaded in grey. Taxa in red at the bottom of the table were present in the survey but not present in the catches creating the KDE polygons for invertebrate bioturbation.

Phylum	Class	Order	Family	Genus	Scientific Name (WoRMS)	Total Biomass (Kg)	Number of Trawl Records	Mean Biomass per Trawl (Kg)
Echinodermata	Holothuroidea	Dendrochirotida	Cucumariidae	Cucumaria	Cucumaria frondosa	1236.390	73	16.937
Echinodermata	Holothuroidea				Holothuroidea	229.123	26	8.812
Echinodermata	Ophiuroidea	Ophiurida	Ophiuridae	Ophiura	Ophiura sarsii	40.591	28	1.450
Mollusca	Gastropoda				Gastropoda	21.613	54	0.400
Echinodermata	Holothuroidea	Dendrochirotida	Psolidae	Psolus	Psolus	17.321	3	5.774
Echinodermata	Echinoidea	Clypeasteroida	Echinarachniidae	Echinarachnius	Echinarachnius parma	10.905	27	0.404
Echinodermata	Asteroidea	Forcipulatida	Asteriidae	Leptasterias	Leptasterias	10.497	18	0.583
Annelida	Polychaeta				Polychaeta	9.756	24	0.407
Echinodermata	Ophiuroidea				Ophiuroidea	8.960	3	2.987
Echinodermata	Asteroidea	Forcipulatida	Asteriidae	Asterias	Asterias rubens	5.857	12	0.488
Mollusca	Gastropoda	Littorinimorpha	Naticidae		Naticidae	2.088	11	0.190
Arthropoda	Malacostraca	Decapoda	Paguridae		Paguridae	1.700	15	0.113
Mollusca	Bivalvia				Bivalvia	0.750	4	0.188
Echinodermata	Asteroidea	Paxillosida	Ctenodiscidae	Ctenodiscus	Ctenodiscus	0.460	7	0.066
Echinodermata	Echinoidea	Spatangoida			Spatangoida	0.366	2	0.183
Arthropoda	Malacostraca	Decapoda	Thoridae	Eualus	Eualus gaimardii	0.120	2	0.060
Echinodermata	Asteroidea	Forcipulatida	Asteriidae	Urasterias	Urasterias lincki	0.107	1	0.107
Mollusca	Bivalvia	Venerida	Mactridae	Spisula	Spisula	0.101	2	0.051
Mollusca	Bivalvia	Pectinida	Pectinidae	Placopecten	Placopecten magellanicus	0.100	1	0.100
Mollusca	Gastropoda	Nudibranchia			Nudibranchia	0.090	3	0.030
Mollusca	Bivalvia	Pectinida	Pectinidae	Chlamys	Chlamys islandica	0.084	3	0.028
Cnidaria	Anthozoa	Pennatulacea			Pennatulacea	0.080	1	0.080
Echinodermata	Asteroidea	Velatida	Pterasteridae	Diplopteraster	Diplopteraster multipes	0.071	1	0.071

Arthropoda	Pycnogonida				Pycnogonida	0.028	2	0.014
Echinodermata	Asteroidea	Velatida	Pterasteridae	Pteraster	Pteraster pulvillus			
Arthropoda	Malacostraca	Decapoda	Thoridae	Eualus	Eualus belcheri			
Arthropoda	Malacostraca	Decapoda	Thoridae	Eualus	Eualus macilentus			
Echinodermata	Asteroidea	Velatida	Pterasteridae	Pteraster	Pteraster militaris			
Sipuncula					Sipuncula			

Appendix 6. Invertebrate species Classified as Bioturbators from the Canadian Spring Surveys of NAFO Division 3LNO (see Table 1) with Associated Total Biomass, Number of Trawl Records and Mean Biomass/Trawl, ordered by Total Biomass. Row outlined in red indicates the last taxon contributing to 90% of the cumulative biomass in the catches. NAFO VME Indicator taxa are shaded in grey. Taxa in red at the bottom of the table were present in the survey but not present in the catches creating the KDE polygons for invertebrate bioturbation.

Phylum	Class	Order	Family	Genus	Scientific Name (WoRMS)	Total Biomass (Kg)	Number of Trawl Records	Mean Biomass per Trawl (Kg)
Echinodermata	Holothuroidea	Dendrochirotida	Cucumariidae	Cucumaria	Cucumaria frondosa	5772.444	89	64.859
Echinodermata	Echinoidea	Clypeasteroida	Echinarachniidae	Echinarachnius	Echinarachnius parma	386.996	76	5.092
Echinodermata	Ophiuroidea	Ophiurida	Ophiuridae	Ophiura	Ophiura sarsii	64.004	20	3.200
Echinodermata	Holothuroidea				Holothuroidea	41.582	16	2.599
Mollusca	Gastropoda				Gastropoda	18.164	64	0.284
Echinodermata	Asteroidea	Forcipulatida	Asteriidae	Asterias	Asterias rubens	11.593	25	0.464
Echinodermata	Asteroidea	Forcipulatida	Asteriidae	Leptasterias	Leptasterias	10.943	28	0.391
Echinodermata	Echinoidea	Spatangoida			Spatangoida	9.893	2	4.947
Echinodermata	Ophiuroidea				Ophiuroidea	5.714	4	1.429
Echinodermata	Asteroidea	Paxillosida	Ctenodiscidae	Ctenodiscus	Ctenodiscus	4.243	8	0.530
Mollusca	Bivalvia	Pectinida	Pectinidae	Chlamys	Chlamys islandica	3.241	8	0.405
Echinodermata	Holothuroidea	Dendrochirotida	Psolidae	Psolus	Psolus	3.203	9	0.356
Mollusca	Bivalvia				Bivalvia	2.020	13	0.155
Annelida	Polychaeta				Polychaeta	2.015	21	0.096
Mollusca	Gastropoda	Littorinimorpha	Naticidae		Naticidae	1.613	10	0.161
Arthropoda	Malacostraca	Decapoda	Paguridae		Paguridae	0.967	7	0.138
Cnidaria	Anthozoa	Pennatulacea			Pennatulacea	0.815	2	0.408
Mollusca	Gastropoda	Nudibranchia			Nudibranchia	0.500	5	0.100
Platyhelminthes					Platyhelminthes	0.229	1	0.229
Arthropoda	Malacostraca	Decapoda	Thoridae	Eualus	Eualus macilentus	0.070	1	0.070
Arthropoda	Malacostraca	Decapoda	Thoridae	Eualus	Eualus gaimardii	0.040	1	0.040
Arthropoda	Pycnogonida				Pycnogonida	0.020	2	0.010
Echinodermata	Asteroidea	Velatida	Pterasteridae	Diplopteraster	Diplopteraster multipes			

Echinodermata	Asteroidea	Forcipulatida	Asteriidae	Urasterias	Urasterias lincki			
Mollusca	Bivalvia	Venerida	Mactridae	Spisula	Spisula			
Echinodermata	Asteroidea	Velatida	Pterasteridae	Pteraster	Pteraster pulvillus			
Sipuncula					Sipuncula			

Appendix 7. Fish species Classified as Bioturbators from the Canadian Surveys of NAFO Divisions 3LNO (see Table 1) with Associated Total Biomass, Number of Trawl Records and Mean Biomass/Trawl, ordered by Total Biomass. Row outlined in red indicates the last taxon contributing to 90% of the cumulative biomass in the catches. Taxa in red at the bottom of the table were present in the survey but not present in the catches creating the KDE polygons for fish bioturbation.

Phylum	Class	Order	Family	Genus	Scientific Name (WoRMS)	Total Biomass (Kg)	Number of Trawl Records	Mean Biomass per Trawl (Kg)
Chordata	Actinopterygii	Pleuronectiformes	Pleuronectidae	Limanda	Limanda ferruginea	36306.944	204	177.975
Chordata	Actinopterygii	Pleuronectiformes	Pleuronectidae	Hippoglossoides	Hippoglossoides platessoides	30283.506	275	110.122
Chordata	Elasmobranchii	Rajiformes	Rajidae	Amblyraja	Amblyraja radiata	10611.208	251	42.276
Chordata	Actinopterygii	Perciformes	Ammodytidae	Ammodytes	Ammodytes dubius	6651.635	148	44.943
Chordata	Actinopterygii	Pleuronectiformes	Pleuronectidae	Glyptocephalus	Glyptocephalus cynoglossus	1626.232	126	12.907
Chordata	Actinopterygii	Pleuronectiformes	Pleuronectidae	Reinhardtius	Reinhardtius hippoglossoides	1273.668	87	14.640
Chordata	Actinopterygii	Pleuronectiformes	Pleuronectidae	Hippoglossus	Hippoglossus hippoglossus	320.633	16	20.040
Chordata	Elasmobranchii	Rajiformes	Arhynchobatidae	Bathyraja	Bathyraja spinicauda	107.818	13	8.294
Chordata	Elasmobranchii	Rajiformes	Rajidae	Malacoraja	Malacoraja senta	4.557	7	0.651
Chordata	Elasmobranchii	Rajiformes	Rajidae	Rajella	Rajella fyllae	0.610	2	0.305
Chordata	Elasmobranchii	Rajiformes	Rajidae	Amblyraja	Amblyraja jenseni			
Chordata	Elasmobranchii	Rajiformes	Rajidae	Rajella	Rajella bathyphila			
Chordata	Elasmobranchii	Rajiformes	Rajidae	Raja	Raja			
Chordata	Actinopterygii	Pleuronectiformes			Pleuronectiformes			

Appendix 8. Invertebrate species Classified as Bioturbators from the EU Surveys of NAFO Division 3LNO (see Table 1) with Associated Total Biomass, Number of Trawl Records and Mean Biomass/Trawl, ordered by Total Biomass. Row outlined in red indicates the last taxon contributing to 90% of the cumulative biomass in the catches. NAFO VME Indicator taxa are shaded in grey. Taxa in red at the bottom of the table were present in the survey but not present in the catches creating the KDE polygons for invertebrate bioturbation.

Phylum	Class	Order	Family	Genus	Scientific Name (WoRMS)	Total Biomass (Kg)	Number of Trawl Records	Mean Biomass per Trawl (Kg)
Echinodermata	Holothuroidea	Dendrochirotida	Cucumariidae	Cucumaria	Cucumaria frondosa	3262.189	161	20.262
Echinodermata	Holothuroidea				Holothuroidea	692.438	29	23.877
Arthropoda	Malacostraca	Decapoda	Oregoniidae	Chionoecetes	Chionoecetes opilio	269.233	66	4.079
Mollusca	Gastropoda	Littorinimorpha	Naticidae	Euspira	Euspira	90.105	4	22.526
Echinodermata	Ophiuroidea	Ophiurida	Ophiosphalmidae	Ophiomusium	Ophiomusa lymani	84.609	16	5.288
Echinodermata	Echinoidea	Clypeasteroida	Echinarachniidae	Echinarachnius	Echinarachnius parma	77.696	139	0.559
Annelida	Polychaeta	Sabellida	Sabellidae		Sabellidae	64.863	15	4.324
Echinodermata	Ophiuroidea	Ophiurida	Ophiuridae	Ophiura	Ophiura sarsii	61.522	54	1.139
Cnidaria	Anthozoa	Pennatulacea	Anthoptilidae	Anthoptilum	Anthoptilum	20.108	16	1.257
Echinodermata	Holothuroidea	Dendrochirotida	Cucumariidae	Stereoderma	Stereoderma	16.047	54	0.297
Echinodermata	Holothuroidea	Synallactida	Synallactidae	Paelopatides	Paelopatides	15.828	5	3.166
Mollusca	Gastropoda	Neogastropoda	Buccinidae	Buccinum	Buccinum	15.727	80	0.197
Echinodermata	Asteroidea	Forcipulatida	Asteriidae		Asteriidae	15.724	58	0.271
Echinodermata	Asteroidea	Paxillosida	Ctenodiscidae	Ctenodiscus	Ctenodiscus crispatus	11.790	11	1.072
Echinodermata	Echinoidea	Spatangoida	Schizasteridae	Brisaster	Brisaster fragilis	11.669	17	0.686
Mollusca	Gastropoda				Gastropoda	9.872	15	0.658
Cnidaria	Anthozoa	Scleractinia	Flabellidae	Flabellum	Flabellum	7.577	1	7.577
Echinodermata	Asteroidea	Velatida	Pterasteridae	Pteraster	Pteraster pulvillus	6.151	1	6.151
Mollusca	Gastropoda	Neogastropoda	Buccinidae	Colus	Colus	4.892	39	0.125
Arthropoda	Malacostraca	Decapoda	Crangonidae	Pontophilus	Pontophilus norvegicus	4.311	17	0.254
Arthropoda	Malacostraca	Decapoda	Thoridae	Eualus	Eualus gaimardii	3.750	1	3.750
Mollusca	Bivalvia				Bivalvia	3.653	15	0.244
Cnidaria	Anthozoa	Pennatulacea	Pennatulidae	Pennatula	Pennatula aculeata	3.452	7	0.493

Arthropoda	Malacostraca	Decapoda	Crangonidae	Argis	Argis dentata	3.329	30	0.111
Annelida	Polychaeta		Maldanidae		Maldanidae	3.187	7	0.455
Echinodermata	Asteroidea	Forcipulatida	Asteriidae	Leptasterias	Leptasterias	3.181	9	0.353
Echinodermata	Asteroidea	Velatida	Pterasteridae		Pterasteridae	2.375	9	0.264
Echinodermata	Holothuroidea	Molpadiida			Molpadida	2.030	9	0.226
Mollusca	Gastropoda	Neogastropoda	Buccinidae	Neptunea	Neptunea despecta	1.844	17	0.108
Mollusca	Gastropoda	Neogastropoda	Buccinidae		Buccinidae	1.717	15	0.114
Annelida	Polychaeta				Polychaeta	1.576	36	0.044
Mollusca	Bivalvia	Carditida	Astartidae	Astarte	Astarte	1.382	19	0.073
Mollusca	Bivalvia	Adapedonta	Hiatellidae	Cyrtodaria	Cyrtodaria siliqua	1.104	15	0.074
Arthropoda	Pycnogonida				Pycnogonida	1.061	6	0.177
Mollusca	Gastropoda	Neogastropoda	Buccinidae	Colus	Colus pubescens	0.904	6	0.151
Cnidaria	Anthozoa	Pennatulacea	Halipteridae	Halipteris	Halipteris finmarchica	0.860	8	0.108
Mollusca	Gastropoda	Littorinimorpha	Aporrhaidae	Aporrhais	Arrhoges occidentalis	0.832	20	0.042
Echinodermata	Holothuroidea	Elasipodida	Laetmogonidae		Laetmogonidae	0.821	1	0.821
Mollusca	Gastropoda	Littorinimorpha	Naticidae		Naticidae	0.742	34	0.022
Annelida	Polychaeta	Phyllodocida	Aphroditidae	Aphrodita	Aphrodita	0.665	7	0.095
Mollusca	Bivalvia	Nuculanida	Yoldiidae	Megayoldia	Megayoldia thraciaeformis	0.644	6	0.107
Arthropoda	Malacostraca	Decapoda	Crangonidae	Sabinea	Sabinea sarsii	0.611	14	0.044
Echinodermata	Holothuroidea	Elasipodida	Psychropotidae	Benthodytes	Benthodytes	0.570	1	0.570
Cnidaria	Anthozoa	Scleractinia	Flabellidae	Flabellum	Flabellum (Ulocyathus) alabastrum	0.403	6	0.067
Mollusca	Gastropoda	Nudibranchia			Nudibranchia	0.358	31	0.012
Echinodermata	Asteroidea	Forcipulatida	Asteriidae	Stephanasterias	Stephanasterias albula	0.335	18	0.019
Annelida	Polychaeta	Phyllodocida	Polynoidae		Polynoidae	0.311	36	0.009
Arthropoda	Malacostraca	Decapoda	Paguridae	Pagurus	Pagurus arcuatus	0.301	8	0.038
Arthropoda	Malacostraca	Decapoda	Paguridae		Paguridae	0.293	17	0.017
Mollusca	Bivalvia	Venerida	Arcticidae	Arctica	Arctica islandica	0.271	7	0.039
Mollusca	Gastropoda	Neogastropoda	Buccinidae	Turrisipho	Turrisipho	0.255	9	0.028
Arthropoda	Malacostraca	Decapoda	Crangonidae	Sabinea	Sabinea hystrix	0.236	9	0.026

Arthropoda	Pycnogonida	Pantopoda	Nymphonidae	Nymphon	Nymphon	0.233	2	0.117
Mollusca	Bivalvia	Venerida	Mesodesmatidae	Mesodesma	Mesodesma arctatum	0.228	23	0.010
Mollusca	Bivalvia	Pectinida	Pectinidae	Chlamys	Chlamys islandica	0.213	11	0.019
Annelida	Polychaeta	Eunicida	Onuphidae	Nothria	Nothria	0.212	3	0.071
Mollusca	Gastropoda	Cephalaspidea	Scaphandridae	Scaphander	Scaphander punctostriatus	0.204	6	0.034
Sipuncula					Sipuncula	0.168	8	0.021
Mollusca	Bivalvia	Adapedonta	Hiatellidae	Hiatella	Hiatella arctica	0.120	6	0.020
Cnidaria	Anthozoa	Pennatulacea	Pennatulidae	Pennatula	Ptilella grandis	0.092	9	0.010
Echinodermata	Holothuroidea	Dendrochirotida	Psolidae	Psolus	Psolus	0.086	8	0.011
Mollusca	Gastropoda	Neogastropoda	Buccinidae	Beringius	Beringius turtoni	0.085	1	0.085
Cnidaria	Anthozoa	Pennatulacea	Funiculinidae	Funiculina	Funiculina quadrangularis	0.083	7	0.012
Mollusca	Bivalvia	Venerida	Mactridae	Mactromeris	Mactromeris polynyma	0.080	3	0.027
Arthropoda	Malacostraca	Decapoda	Crangonidae	Sabinea	Sabinea septemcarinata	0.073	3	0.024
Nemertea					Nemertea	0.058	3	0.019
Arthropoda	Pycnogonida	Pantopoda	Colossendeidae	Colossendeis	Colossendeis	0.056	12	0.005
Echinodermata	Ophiuroidea	Ophiurida	Ophiuridae	Homophiura	Ophioplinthus	0.054	2	0.027
Arthropoda	Malacostraca	Amphipoda	Caprellidae		Caprellidae	0.043	4	0.011
Mollusca	Bivalvia	Nuculanida	Nuculanidae	Nuculana	Nuculana	0.035	9	0.004
Mollusca	Scaphopoda				Scaphopoda	0.034	1	0.034
Mollusca	Gastropoda	Neogastropoda	Buccinidae	Volutopsius	Volutopsius norwegicus	0.030	2	0.015
Echinodermata	Asteroidea	Notomyotida	Benthopectinidae		Benthopectinidae	0.018	2	0.009
Mollusca	Bivalvia	Cardiida	Cardiidae		Cardiidae	0.018	3	0.006
Annelida	Polychaeta	Eunicida	Eunicidae		Eunicidae	0.016	3	0.005
Annelida	Polychaeta	Phyllodocida	Aphroditidae	Laetmonice	Laetmonice	0.013	2	0.007
Cnidaria	Anthozoa	Pennatulacea	Pennatulidae	Pennatula	Pennatula	0.013	2	0.007
Cnidaria	Anthozoa	Pennatulacea	Protoptilidae	Distichoptilum	Distichoptilum gracile	0.012	2	0.006
Mollusca	Gastropoda	Neogastropoda	Buccinidae	Colus	Colus islandicus	0.009	1	0.009
Mollusca	Bivalvia	Carditida	Carditidae		Carditidae	0.008	1	0.008
Mollusca	Bivalvia	Venerida	Mesodesmatidae	Mesodesma	Mesodesma deauratum	0.008	4	0.002

Mollusca	Gastropoda	Neogastropoda	Muricidae	Boreotrophon	Boreotrophon	0.007	2	0.004
Annelida	Polychaeta				Echiura	0.006	1	0.006
Arthropoda	Malacostraca	Decapoda	Thoridae	Eualus	Eualus	0.004	1	0.004
Arthropoda	Ostracoda				Ostracoda	0.004	2	0.002
Cnidaria	Anthozoa	Pennatulacea	Umbellulidae	Umbellula	Umbellula	0.004	1	0.004
Mollusca	Bivalvia		Cuspidariidae	Cuspidaria	Cuspidaria	0.003	2	0.002
Mollusca	Gastropoda	Neogastropoda	Volutomitridae	Volutomitra	Volutomitra groenlandica	0.003	1	0.003
Cnidaria	Anthozoa	Alcyonacea	Nephtheidae	Gersemia	Gersemia fruticosa	0.002	1	0.002
Mollusca	Gastropoda				Opisthobranchia	0.001	1	0.001
Arthropoda	Pycnogonida	Pantopoda	Pycnogonidae	Pycnogonum	Pycnogonum	0.001	1	0.001
Platyhelminthes	Turbellaria				Turbellaria	0.001	1	0.001
Annelida	Polychaeta	Eunicida	Eunicidae	Eunice	Eunice norvegica			
Annelida	Polychaeta	Amphinomida	Euphrosinidae	Euphrosine	Euphrosine			
Annelida	Polychaeta	Phyllodocida	Nephtyidae		Nephtyidae			
Annelida					Annelida			
Annelida	Polychaeta	Terebellida	Terebellidae		Terebellidae			
Arthropoda	Malacostraca	Decapoda	Thoridae	Eualus	Eualus fabricii			
Arthropoda	Malacostraca	Decapoda	Thoridae	Eualus	Eualus belcheri			
Arthropoda	Malacostraca	Decapoda	Thoridae	Eualus	Eualus macilentus			
Arthropoda	Malacostraca	Decapoda	Galatheidae	Galathea	Galathea			
Arthropoda	Malacostraca	Decapoda	Crangonidae	Metacrangon	Metacrangon jacqueti			
Arthropoda	Malacostraca	Decapoda	Crangonidae	Sclerocrangon	Sclerocrangon boreas			
Arthropoda	Malacostraca	Decapoda	Crangonidae	Sclerocrangon	Sclerocrangon ferox			
Cnidaria	Anthozoa	Pennatulacea	Protoptilidae	Distichoptilum	Distichoptilum			
Cnidaria	Anthozoa	Pennatulacea	Funiculinidae	Funiculina	Funiculina			
Cnidaria	Anthozoa	Pennatulacea	Halipteridae		Halipteridae			
Cnidaria	Anthozoa	Pennatulacea	Kophobelemnidae	Kophobelemnon	Kophobelemnon stelliferum			
Echinodermata	Holothuroidea	Molpadida	Caudinidae	Caudina	Caudina			
Mollusca	Bivalvia	Arcida	Arcidae	Bathyarca	Bathyarca			

Mollusca	Bivalvia		Verticordiidae	Halicardia	Halicardia flexuosa			
Mollusca	Bivalvia	Myida	Myidae	Mya	Mya arenaria			
Mollusca	Bivalvia	Adapedonta	Pharidae	Siliqua	Siliqua costata			
Mollusca	Bivalvia	Solemyida	Solemyidae	Solemya	Solemya borealis			
Mollusca	Gastropoda	Neogastropoda	Buccinidae	Colus	Colus stimpsoni			
Mollusca	Gastropoda	Nudibranchia	Tritoniidae	Tritonia	Tritonia			
Mollusca	Gastropoda	Neogastropoda	Turridae		Turridae			

Appendix 9. Invertebrate species Classified as Bioturbators from the EU Surveys of NAFO Divisions 3LNO (see Table 1) and Found only in Trawl Sets Greater than 750 M Depth, with Associated Mean Depth, Number of Trawl Records, Total Biomass, and Mean Biomass/Trawl, ordered by Total Biomass. NAFO VME Indicator taxa are shaded in grey. Taxa in red occurred >70% of sets and >80% of their biomass below 750 m.

Phylum	Class	Order	Family	Genus	Scientific Name (WoRMS)	Mean Depth (m)	Number of Trawl Sets	Total Biomass (Kg)	Mean Biomass/Trawl Set (Kg)
Echinodermata	Holothuroidea	Synallactida	Synallactidae	Paelopatides	Paelopatides	1352.5	5	15.828	3.166
Cnidaria	Anthozoa	Scleractinia	Flabellidae	Flabellum	Flabellum	831.9	1	7.577	7.577
Arthropoda	Malacostraca	Decapoda	Thoridae	Eualus	Eualus gaimardii	1007.6	1	3.750	3.750
Cnidaria	Anthozoa	Pennatulacea	Pennatulidae	Pennatula	Pennatula aculeata	1155.9	7	3.452	0.493
Echinodermata	Holothuroidea	Elasipodida	Psychropotidae	Benthodytes	Benthodytes	1408.0	1	0.570	0.570
Cnidaria	Anthozoa	Scleractinia	Flabellidae	Flabellum	Flabellum alabastrum	1157.6	6	0.403	0.067
Arthropoda	Malacostraca	Decapoda	Crangonidae	Sabinea	Sabinea hystrix	1218.2	9	0.236	0.026
Echinodermata	Ophiuroidea	Ophiurida	Ophiuridae	Homophiura	Ophioplinthus	1308.9	2	0.054	0.027
Echinodermata	Asteroidea	Notomyotida	Benthopectinidae		Benthopectinidae	1130.2	2	0.018	0.009
Cnidaria	Anthozoa	Pennatulacea	Pennatulidae	Pennatula	Pennatula	1165.8	2	0.013	0.007
Cnidaria	Anthozoa	Pennatulacea	Protoptilidae	Distichoptilum	Distichoptilum gracile	1194.0	2	0.012	0.006
Annelida	Polychaeta				Echiura	1214.5	1	0.006	0.006
Arthropoda	Ostracoda				Ostracoda	1098.5	2	0.004	0.002
Cnidaria	Anthozoa	Pennatulacea	Umbellulidae	Umbellula	Umbellula	1137.8	1	0.004	0.004
Echinodermata	Ophiuroidea	Ophiurida	Ophiosphalmidae	Ophiomusium	Ophiomusa lymani		15	84.604	
Cnidaria	Anthozoa	Pennatulacea	Anthoptilidae	Anthoptilum	Anthoptilum		13	20.081	
Annelida	Polychaeta		Maldanidae		Maldanidae		6	3.185	
Cnidaria	Anthozoa	Pennatulacea	Halipteridae	Halipteris	Halipteris finmarchica		6	0.759	
Cnidaria	Anthozoa	Pennatulacea	Funiculinidae	Funiculina	Funiculina quadrangularis		5	0.077	
Arthropoda	Pycnogonida	Pantopoda	Colossendeidae	Colossendeis	Colossendeis		9	0.045	

Appendix 10. Fish species Classified as Bioturbators from the EU Surveys of NAFO Divisions 3LNO (see Table 1) with Associated Total Biomass, Number of Trawl Records and Mean Biomass/Trawl, ordered by Total Biomass. Row outlined in red indicates the last taxon contributing to 90% of the cumulative biomass in the catches. Taxa in red at the bottom of the table were present in the survey but not present in the catches creating the KDE polygons for fish bioturbation.

Phylum	Class	Order	Family	Genus	Scientific Name (WoRMS)	Total Biomass (Kg)	Number of Trawl Records	Mean Biomass per Trawl (Kg)
Chordata	Actinopterygii	Pleuronectiformes	Pleuronectidae	Limanda	Limanda ferruginea	107646.546	271	397.220
Chordata	Actinopterygii	Pleuronectiformes	Pleuronectidae	Hippoglossoides	Hippoglossoides platessoides	75941.067	348	218.221
Chordata	Actinopterygii	Perciformes	Ammodytidae	Ammodytes	Ammodytes dubius	28136.978	260	108.219
Chordata	Elasmobranchii	Rajiformes	Rajidae	Amblyraja	Amblyraja radiata	12124.569	294	41.240
Chordata	Actinopterygii	Pleuronectiformes	Pleuronectidae	Reinhardtius	Reinhardtius hippoglossoides	1877.860	98	19.162
Chordata	Actinopterygii	Pleuronectiformes	Pleuronectidae	Glyptocephalus	Glyptocephalus cynoglossus	1055.601	107	9.865
Chordata	Actinopterygii	Pleuronectiformes	Pleuronectidae	Hippoglossus	Hippoglossus hippoglossus	186.995	17	11.000
Chordata	Elasmobranchii	Rajiformes	Rajidae	Amblyraja	Amblyraja hyperborea	33.450	3	11.150
Chordata	Elasmobranchii	Rajiformes	Arhynchobatidae	Bathyraja	Bathyraja spinicauda	26.728	7	3.818
Chordata	Elasmobranchii	Rajiformes	Rajidae	Malacoraja	Malacoraja senta	3.783	3	1.261
Chordata	Elasmobranchii	Rajiformes	Rajidae	Rajella	Rajella bathyphila	2.930	1	2.930
Chordata	Elasmobranchii	Rajiformes	Rajidae	Rajella	Rajella fyllae	1.395	2	0.698
Chordata	Elasmobranchii	Rajiformes	Rajidae	Dipturus	Dipturus linteus			
Chordata	Elasmobranchii	Rajiformes	Rajidae	Malacoraja	Malacoraja spinacidermis			
Chordata	Actinopterygii	Pleuronectiformes	Achiropsettidae	Mancopsetta	Mancopsetta maculata			
Chordata	Actinopterygii	Pleuronectiformes	Pleuronectidae		Pleuronectidae			
Chordata	Elasmobranchii	Rajiformes	Rajidae	Raja	Raja			

Appendix 11. Species Classified as Nutrient Cyclers (Filter-feeders) from the Canadian Surveys (see Table 1).

Phylum	Class	Order	Family	Genus	Scientific Name (WoRMS)	References	Notes
Arthropoda	Hexanauplia				Copepoda		Copepods must beat their cephalic appendages to drive the feeding current
Arthropoda	Hexanauplia				Cirripedia	[1]	
Arthropoda	Malacostraca	Euphausiacea			Euphausiacea	[2]	
Arthropoda	Malacostraca	Mysida			Mysida	[1]	
Brachiopoda					Brachiopoda	[3]	
Bryozoa					Bryozoa	[3]	
Chordata	Ascidiacea	Stolidobranchia	Pyuridae	Boltenia	Boltenia		Almost all ascidians are filter-feeders (exceptions in family Octacnemidae)
Chordata	Ascidiacea				Ascidiacea	[4]	Almost all ascidians are filter-feeders (exceptions in family Octacnemidae)
Cnidaria	Anthozoa	Alcyonacea	Nephtheidae		Nephtheidae		
Cnidaria	Anthozoa	Alcyonacea			Alcyonacea		
Cnidaria	Anthozoa	Antipatharia			Antipatharia	[5]	Antipatharians apparently feed on mesozooplankton but also use mucus nets, possibly for capture of POM. Feeding modes in this group are poorly known.
Cnidaria	Anthozoa	Pennatulacea			Pennatulacea		Passive-filter-feeder; tentacular filtration of weakly swimming mesozooplankton, particulates, dissolved organic matter, and picoplankton
Cnidaria	Anthozoa	Scleractinia			Scleractinia	[6]	All scleractinian corals are heterotrophs that obtain at least part of their nutrition by suspension feeding. Most are thought to be active zooplankton predators.
Cnidaria	Hydrozoa				Hydrozoa	[7]	Passive filter-feeders
Cnidaria					Cnidaria		Inferred from the majority of species evaluated herein.

Echinodermata	Asteroidea	Brisingida	Brisingidae	Novodinia	Novodinia americana	[8], [9]	
Echinodermata	Crinoidea				Crinoidea		All crinoids are filter-feeders
Echinodermata	Holothuroidea	Dendrochirotida	Cucumariidae	Cucumaria	Cucumaria frondosa	[10]	
Echinodermata	Holothuroidea	Dendrochirotida	Psolidae	Psolus	Psolus	[11]	
Echinodermata	Holothuroidea				Holothuroidea	[12]	Based on species composition (*Cucumaria* and *Psolus*)
Echinodermata	Ophiuroidea	Amphilepidida	Ophiopholidae	Ophiopholis	Ophiopholis aculeata	[4]	
Hemichordata					Hemichordata		All hemichordates are suspension feeders
Mollusca	Bivalvia	Mytilida	Mytilidae		Mytilidae		Active filter-feeders
Mollusca	Bivalvia	Pectinida	Pectinidae	Chlamys	Chlamys islandica		Active filter-feeders
Mollusca	Bivalvia	Pectinida	Pectinidae	Placopecten	Placopecten magellanicus		Active filter-feeders
Mollusca	Bivalvia	Venerida	Mactridae	Spisula	Spisula		Active filter-feeders
Mollusca	Bivalvia				Bivalvia		Active filter-feeders
Phoronida					Phoronida		Filter-feed with a lophophore
Porifera					Porifera		Active filter-feeders

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[12] Expert opinion: H. Munro

Appendix 12. Species Classified as Nutrient Cyclers (Filter-feeders) from the EU Surveys (see Table 1).

Phylum	Class	Order	Family	Genus	Scientific Name (WoRMS)	References	Notes
Annelida	Polychaeta	Sabellida	Sabellidae		Sabellidae	[1]	The filter-feeding habit is by far the most important in the family.
Annelida	Polychaeta	Sabellida	Serpulidae		Serpulidae	[1]	All members filter-feed, using the tentacular crown.
Annelida	Polychaeta				Echiura	[2]	
Arthropoda	Hexanauplia	Lepadiformes	Lepadidae	Lepas	Lepas	[2]	
Arthropoda	Hexanauplia	Scalpelliformes	Scalpellidae	Arcoscalpellum	Arcoscalpellum	[2]	
Arthropoda	Hexanauplia	Scalpelliformes	Scalpellidae	Arcoscalpellum	Arcoscalpellum michelottianum	[2]	
Arthropoda	Hexanauplia	Scalpelliformes	Scalpellidae	Ornatoscalpellum	Ornatoscalpellum	[2]	
Arthropoda	Hexanauplia	Scalpelliformes	Scalpellidae	Ornatoscalpellum	Ornatoscalpellum stroemii	[2]	
Arthropoda	Hexanauplia	Scalpelliformes	Scalpellidae		Scalpellidae	[2]	
Arthropoda	Hexanauplia	Sessilia	Archaeobalanidae	Chirona	Chirona hameri	[2]	
Arthropoda	Hexanauplia	Sessilia	Balanidae		Balanidae	[2]	
Arthropoda	Hexanauplia	Sessilia			Balanomorpha	[2]	
Arthropoda	Hexanauplia				Cirripedia	[2]	
Arthropoda	Malacostraca	Amphipoda	Gammaridae		Gammaridae	[3]	
Arthropoda	Malacostraca	Euphausiacea	Euphausiidae	Euphausia	Euphausia	[4]	Able to filter feed, using 'compression filtration' or to feed raptorially on zooplankton
Arthropoda	Malacostraca	Euphausiacea	Euphausiidae	Meganyctiphanes	Meganyctiphanes norvegica	[4]	Able to filter feed, using 'compression filtration' or to feed raptorially on zooplankton
Arthropoda	Malacostraca	Euphausiacea	Euphausiidae	Thysanoessa	Thysanoessa	[4]	Able to filter feed, using 'compression filtration' or to feed raptorially on zooplankton
Arthropoda	Malacostraca	Euphausiacea	Euphausiidae		Euphausiidae	[4]	Able to filter feed, using 'compression filtration' or to feed raptorially on zooplankton
Arthropoda	Malacostraca	Euphausiacea			Euphausiacea	[4]	Able to filter feed, using 'compression filtration' or to feed raptorially on zooplankton

Arthropoda	Malacostraca	Lophogastrida	Gnathophausiidae	Gnathophausia	Gnathophausia		Gnathophausia seems to use its mouthparts to filter large particles from the seawater
Arthropoda	Malacostraca	Lophogastrida	Gnathophausiidae	Gnathophausia	Gnathophausia zoea		Gnathophausia seems to use its mouthparts to filter large particles from the seawater
Arthropoda	Malacostraca	Mysida	Mysidae	Boreomysis	Boreomysis	[2]	
Arthropoda	Malacostraca	Mysida	Mysidae	Boreomysis	Boreomysis tridens	[2]	
Arthropoda	Malacostraca	Mysida	Mysidae	Pseudomma	Pseudomma	[2]	
Arthropoda	Malacostraca	Mysida	Mysidae		Mysidae	[2]	
Arthropoda	Malacostraca	Mysida			Mysida	[2]	
Brachiopoda	Rhynchonellata	Rhynchonellida	Hemithirididae	Hemithiris	Hemithiris psittacea	[3]	
Brachiopoda	Rhynchonellata	Terebratulida	Cancellothyrididae	Terebratulina	Terebratulina retusa	[3]	
Brachiopoda	Rhynchonellata	Terebratulida	Cancellothyrididae	Terebratulina	Terebratulina septentrionalis	[3]	
Brachiopoda					Brachiopoda	[3]	
Bryozoa					Bryozoa	[3]	
Chordata	Ascidiacea	Aplousobranchia	Didemnidae		Didemnidae	[5]	Active-filter-feeder
Chordata	Ascidiacea	Phlebobranchia	Ascidiidae	Ascidia	Ascidia	[5]	Active-filter-feeder
Chordata	Ascidiacea	Stolidobranchia	Molgulidae		Molgulidae		Active-filter-feeder
Chordata	Ascidiacea	Stolidobranchia	Pyuridae	Boltenia	Boltenia		Active-filter-feeder
Chordata	Ascidiacea	Stolidobranchia	Pyuridae	Boltenia	Boltenia ovifera		Active-filter-feeder
Chordata	Ascidiacea	Stolidobranchia	Pyuridae		Pyuridae		Active-filter-feeder
Chordata	Ascidiacea				Ascidiacea	[5]	Active-filter-feeder
Cnidaria	Anthozoa	Actiniaria	Actinernidae	Actinernus	Actinernus	[6]	
Cnidaria	Anthozoa	Actiniaria	Actinoscyphiidae	Actinoscyphia	Actinoscyphia	[6], [11]	
Cnidaria	Anthozoa	Actiniaria	Liponematidae	Liponema	Liponema	[6]	
Cnidaria	Anthozoa	Alcyonacea	Acanthogorgiidae	Acanthogorgia	Acanthogorgia		Passive-filter-feeder
Cnidaria	Anthozoa	Alcyonacea	Alcyoniidae	Alcyonium	Alcyonium		
Cnidaria	Anthozoa	Alcyonacea	Alcyoniidae	Anthomastus	Anthomastus	[5]	Passive-filter-feeder
Cnidaria	Anthozoa	Alcyonacea	Alcyoniidae	Anthomastus	Anthomastus grandiflorus	[5]	Passive-filter-feeder
Cnidaria	Anthozoa	Alcyonacea	Alcyoniidae	Heteropolypus	Heteropolypus		

Cnidaria	Anthozoa	Alcyonacea	Alcyoniidae	Pseudoanthomastus	Pseudoanthomastus	[5]	Passive-filter-feeder
Cnidaria	Anthozoa	Alcyonacea	Anthothelidae	Anthothela	Anthothela		
Cnidaria	Anthozoa	Alcyonacea	Anthothelidae	Anthothela	Anthothela grandiflora	[5]	Passive-filter-feeder
Cnidaria	Anthozoa	Alcyonacea	Anthothelidae		Anthothelidae		
Cnidaria	Anthozoa	Alcyonacea	Chrysogorgiidae	Radicipes	Radicipes		
Cnidaria	Anthozoa	Alcyonacea	Clavulariidae	Telestula	Telestula septentrionalis	[5]	Passive-filter-feeder
Cnidaria	Anthozoa	Alcyonacea	Isididae	Acanella	Acanella		
Cnidaria	Anthozoa	Alcyonacea	Isididae	Acanella	Acanella arbuscula	[5]	Passive-filter-feeder
Cnidaria	Anthozoa	Alcyonacea	Isididae	Keratoisis	Keratoisis		
Cnidaria	Anthozoa	Alcyonacea	Isididae		Isididae	[6]	
Cnidaria	Anthozoa	Alcyonacea	Nephtheidae	Drifa	Drifa		
Cnidaria	Anthozoa	Alcyonacea	Nephtheidae	Duva	Duva florida	[5]	Passive-filter-feeder
Cnidaria	Anthozoa	Alcyonacea	Nephtheidae	Gersemia	Gersemia	[5]	Passive-filter-feeder
Cnidaria	Anthozoa	Alcyonacea	Nephtheidae	Gersemia	Gersemia fruticosa		
Cnidaria	Anthozoa	Alcyonacea	Nephtheidae	Gersemia	Gersemia rubiformis		
Cnidaria	Anthozoa	Alcyonacea	Nephtheidae		Nephtheidae		
Cnidaria	Anthozoa	Alcyonacea	Paragorgiidae	Paragorgia	Paragorgia		
Cnidaria	Anthozoa	Alcyonacea	Paragorgiidae	Paragorgia	Paragorgia arborea		
Cnidaria	Anthozoa	Alcyonacea	Plexauridae	Paramuricea	Paramuricea	[5]	Passive-filter-feeder
Cnidaria	Anthozoa	Alcyonacea	Plexauridae		Plexauridae		
Cnidaria	Anthozoa	Alcyonacea	Primnoidae	Primnoa	Primnoa resedaeformis	[5], [6]	Passive-filter-feeder
Cnidaria	Anthozoa	Alcyonacea			Alcyonacea		
Cnidaria	Anthozoa	Antipatharia	Antipathidae	Stichopathes	Stichopathes	[6]	Antipatharians apparently feed on mesozooplankton but also use mucus nets, possibly for capture of POM. Feeding modes in this group are poorly known.
Cnidaria	Anthozoa	Antipatharia	Schizopathidae	Stauropathes	Stauropathes arctica	[6]	Antipatharians apparently feed on mesozooplankton but also use mucus nets, possibly for capture of POM. Feeding modes in this group are poorly known.

Cnidaria	Anthozoa	Antipatharia			Antipatharia	[6]	Antipatharians apparently feed on mesozooplankton but also use mucus nets, possibly for capture of POM. Feeding modes in this group are poorly known.
Cnidaria	Anthozoa	Pennatulacea	Anthoptilidae	Anthoptilum	Anthoptilum		Passive-filter-feeder; tentacular filtration of weakly swimming mesozooplankton, particulates, dissolved organic matter, and picoplankton
Cnidaria	Anthozoa	Pennatulacea	Funiculinidae	Funiculina	Funiculina		Passive-filter-feeder; tentacular filtration of weakly swimming mesozooplankton, particulates, dissolved organic matter, and picoplankton
Cnidaria	Anthozoa	Pennatulacea	Funiculinidae	Funiculina	Funiculina quadrangularis	[5]	Passive-filter-feeder; tentacular filtration of weakly swimming mesozooplankton, particulates, dissolved organic matter, and picoplankton
Cnidaria	Anthozoa	Pennatulacea	Halipteridae	Halipteris	Halipteris christii	[5]	Passive-filter-feeder; tentacular filtration of weakly swimming mesozooplankton, particulates, dissolved organic matter, and picoplankton
Cnidaria	Anthozoa	Pennatulacea	Halipteridae	Halipteris	Halipteris finmarchica	[5]	Passive-filter-feeder; tentacular filtration of weakly swimming mesozooplankton, particulates, dissolved organic matter, and picoplankton
Cnidaria	Anthozoa	Pennatulacea	Halipteridae		Halipteridae		Passive-filter-feeder; tentacular filtration of weakly swimming mesozooplankton, particulates, dissolved organic matter, and picoplankton
Cnidaria	Anthozoa	Pennatulacea	Kophobelemnidae	Kophobelemnon	Kophobelemnon stelliferum	[5]	Passive-filter-feeder; tentacular filtration of weakly swimming mesozooplankton, particulates, dissolved organic matter, and picoplankton
Cnidaria	Anthozoa	Pennatulacea	Pennatulidae	Pennatula	Pennatula		Passive-filter-feeder; tentacular filtration of weakly swimming mesozooplankton, particulates,

							dissolved organic matter, and picoplankton
Cnidaria	Anthozoa	Pennatulacea	Pennatulidae	Pennatula	Pennatula aculeata	[5]	Passive-filter-feeder; tentacular filtration of weakly swimming mesozooplankton, particulates, dissolved organic matter, and picoplankton
Cnidaria	Anthozoa	Pennatulacea	Pennatulidae	Pennatula	Ptilella grandis	[5] as *Pennatula grandis*	Passive-filter-feeder; tentacular filtration of weakly swimming mesozooplankton, particulates, dissolved organic matter, and picoplankton
Cnidaria	Anthozoa	Pennatulacea	Protoptilidae	Distichoptilum	Distichoptilum		Passive-filter-feeder; tentacular filtration of weakly swimming mesozooplankton, particulates, dissolved organic matter, and picoplankton
Cnidaria	Anthozoa	Pennatulacea	Protoptilidae	Distichoptilum	Distichoptilum gracile	[5]	Passive-filter-feeder; tentacular filtration of weakly swimming mesozooplankton, particulates, dissolved organic matter, and picoplankton
Cnidaria	Anthozoa	Pennatulacea	Umbellulidae	Umbellula	Umbellula		Passive-filter-feeder; tentacular filtration of weakly swimming mesozooplankton, particulates, dissolved organic matter, and picoplankton
Cnidaria	Anthozoa	Pennatulacea			Pennatulacea		Passive-filter-feeder; tentacular filtration of weakly swimming mesozooplankton, particulates, dissolved organic matter, and picoplankton
Cnidaria	Anthozoa	Scleractinia	Caryophylliidae	Caryophyllia	Caryophyllia	[7]	All scleractinian corals are heterotrophs that obtain at least part of their nutrition by suspension feeding. Most arethought to be active zooplankton predators.
Cnidaria	Anthozoa	Scleractinia	Caryophylliidae	Caryophyllia	Caryophyllia seguenzae	[7]	All scleractinian corals are heterotrophs that obtain at least part of their nutrition by suspension feeding. Most

							arethought to be active zooplankton predators.
Cnidaria	Anthozoa	Scleractinia	Caryophylliidae	Desmophyllum	Desmophyllum	[7]	All scleractinian corals are heterotrophs that obtain at least part of their nutrition by suspension feeding. Most arethought to be active zooplankton predators.
Cnidaria	Anthozoa	Scleractinia	Caryophylliidae	Desmophyllum	Desmophyllum dianthus	[7]	All scleractinian corals are heterotrophs that obtain at least part of their nutrition by suspension feeding. Most arethought to be active zooplankton predators.
Cnidaria	Anthozoa	Scleractinia	Caryophylliidae	Lophelia	Desmophyllum pertusum	[7]	All scleractinian corals are heterotrophs that obtain at least part of their nutrition by suspension feeding. Most arethought to be active zooplankton predators.
Cnidaria	Anthozoa	Scleractinia	Caryophylliidae		Caryophylliidae	[7]	All scleractinian corals are heterotrophs that obtain at least part of their nutrition by suspension feeding. Most arethought to be active zooplankton predators.
Cnidaria	Anthozoa	Scleractinia	Flabellidae	Flabellum	Flabellum	[7]	All scleractinian corals are heterotrophs that obtain at least part of their nutrition by suspension feeding. Most arethought to be active zooplankton predators.
Cnidaria	Anthozoa	Scleractinia	Flabellidae	Flabellum	Flabellum (Ulocyathus) alabastrum	[7]	All scleractinian corals are heterotrophs that obtain at least part of their nutrition by suspension feeding. Most arethought to be active zooplankton predators.
Cnidaria	Anthozoa	Scleractinia			Scleractinia	[7]	All scleractinian corals are heterotrophs that obtain at least part of their nutrition by suspension feeding. Most

							arethought to be active zooplankton predators.
Cnidaria	Anthozoa	Zoantharia	Epizoanthidae	Epizoanthus	Epizoanthus	[8]	Zoanthids are benthic suspension feeders belonging to the order Zoantharia.
Cnidaria	Anthozoa	Zoantharia	Epizoanthidae		Epizoanthidae	[8]	Zoanthids are benthic suspension feeders belonging to the order Zoantharia.
Cnidaria	Anthozoa				Anthozoa	[8]	Zoanthids are benthic suspension feeders belonging to the order Zoantharia.
Cnidaria	Anthozoa				Ceriantharia	[8]	Zoanthids are benthic suspension feeders belonging to the order Zoantharia.
Cnidaria	Hydrozoa	Leptothecata	Aglaopheniidae	Aglaophenopsis	Aglaophenopsis	[9]	Passive filter-feeders
Cnidaria	Hydrozoa	Leptothecata	Aglaopheniidae	Cladocarpus	Cladocarpus	[9]	Passive filter-feeders
Cnidaria	Hydrozoa	Leptothecata	Haleciidae	Halecium	Halecium	[9]	Passive filter-feeders
Cnidaria	Hydrozoa	Leptothecata	Laodiceidae	Staurostoma	Staurostoma mertensii	[9]	Passive filter-feeders
Cnidaria	Hydrozoa	Leptothecata	Sertularellidae	Sertularella	Sertularella	[9]	Passive filter-feeders
Cnidaria	Hydrozoa	Leptothecata	Sertulariidae	Abietinaria	Abietinaria	[9]	Passive filter-feeders
Cnidaria	Hydrozoa	Leptothecata	Sertulariidae	Sertularia	Sertularia cupressina	[9]	Passive filter-feeders
Cnidaria	Hydrozoa	Leptothecata	Sertulariidae	Thuiaria	Thuiaria carica	[9]	Passive filter-feeders
Cnidaria	Hydrozoa	Leptothecata	Sertulariidae	Thuiaria	Thuiaria thuja	[9]	Passive filter-feeders
Cnidaria	Hydrozoa	Leptothecata	Sertulariidae		Sertulariidae	[9]	Passive filter-feeders
Cnidaria	Hydrozoa	Leptothecata	Tiarannidae	Stegopoma	Ptychogena crocea	[9]	Passive filter-feeders
Cnidaria	Hydrozoa				Hydrozoa	[9]	Passive filter-feeders
Cnidaria					Cnidaria		Inferred from the majority of species evaluated herein.
Echinodermata	Asteroidea	Brisingida	Brisingidae	Brisinga	Brisinga	[10]	Brisingids feed at the seabed as suspension feeders
Echinodermata	Asteroidea	Brisingida	Brisingidae	Novodinia	Novodinia	[10]	Brisingids feed at the seabed as suspension feeders
Echinodermata	Asteroidea	Brisingida	Brisingidae		Brisingidae	[10]	Brisingids feed at the seabed as suspension feeders
Echinodermata	Crinoidea				Crinoidea		All crinoids are filter-feeders
Echinodermata	Holothuroidea	Dendrochirotida	Cucumariidae	Cucumaria	Cucumaria frondosa	[12], [14]	Passive filter-feeder

Echinodermata	Holothuroidea	Dendrochirotida	Cucumariidae	Stereoderma	Stereoderma		
Echinodermata	Holothuroidea	Dendrochirotida	Psolidae	Psolus	Psolus	[13]	Passive filter-feeder
Echinodermata	Ophiuroidea	Amphilepidida	Ophiopholidae	Ophiopholis	Ophiopholis aculeata	[5]	
Echinodermata	Ophiuroidea	Euryalida	Asteronychidae	Asteronyx	Asteronyx loveni	[5]	
Mollusca	Bivalvia	Adapedonta	Hiatellidae	Cyrtodaria	Cyrtodaria siliqua		Active-filter-feeder
Mollusca	Bivalvia	Adapedonta	Hiatellidae	Hiatella	Hiatella arctica		Active-filter-feeder
Mollusca	Bivalvia	Adapedonta	Pharidae	Siliqua	Siliqua costata		Active-filter-feeder
Mollusca	Bivalvia	Arcida	Arcidae	Bathyarca	Bathyarca		Active-filter-feeder
Mollusca	Bivalvia	Arcida	Limopsidae	Limopsis	Limopsis		Active-filter-feeder
Mollusca	Bivalvia	Cardiida	Cardiidae		Cardiidae		Active-filter-feeder
Mollusca	Bivalvia	Carditida	Astartidae	Astarte	Astarte		Active-filter-feeder
Mollusca	Bivalvia	Carditida	Carditidae		Carditidae		Active-filter-feeder
Mollusca	Bivalvia	Limida	Limidae	Acesta	Acesta cryptadelphe		Active-filter-feeder
Mollusca	Bivalvia	Myida	Myidae	Mya	Mya arenaria		Active-filter-feeder
Mollusca	Bivalvia	Mytilida	Mytilidae	Mytilus	Mytilus		Active-filter-feeder
Mollusca	Bivalvia	Mytilida	Mytilidae	Mytilus	Mytilus edulis		Active-filter-feeder
Mollusca	Bivalvia	Nuculanida	Nuculanidae	Nuculana	Nuculana		Active-filter-feeder
Mollusca	Bivalvia	Nuculanida	Yoldiidae	Megayoldia	Megayoldia thraciaeformis		Active-filter-feeder
Mollusca	Bivalvia	Pectinida	Anomiidae	Heteranomia	Heteranomia squamula		Active-filter-feeder
Mollusca	Bivalvia	Pectinida	Anomiidae		Anomiidae		Active-filter-feeder
Mollusca	Bivalvia	Pectinida	Pectinidae	Chlamys	Chlamys islandica		Active-filter-feeder
Mollusca	Bivalvia	Pectinida	Pectinidae	Delectopecten	Delectopecten vitreus		Active-filter-feeder
Mollusca	Bivalvia	Solemyida	Solemyidae	Solemya	Solemya borealis		Active-filter-feeder
Mollusca	Bivalvia	Venerida	Arcticidae	Arctica	Arctica islandica		Active-filter-feeder
Mollusca	Bivalvia	Venerida	Mactridae	Mactromeris	Mactromeris polynyma		Active-filter-feeder
Mollusca	Bivalvia	Venerida	Mesodesmatidae	Mesodesma	Mesodesma arctatum		Active-filter-feeder
Mollusca	Bivalvia	Venerida	Mesodesmatidae	Mesodesma	Mesodesma deauratum		Active-filter-feeder
Mollusca	Bivalvia		Cuspidariidae	Cuspidaria	Cuspidaria		Active-filter-feeder

Mollusca	Bivalvia		Verticordiidae	Halicardia	Halicardia flexuosa		Active-filter-feeder
Mollusca	Bivalvia				Bivalvia		Active-filter-feeder
Porifera	Calcarea	Leucosolenida	Sycettidae		Sycettidae		Active-filter-feeder
Porifera	Demospongiae	Astrophorida			Astrophorina		Active-filter-feeder
Porifera	Demospongiae	Axinellida	Axinellidae	Phakellia	Phakellia	[5]	Active-filter-feeder
Porifera	Demospongiae	Axinellida	Axinellidae		Axinellidae		Active-filter-feeder
Porifera	Demospongiae	Poecilosclerida	Cladorhizidae	Chondrocladia	Chondrocladia	[5]	Passive filter-feeders also capture prey, like copepods and other crustaceans, with velcro-like hooks on external body surfaces
Porifera	Demospongiae	Poecilosclerida	Isodictyidae	Isodictya	Isodictya palmata		Active-filter-feeder
Porifera	Demospongiae	Poecilosclerida	Mycalidae	Mycale	Mycale		Active-filter-feeder
Porifera	Demospongiae	Polymastiida	Polymastiidae	Radiella	Polymastia hemisphaerica	[5]	Active-filter-feeder
Porifera	Demospongiae	Polymastiida	Polymastiidae	Radiella	Radiella		Active-filter-feeder
Porifera	Demospongiae	Polymastiida	Polymastiidae	Tentorium	Tentorium		Active-filter-feeder
Porifera	Demospongiae	Polymastiida	Polymastiidae	Tentorium	Tentorium semisuberites	[5]	Active-filter-feeder
Porifera	Demospongiae	Polymastiida	Polymastiidae		Polymastiidae		Active-filter-feeder
Porifera	Demospongiae	Suberitida	Stylocordylidae	Stylocordyla	Stylocordyla	[5]	Active-filter-feeder
Porifera	Demospongiae	Suberitida	Suberitidae	Rhizaxinella	Rhizaxinella	[5]	Active-filter-feeder
Porifera	Demospongiae	Tetractinellida	Ancorinidae	Stelletta	Stelletta		Active-filter-feeder
Porifera	Demospongiae	Tetractinellida	Ancorinidae	Stryphnus	Stryphnus		Active-filter-feeder
Porifera	Demospongiae	Tetractinellida	Ancorinidae		Ancorinidae		Active-filter-feeder
Porifera	Demospongiae	Tetractinellida	Geodiidae	Geodia	Geodia		Active-filter-feeder
Porifera	Demospongiae	Tetractinellida	Geodiidae		Geodiidae		Active-filter-feeder
Porifera	Demospongiae	Tetractinellida	Tetillidae	Craniella	Craniella	[5]	Active-filter-feeder
Porifera	Demospongiae	Tetractinellida	Tetillidae		Tetillidae		Active-filter-feeder
Porifera	Demospongiae	Tetractinellida	Theneidae	Thenea	Thenea	[5]	Active-filter-feeder
Porifera	Demospongiae	Tetractinellida	Theneidae	Thenea	Thenea levis		Active-filter-feeder
Porifera	Demospongiae	Tetractinellida	Vulcanellidae	Poecillastra	Poecillastra compressa		Active-filter-feeder

Porifera	Demospongiae	Tetractinellida	Vulcanellidae		Vulcanellidae		Active-filter-feeder
Porifera	Demospongiae	Tetractinellida			Astrophorina		Active-filter-feeder
Porifera	Hexactinellida	Amphidiscosida	Pheronematidae		Pheronematidae		Active-filter-feeder
Porifera	Hexactinellida	Lyssacinosida	Euplectellidae		Euplectellidae		Active-filter-feeder
Porifera	Hexactinellida	Lyssacinosida	Rossellidae	Asconema	Asconema		Active-filter-feeder
Porifera					Porifera		Active-filter-feeder

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Appendix 13. Invertebrate species Classified as Nutrient Cyclers from the Canadian Surveys of NAFO Divisions 3LNO (see Table 1) with Associated Total Biomass, Number of Trawl Records and Mean Biomass/Trawl, ordered by Total Biomass. Row outlined in red indicates the last taxon contributing to 90% of the cumulative biomass in the catches. NAFO VME Indicator taxa are shaded in grey. Taxa in red at the bottom of the table were present in the survey but not present in the catches creating the KDE polygons for invertebrate nutrient recycling.

Phylum	Class	Order	Family	Genus	Scientific Name (WoRMS)	Total Biomass (Kg)	Number of Trawl Records	Mean Biomass per Trawl (Kg)
Echinodermata	Holothuroidea	Dendrochirotida	Cucumariidae	Cucumaria	Cucumaria frondosa	6865.175	118	58.179
Porifera					Porifera	3656.605	101	36.204
Echinodermata	Holothuroidea				Holothuroidea	248.704	27	9.211
Chordata	Ascidiacea	Stolidobranchia	Pyuridae	Boltenia	Boltenia	123.698	29	4.265
Cnidaria	Anthozoa	Alcyonacea	Nephtheidae		Nephtheidae	94.005	117	0.803
Brachiopoda					Brachiopoda	61.454	21	2.926
Echinodermata	Ophiuroidea	Amphilepidida	Ophiopholidae	Ophiopholis	Ophiopholis aculeata	16.447	30	0.548
Echinodermata	Holothuroidea	Dendrochirotida	Psolidae	Psolus	Psolus	15.722	12	1.310
Cnidaria	Anthozoa	Alcyonacea			Alcyonacea	10.902	22	0.574
Echinodermata	Asteroidea	Brisingida	Brisingidae	Novodinia	Novodinia americana	7.958	5	1.592
Mollusca	Bivalvia	Mytilida	Mytilidae		Mytilidae	7.528	18	0.418
Chordata	Ascidiacea				Ascidiacea	7.165	23	0.312
Cnidaria	Anthozoa	Pennatulacea			Pennatulacea	4.487	13	0.345
Echinodermata	Crinoidea				Crinoidea	3.371	2	1.686
Mollusca	Bivalvia				Bivalvia	2.711	25	0.108
Cnidaria	Anthozoa	Scleractinia			Scleractinia	2.340	3	0.780
Arthropoda	Malacostraca	Euphausiacea			Euphausiacea	0.853	7	0.122
Arthropoda	Malacostraca	Mysida			Mysida	0.709	7	0.101
Mollusca	Bivalvia	Pectinida	Pectinidae	Placopecten	Placopecten magellanicus	0.678	10	0.068
Cnidaria					Cnidaria	0.660	4	0.165
Arthropoda	Hexanauplia				Cirripedia	0.270	1	0.270
Mollusca	Bivalvia	Venerida	Mactridae	Spisula	Spisula	0.101	2	0.051
Bryozoa					Bryozoa	0.089	4	0.022

Hemichordata					Hemichordata	0.010	1	0.010
Cnidaria	Hydrozoa				Hydrozoa	0.009	1	0.009
Cnidaria	Anthozoa	Antipatharia			Antipatharia			
Mollusca	Bivalvia	Pectinida	Pectinidae	Placopecten	Placopecten magellanicus			

Appendix 14. Invertebrate species Classified as Nutrient Cyclers from the EU Surveys of NAFO Divisions 3LNO (see Table 1) with Associated Total Biomass, Number of Trawl Records and Mean Biomass/Trawl, ordered by Total Biomass. Row outlined in red indicates the last taxon contributing to 90% of the cumulative biomass in the catches. NAFO VME Indicator taxa are shaded in grey. Taxa in red at the bottom of the table were present in the survey but not present in the catches creating the KDE polygons for invertebrate nutrient recycling.

Phylum	Class	Order	Family	Genus	Scientific Name (WoRMS)	Total Biomass (Kg)	Number of Trawl Records	Mean Biomass per Trawl (Kg)
Porifera	Demospongiae	Tetractinellida	Geodiidae		Geodiidae	13694.633	49	279.482
Porifera	Demospongiae	Astrophorida			Astrophorina	11852.646	72	164.620
Porifera	Demospongiae	Tetractinellida	Geodiidae	Geodia	Geodia	5514.306	38	145.113
Porifera					Porifera	5242.037	262	20.008
Echinodermata	Holothuroidea	Dendrochirotida	Cucumariidae	Cucumaria	Cucumaria frondosa	3181.619	117	27.193
Porifera	Hexactinellida	Lyssacinosida	Rossellidae	Asconema	Asconema	663.055	126	5.262
Porifera	Hexactinellida	Amphidiscosida	Pheronematidae		Pheronematidae	409.980	1	409.980
Porifera	Demospongiae	Tetractinellida	Ancorinidae	Stelletta	Stelletta	280.167	20	14.008
Chordata	Ascidiacea	Stolidobranchia	Pyuridae	Boltenia	Boltenia ovifera	147.292	34	4.332
Porifera	Demospongiae	Tetractinellida	Tetillidae		Tetillidae	141.137	110	1.283
Chordata	Ascidiacea				Ascidiacea	98.004	188	0.521
Cnidaria	Anthozoa	Alcyonacea	Nephtheidae	Duva	Duva florida	83.450	242	0.345
Annelida	Polychaeta	Sabellida	Sabellidae		Sabellidae	71.306	101	0.706
Porifera	Demospongiae	Poecilosclerida	Mycalidae	Mycale	Mycale	67.803	24	2.825
Cnidaria	Anthozoa	Alcyonacea	Isididae	Keratoisis	Keratoisis	55.687	20	2.784
Porifera	Demospongiae	Axinellida	Axinellidae		Axinellidae	50.055	34	1.472
Porifera	Demospongiae	Tetractinellida	Theneidae	Thenea	Thenea	43.509	48	0.906
Porifera	Demospongiae	Tetractinellida	Tetillidae	Craniella	Craniella	42.786	25	1.711
Cnidaria	Anthozoa	Alcyonacea	Paragorgiidae	Paragorgia	Paragorgia	41.193	3	13.731
Porifera	Demospongiae	Polymastiida	Polymastiidae		Polymastiidae	38.843	132	0.294
Cnidaria					Cnidaria	34.412	7	6.881
Bryozoa					Bryozoa	27.333	128	0.214
Cnidaria	Anthozoa	Pennatulacea	Anthoptilidae	Anthoptilum	Anthoptilum	23.935	85	0.282

Porifera	Demospongiae	Tetractinellida	Ancorinidae	Stryphnus	Stryphnus	23.830	2	11.915
Echinodermata	Asteroidea	Brisingida	Brisingidae		Brisingidae	16.575	53	0.313
Arthropoda	Malacostraca	Euphausiacea	Euphausiidae		Euphausiidae	15.855	96	0.165
Cnidaria	Anthozoa	Alcyonacea	Nephtheidae	Gersemia	Gersemia	15.635	46	0.340
Cnidaria	Anthozoa	Actiniaria	Actinoscyphiidae	Actinoscyphia	Actinoscyphia	15.578	12	1.298
Cnidaria	Hydrozoa				Hydrozoa	15.132	244	0.062
Arthropoda	Hexanauplia	Sessilia	Balanidae		Balanidae	13.333	5	2.667
Porifera	Demospongiae	Tetractinellida	Ancorinidae		Ancorinidae	13.160	3	4.387
Echinodermata	Holothuroidea	Dendrochirotida	Cucumariidae	Stereoderma	Stereoderma	11.418	39	0.293
Arthropoda	Hexanauplia	Sessilia			Balanomorpha	10.259	33	0.311
Cnidaria	Anthozoa	Scleractinia	Flabellidae	Flabellum	Flabellum	7.577	1	7.577
Arthropoda	Malacostraca	Lophogastrida	Gnathophausiidae	Gnathophausia	Gnathophausia zoea	6.029	148	0.041
Cnidaria	Anthozoa	Alcyonacea	Plexauridae		Plexauridae	5.924	5	1.185
Cnidaria	Anthozoa	Alcyonacea	Nephtheidae		Nephtheidae	5.834	121	0.048
Cnidaria	Anthozoa	Alcyonacea	Isididae	Acanella	Acanella	5.653	63	0.090
Chordata	Ascidiacea	Aplousobranchia	Didemnidae		Didemnidae	5.543	24	0.231
Cnidaria	Anthozoa	Alcyonacea	Paragorgiidae	Paragorgia	Paragorgia arborea	5.137	3	1.712
Cnidaria	Anthozoa	Pennatulacea	Pennatulidae	Pennatula	Pennatula	3.561	23	0.155
Cnidaria	Anthozoa	Antipatharia	Schizopathidae	Stauropathes	Stauropathes arctica	3.341	3	1.114
Brachiopoda	Rhynchonellata	Terebratulida	Cancellothyrididae	Terebratulina	Terebratulina septentrionalis	3.106	110	0.028
Mollusca	Bivalvia	Carditida	Astartidae	Astarte	Astarte	2.841	137	0.021
Mollusca	Bivalvia				Bivalvia	2.738	17	0.161
Arthropoda	Hexanauplia				Cirripedia	2.575	9	0.286
Cnidaria	Anthozoa	Zoantharia	Epizoanthidae		Epizoanthidae	2.575	58	0.044
Mollusca	Bivalvia	Mytilida	Mytilidae	Mytilus	Mytilus	2.405	15	0.160
Echinodermata	Ophiuroidea	Amphilepidida	Ophiopholidae	Ophiopholis	Ophiopholis aculeata	2.247	117	0.019
Arthropoda	Malacostraca	Euphausiacea	Euphausiidae	Meganyctiphanes	Meganyctiphanes norvegica	2.167	98	0.022
Porifera	Demospongiae	Poecilosclerida	Cladorhizidae	Chondrocladia	Chondrocladia	2.127	12	0.177

Porifera	Demospongiae	Polymastiida	Polymastiidae	Tentorium	Tentorium semisuberites	2.074	103	0.020
Cnidaria	Anthozoa	Pennatulacea	Halipteridae	Halipteris	Halipteris finmarchica	2.059	28	0.074
Porifera	Demospongiae	Polymastiida	Polymastiidae	Radiella	Radiella	1.962	32	0.061
Arthropoda	Malacostraca	Amphipoda	Gammaridae		Gammaridae	1.888	48	0.039
Cnidaria	Anthozoa	Alcyonacea	Alcyoniidae	Heteropolypus	Heteropolypus	1.874	56	0.033
Porifera	Demospongiae	Tetractinellida	Vulcanellidae	Poecillastra	Poecillastra compressa	1.290	1	1.290
Cnidaria	Anthozoa	Alcyonacea	Acanthogorgiidae	Acanthogorgia	Acanthogorgia	1.272	12	0.106
Cnidaria	Anthozoa	Actiniaria	Liponematidae	Liponema	Liponema	1.272	3	0.424
Porifera	Calcarea	Leucosolenida	Sycettidae		Sycettidae	1.250	1	1.250
Echinodermata	Crinoidea				Crinoidea	0.839	33	0.025
Cnidaria	Anthozoa	Pennatulacea	Pennatulidae	Pennatula	Ptilella grandis	0.831	19	0.044
Porifera	Demospongiae	Suberitida	Stylocordylidae	Stylocordyla	Stylocordyla	0.831	12	0.069
Cnidaria	Anthozoa	Actiniaria	Actinernidae	Actinernus	Actinernus	0.808	8	0.101
Mollusca	Bivalvia	Adapedonta	Hiatellidae	Cyrtodaria	Cyrtodaria siliqua	0.808	9	0.090
Arthropoda	Malacostraca	Euphausiacea	Euphausiidae	Thysanoessa	Thysanoessa	0.799	74	0.011
Cnidaria	Anthozoa	Alcyonacea	Alcyoniidae	Anthomastus	Anthomastus	0.754	26	0.029
Cnidaria	Anthozoa	Alcyonacea	Anthothelidae	Anthothela	Anthothela grandiflora	0.706	1	0.706
Cnidaria	Anthozoa	Alcyonacea	Alcyoniidae	Pseudoanthomastus	Pseudoanthomastus	0.649	6	0.108
Arthropoda	Hexanauplia	Scalpelliformes	Scalpellidae		Scalpellidae	0.646	16	0.040
Mollusca	Bivalvia	Pectinida	Pectinidae	Chlamys	Chlamys islandica	0.442	16	0.028
Mollusca	Bivalvia	Nuculanida	Yoldiidae	Megayoldia	Megayoldia thraciaeformis	0.432	2	0.216
Cnidaria	Anthozoa	Alcyonacea	Nephtheidae	Drifa	Drifa	0.404	12	0.034
Arthropoda	Malacostraca	Mysida	Mysidae		Mysidae	0.442	68	0.009
Chordata	Ascidiacea	Stolidobranchia	Pyuridae	Boltenia	Boltenia	0.355	3	0.118
Cnidaria	Hydrozoa	Leptothecata	Sertulariidae	Thuiaria	Thuiaria thuja	0.300	38	0.008
Cnidaria	Anthozoa	Scleractinia	Flabellidae	Flabellum	Flabellum (Ulocyathus) alabastrum	0.290	7	0.041
Arthropoda	Hexanauplia	Scalpelliformes	Scalpellidae	Ornatoscalpellum	Ornatoscalpellum stroemii	0.267	17	0.016

Arthropoda	Hexanauplia	Sessilia	Archaeobalanidae	Chirona	Chirona hameri	0.263	1	0.263
Cnidaria	Hydrozoa	Leptothecata	Aglaopheniidae	Cladocarpus	Cladocarpus	0.245	13	0.019
Mollusca	Bivalvia	Pectinida	Pectinidae	Delectopecten	Delectopecten vitreus	0.200	17	0.012
Mollusca	Bivalvia	Venerida	Arcticidae	Arctica	Arctica islandica	0.175	9	0.019
Echinodermata	Ophiuroidea	Euryalida	Asteronychidae	Asteronyx	Asteronyx loveni	0.169	16	0.011
Cnidaria	Hydrozoa	Leptothecata	Aglaopheniidae	Aglaophenopsis	Aglaophenopsis	0.134	8	0.017
Porifera	Demospongiae	Suberitida	Suberitidae	Rhizaxinella	Rhizaxinella	0.125	6	0.021
Mollusca	Bivalvia	Adapedonta	Hiatellidae	Hiatella	Hiatella arctica	0.117	5	0.023
Mollusca	Bivalvia	Venerida	Mesodesmatidae	Mesodesma	Mesodesma arctatum	0.115	15	0.008
Mollusca	Bivalvia	Nuculanida	Nuculanidae	Nuculana	Nuculana	0.115	17	0.007
Cnidaria	Anthozoa	Pennatulacea	Funiculinidae	Funiculina	Funiculina quadrangularis	0.114	13	0.009
Arthropoda	Hexanauplia	Scalpelliformes	Scalpellidae	Arcoscalpellum	Arcoscalpellum michelottianum	0.095	7	0.014
Echinodermata	Holothuroidea	Dendrochirotida	Psolidae	Psolus	Psolus	0.086	17	0.005
Chordata	Ascidiacea	Stolidobranchia	Molgulidae		Molgulidae	0.080	3	0.027
Mollusca	Bivalvia	Venerida	Mactridae	Mactromeris	Mactromeris polynyma	0.074	2	0.037
Cnidaria	Anthozoa	Pennatulacea			Pennatulacea	0.070	9	0.008
Cnidaria	Hydrozoa	Leptothecata	Sertulariidae	Abietinaria	Abietinaria	0.069	6	0.012
Cnidaria	Hydrozoa	Leptothecata	Sertularellidae	Sertularella	Sertularella	0.067	6	0.011
Cnidaria	Anthozoa				Anthozoa	0.064	1	0.064
Arthropoda	Malacostraca	Mysida			Mysida	0.061	9	0.007
Cnidaria	Anthozoa	Pennatulacea	Umbellulidae	Umbellula	Umbellula	0.060	7	0.009
Porifera	Demospongiae	Polymastiida	Polymastiidae	Tentorium	Tentorium	0.059	3	0.020
Chordata	Ascidiacea	Stolidobranchia	Pyuridae		Pyuridae	0.054	4	0.014
Arthropoda	Malacostraca	Euphausiacea	Euphausiidae	Euphausia	Euphausia	0.048	1	0.048
Porifera	Demospongiae	Axinellida	Axinellidae	Phakellia	Phakellia	0.046	1	0.046
Cnidaria	Anthozoa	Alcyonacea	Chrysogorgiidae	Radicipes	Radicipes	0.042	10	0.004
Annelida	Polychaeta				Echiura	0.033	5	0.007
Brachiopoda	Rhynchonellata	Terebratulida	Cancellothyrididae	Terebratulina	Terebratulina retusa	0.030	1	0.030

Cnidaria	Anthozoa	Pennatulacea	Protoptilidae	Distichoptilum	Distichoptilum gracile	0.022	7	0.003
Chordata	Ascidiacea	Phlebobranchia	Ascidiidae	Ascidia	Ascidia	0.021	1	0.021
Porifera	Hexactinellida	Lyssacinosida	Euplectellidae		Euplectellidae	0.020	1	0.020
Cnidaria	Anthozoa	Alcyonacea			Alcyonacea	0.020	3	0.007
Brachiopoda					Brachiopoda	0.018	5	0.004
Porifera	Demospongiae	Tetractinellida	Theneidae	Thenea	Thenea levis	0.017	1	0.017
Mollusca	Bivalvia	Carditida	Carditidae		Carditidae	0.015	1	0.015
Cnidaria	Anthozoa	Zoantharia	Epizoanthidae	Epizoanthus	Epizoanthus	0.014	1	0.014
Mollusca	Bivalvia	Arcida	Limopsidae	Limopsis	Limopsis	0.014	2	0.007
Arthropoda	Malacostraca	Mysida	Mysidae	Boreomysis	Boreomysis	0.012	11	0.001
Cnidaria	Anthozoa	Scleractinia	Caryophylliidae	Lophelia	Desmophyllum pertusum	0.011	2	0.006
Cnidaria	Hydrozoa	Leptothecata	Haleciidae	Halecium	Halecium	0.010	1	0.010
Cnidaria	Anthozoa	Antipatharia			Antipatharia	0.009	1	0.009
Brachiopoda	Rhynchonellata	Rhynchonellida	Hemithirididae	Hemithiris	Hemithiris psittacea	0.009	3	0.003
Arthropoda	Malacostraca	Mysida	Mysidae	Pseudomma	Pseudomma	0.009	7	0.001
Mollusca	Bivalvia		Cuspidariidae	Cuspidaria	Cuspidaria	0.006	3	0.002
Cnidaria	Anthozoa	Pennatulacea	Funiculinidae	Funiculina	Funiculina	0.006	1	0.006
Mollusca	Bivalvia	Venerida	Mesodesmatidae	Mesodesma	Mesodesma deauratum	0.004	3	0.001
Mollusca	Bivalvia	Cardiida	Cardiidae		Cardiidae	0.002	1	0.002
Cnidaria	Anthozoa	Alcyonacea	Nephtheidae	Gersemia	Gersemia fruticosa	0.002	1	0.002
Mollusca	Bivalvia	Pectinida	Anomiidae	Heteranomia	Heteranomia squamula	0.002	1	0.002
Arthropoda	Hexanauplia	Scalpelliformes	Scalpellidae	Ornatoscalpellum	Ornatoscalpellum	0.002	1	0.002
Annelida	Polychaeta	Sabellida	Serpulidae		Serpulidae	0.002	1	0.002
Cnidaria	Hydrozoa	Leptothecata	Sertulariidae	Sertularia	Sertularia cupressina	0.002	1	0.002
Cnidaria	Anthozoa	Alcyonacea	Alcyoniidae	Alcyonium	Alcyonium	0.001	1	0.001
Arthropoda	Malacostraca	Lophogastrida	Gnathophausiidae	Gnathophausia	Gnathophausia	0.001	1	0.001
Cnidaria	Anthozoa	Pennatulacea	Kophobelemnidae	Kophobelemnon	Kophobelemnon stelliferum	0.001	1	0.001
Mollusca	Bivalvia	Myida	Myidae	Mya	Mya arenaria	0.001	1	0.001

Arthropoda	Hexanauplia	Scalpelliformes	Scalpellidae	Arcoscalpellum	Arcoscalpellum			
Arthropoda	Malacostraca	Mysida	Mysidae	Boreomysis	Boreomysis tridens			
Arthropoda	Hexanauplia	Lepadiformes	Lepadidae	Lepas	Lepas			
Chordata					Ascidiacea			
Cnidaria	Anthozoa	Alcyonacea	Isididae	Acanella	Acanella arbuscula			
Cnidaria	Anthozoa	Alcyonacea	Alcyoniidae	Anthomastus	Anthomastus grandiflorus			
Cnidaria	Anthozoa	Alcyonacea	Anthothelidae		Anthothelidae			
Cnidaria	Anthozoa	Scleractinia	Caryophylliidae	Caryophyllia	Caryophyllia			
Cnidaria	Anthozoa	Scleractinia	Caryophylliidae	Caryophyllia	Caryophyllia seguenzae			
Cnidaria	Anthozoa	Scleractinia	Caryophylliidae		Caryophylliidae			
Cnidaria	Anthozoa				Ceriantharia			
Cnidaria	Anthozoa	Scleractinia	Caryophylliidae	Desmophyllum	Desmophyllum			
Cnidaria	Anthozoa	Pennatulacea	Protoptilidae	Distichoptilum	Distichoptilum			
Cnidaria	Anthozoa	Alcyonacea	Nephtheidae	Gersemia	Gersemia rubiformis			
Cnidaria	Anthozoa	Pennatulacea	Halipteridae		Halipteridae			
Cnidaria	Anthozoa	Scleractinia	Caryophylliidae	Lophelia	Desmophyllum pertusum			
Cnidaria	Hydrozoa	Leptothecata	Sertulariidae		Sertulariidae			
Cnidaria	Hydrozoa	Leptothecata	Laodiceidae	Staurostoma	Staurostoma mertensii			
Cnidaria	Hydrozoa	Leptothecata	Tiarannidae	Stegopoma	Ptychogena crocea			
Cnidaria	Anthozoa	Antipatharia	Antipathidae	Stichopathes	Stichopathes			
Cnidaria	Anthozoa	Alcyonacea	Clavulariidae	Telestula	Telestula septentrionalis			
Cnidaria	Hydrozoa	Leptothecata	Sertulariidae	Thuiaria	Thuiaria carica			
Echinodermata	Asteroidea	Brisingida	Brisingidae	Brisinga	Brisinga			
Echinodermata	Asteroidea	Brisingida	Brisingidae	Novodinia	Novodinia			
Mollusca	Bivalvia	Limida	Limidae	Acesta	Acesta cryptadelphe			
Mollusca	Bivalvia	Pectinida	Anomiidae		Anomiidae			
Mollusca	Bivalvia	Arcida	Arcidae	Bathyarca	Bathyarca			
Mollusca	Bivalvia		Verticordiidae	Halicardia	Halicardia flexuosa			

Mollusca	Bivalvia	Mytilida	Mytilidae	Mytilus	Mytilus edulis			
Mollusca	Bivalvia	Adapedonta	Pharidae	Siliqua	Siliqua costata			
Mollusca	Bivalvia	Solemyida	Solemyidae	Solemya	Solemya borealis			
Porifera	Demospongiae	Poecilosclerida	Isodictyidae	Isodictya	Isodictya palmata			
Porifera	Demospongiae	Tetractinellida	Vulcanellidae		Vulcanellidae			
Porifera	Demospongiae	Polymastiida	Polymastiidae	Radiella	Polymastia hemisphaerica			

Appendix 15. Invertebrate species Classified as Nutrient Cyclers from the EU Surveys of NAFO Division 3M (see Table 1) with Associated Total Biomass, Number of Trawl Records and Mean Biomass/Trawl, ordered by Total Biomass. Row outlined in red indicates the last taxon contributing to 90% of the cumulative biomass in the catches. NAFO VME Indicator taxa are shaded in grey. Taxa in red at the bottom of the table were present in the survey but not present in the catches creating the KDE polygons for invertebrate nutrient recycling.

Phylum	Class	Order	Family	Genus	Scientific Name (WoRMS)	Total Biomass (Kg)	Number of Trawl Records	Mean Biomass per Trawl (Kg)
Porifera	Demospongiae	Tetractinellida	Geodiidae		Geodiidae	26703.192	68	392.694
Porifera	Demospongiae	Astrophorida			Astrophorina	7741.710	46	168.298
Porifera					Porifera	2543.966	226	11.256
Cnidaria	Anthozoa	Alcyonacea	Nephtheidae	Duva	Duva florida	122.280	158	0.774
Cnidaria	Anthozoa	Pennatulacea	Anthoptilidae	Anthoptilum	Anthoptilum	51.793	135	0.384
Cnidaria	Anthozoa	Alcyonacea	Paragorgiidae	Paragorgia	Paragorgia	18.110	3	6.037
Cnidaria	Anthozoa	Alcyonacea	Alcyoniidae	Heteropolypus	Heteropolypus	16.646	93	0.179
Cnidaria	Anthozoa	Actiniaria	Actinoscyphiidae	Actinoscyphia	Actinoscyphia	13.743	11	1.249
Chordata	Ascidiacea				Ascidiacea	13.075	130	0.101
Porifera	Demospongiae	Polymastiida	Polymastiidae		Polymastiidae	12.326	46	0.268
Cnidaria	Anthozoa	Antipatharia	Schizopathidae	Stauropathes	Stauropathes arctica	8.690	44	0.198
Porifera	Demospongiae	Tetractinellida	Tetillidae		Tetillidae	8.097	12	0.675
Cnidaria	Anthozoa	Pennatulacea	Halipteridae	Halipteris	Halipteris finmarchica	7.912	89	0.089
Cnidaria	Anthozoa	Alcyonacea	Plexauridae	Paramuricea	Paramuricea	3.130	3	1.043
Porifera	Demospongiae	Suberitida	Stylocordylidae	Stylocordyla	Stylocordyla	3.036	4	0.759
Cnidaria	Anthozoa	Scleractinia	Flabellidae	Flabellum	Flabellum (Ulocyathus) alabastrum	2.739	96	0.029
Echinodermata	Asteroidea	Brisingida	Brisingidae		Brisingidae	2.715	21	0.129
Cnidaria	Anthozoa	Alcyonacea	Nephtheidae		Nephtheidae	2.710	46	0.059
Cnidaria	Anthozoa	Actiniaria	Liponematidae	Liponema	Liponema	1.511	8	0.189
Chordata	Ascidiacea	Aplousobranchia	Didemnidae		Didemnidae	1.437	42	0.034
Cnidaria	Anthozoa	Actiniaria	Actinernidae	Actinernus	Actinernus	1.402	9	0.156
Cnidaria	Anthozoa	Alcyonacea	Isididae	Acanella	Acanella	1.272	58	0.022

Mollusca	Bivalvia	Carditida	Astartidae	Astarte	Astarte	1.106	56	0.020
Cnidaria	Anthozoa	Pennatulacea	Funiculinidae	Funiculina	Funiculina quadrangularis	0.912	52	0.018
Cnidaria	Anthozoa	Alcyonacea	Isididae		Isididae	0.831	7	0.119
Cnidaria	Anthozoa	Alcyonacea	Alcyoniidae	Anthomastus	Anthomastus	0.823	10	0.082
Annelida	Polychaeta	Sabellida	Sabellidae		Sabellidae	0.784	15	0.052
Arthropoda	Malacostraca	Lophogastrida	Gnathophausiidae	Gnathophausia	Gnathophausia zoea	0.719	89	0.008
Echinodermata	Ophiuroidea	Amphilepidida	Ophiopholidae	Ophiopholis	Ophiopholis aculeata	0.648	60	0.011
Cnidaria	Anthozoa	Antipatharia			Antipatharia	0.578	15	0.039
Cnidaria	Anthozoa	Zoantharia	Epizoanthidae		Epizoanthidae	0.571	26	0.022
Echinodermata	Crinoidea				Crinoidea	0.381	19	0.020
Cnidaria	Hydrozoa				Hydrozoa	0.344	49	0.007
Cnidaria	Anthozoa	Pennatulacea	Umbellulidae	Umbellula	Umbellula	0.327	27	0.012
Cnidaria	Anthozoa	Alcyonacea	Acanthogorgiidae	Acanthogorgia	Acanthogorgia	0.325	13	0.025
Porifera	Demospongiae	Polymastiida	Polymastiidae	Radiella	Radiella	0.311	20	0.016
Cnidaria	Anthozoa	Pennatulacea			Pennatulacea	0.248	3	0.083
Bryozoa					Bryozoa	0.213	21	0.010
Arthropoda	Hexanauplia				Cirripedia	0.167	8	0.021
Cnidaria	Anthozoa	Alcyonacea			Alcyonacea	0.147	5	0.029
Arthropoda	Malacostraca	Mysida			Mysida	0.146	35	0.004
Porifera	Demospongiae	Polymastiida	Polymastiidae	Tentorium	Tentorium	0.101	5	0.020
Cnidaria					Cnidaria	0.100	4	0.025
Cnidaria	Anthozoa	Pennatulacea	Pennatulidae	Pennatula	Ptilella grandis	0.099	11	0.009
Cnidaria	Anthozoa	Pennatulacea	Pennatulidae	Pennatula	Pennatula	0.098	12	0.008
Mollusca	Bivalvia				Bivalvia	0.095	9	0.011
Echinodermata	Ophiuroidea	Euryalida	Asteronychidae	Asteronyx	Asteronyx loveni	0.091	16	0.006
Arthropoda	Malacostraca	Euphausiacea			Euphausiacea	0.090	29	0.003
Brachiopoda	Rhynchonellata	Terebratulida	Cancellothyrididae	Terebratulina	Terebratulina septentrionalis	0.089	27	0.003
Arthropoda	Malacostraca	Lophogastrida	Gnathophausiidae	Gnathophausia	Gnathophausia	0.073	3	0.024
Cnidaria	Anthozoa	Alcyonacea	Chrysogorgiidae	Radicipes	Radicipes	0.058	26	0.002
Cnidaria	Anthozoa	Pennatulacea	Halipteridae	Halipteris	Halipteris christii	0.038	4	0.010

Cnidaria	Anthozoa	Alcyonacea	Anthothelidae	Anthothela	Anthothela	0.027	1	0.027
Brachiopoda					Brachiopoda	0.022	9	0.002
Cnidaria	Anthozoa	Pennatulacea	Pennatulidae	Pennatula	Pennatula aculeata	0.012	3	0.004
Porifera	Demospongiae	Poecilosclerida	Cladorhizidae	Chondrocladia	Chondrocladia	0.010	1	0.010
Cnidaria	Anthozoa	Alcyonacea	Nephtheidae	Gersemia	Gersemia	0.010	2	0.005
Cnidaria	Anthozoa	Scleractinia			Scleractinia	0.006	1	0.006
Cnidaria	Anthozoa	Pennatulacea	Protoptilidae	Distichoptilum	Distichoptilum gracile	0.005	2	0.003
Cnidaria	Anthozoa				Anthozoa	0.003	3	0.001
Cnidaria	Anthozoa	Pennatulacea	Kophobelemnidae	Kophobelemnon	Kophobelemnon stelliferum	0.003	3	0.001
Mollusca	Bivalvia	Pectinida	Pectinidae	Chlamys	Chlamys islandica	0.002	2	0.001
Cnidaria	Anthozoa	Alcyonacea	Primnoidae	Primnoa	Primnoa resedaeformis			
Mollusca	Bivalvia	Arcida	Limopsidae	Limopsis	Limopsis			

Appendix 16. Species Classified as Habitat Providers from the Canadian Surveys (see Table 1). Those with literature showing enhanced biodiversity associated with the biogenic habitat are noted.

Phylum	Class	Order	Family	Genus	Scientific Name (WoRMS)	Reference Habitat Provision	Notes	Reference Enhanced Biodiversity
Annelida	Polychaeta				Polychaeta		Based on high biomass of sabellids in EU surveys	
Bryozoa					Bryozoa	[1]		[2]
Chordata	Ascidiacea	Stolidobranchia	Pyuridae	Boltenia	Boltenia	[1]		[3]
Cnidaria	Anthozoa	Alcyonacea	Nephtheidae		Nephtheidae	[4]	Based on species composition and classification from EU surveys	
Cnidaria	Anthozoa	Alcyonacea			Alcyonacea		Based on species composition and classification from EU surveys	
Cnidaria	Anthozoa	Antipatharia			Antipatharia	[5]		
Cnidaria	Anthozoa	Pennatulacea			Pennatulacea	[1]		[6]
Cnidaria	Hydrozoa				Hydrozoa			[7]
Mollusca	Bivalvia	Mytilida	Mytilidae		Mytilidae			[10]
Porifera					Porifera	[8]		[9]

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Appendix 17. Species Classified as Habitat Providers from the EU Surveys (see Table 1). Those with literature showing enhanced biodiversity associated with the biogenic habitat are noted.

Phylum	Class	Order	Family	Genus	Scientific Name (WoRMS)	Reference Habitat Provision	Reference Enhanced Biodiversity
Annelida	Polychaeta	Eunicida	Eunicidae	Eunice	Eunice norvegica	[1]	
Annelida	Polychaeta	Eunicida	Onuphidae	Nothria	Nothria	[2]	
Annelida	Polychaeta	Sabellida	Sabellidae		Sabellidae	[2]	[3]
Annelida	Polychaeta	Sabellida	Serpulidae		Serpulidae	[2]	[4]
Annelida	Polychaeta	Terebellida	Terebellidae		Terebellidae	[2]	[5], [6]
Annelida	Polychaeta		Maldanidae		Maldanidae	[2]	
Bryozoa					Bryozoa	[20]	[8]
Chordata	Ascidiacea	Stolidobranchia	Pyuridae	Boltenia	Boltenia	[20]	[9]
Chordata	Ascidiacea	Stolidobranchia	Pyuridae	Boltenia	Boltenia ovifera	[20]	[9]
Chordata	Ascidiacea	Stolidobranchia	Pyuridae		Pyuridae		[9]
Cnidaria	Anthozoa	Alcyonacea	Acanthogorgiidae	Acanthogorgia	Acanthogorgia	[10], [11]	[10], [11]
Cnidaria	Anthozoa	Alcyonacea	Anthothelidae	Anthothela	Anthothela	[12]	
Cnidaria	Anthozoa	Alcyonacea	Anthothelidae	Anthothela	Anthothela grandiflora	[12]	
Cnidaria	Anthozoa	Alcyonacea	Anthothelidae		Anthothelidae	[12]	
Cnidaria	Anthozoa	Alcyonacea	Chrysogorgiidae	Radicipes	Radicipes	[12]	
Cnidaria	Anthozoa	Alcyonacea	Clavulariidae	Telestula	Telestula septentrionalis		
Cnidaria	Anthozoa	Alcyonacea	Isididae	Acanella	Acanella		
Cnidaria	Anthozoa	Alcyonacea	Isididae	Acanella	Acanella arbuscula	[7]	
Cnidaria	Anthozoa	Alcyonacea	Isididae	Keratoisis	Keratoisis	[12]	[10], [11]
Cnidaria	Anthozoa	Alcyonacea	Isididae		Isididae	[12]	[10], [11]
Cnidaria	Anthozoa	Alcyonacea	Nephtheidae	Drifa	Drifa	[18]	
Cnidaria	Anthozoa	Alcyonacea	Nephtheidae	Duva	Duva florida	[18]	
Cnidaria	Anthozoa	Alcyonacea	Nephtheidae	Gersemia	Gersemia		
Cnidaria	Anthozoa	Alcyonacea	Nephtheidae	Gersemia	Gersemia fruticosa		
Cnidaria	Anthozoa	Alcyonacea	Nephtheidae	Gersemia	Gersemia rubiformis		
Cnidaria	Anthozoa	Alcyonacea	Nephtheidae		Nephtheidae		

Cnidaria	Anthozoa	Alcyonacea	Paragorgiidae	Paragorgia	Paragorgia		[10], [11]
Cnidaria	Anthozoa	Alcyonacea	Paragorgiidae	Paragorgia	Paragorgia arborea	[10], [11]	[10], [11]
Cnidaria	Anthozoa	Alcyonacea	Plexauridae	Paramuricea	Paramuricea	[7]	[10], [11]
Cnidaria	Anthozoa	Alcyonacea	Plexauridae		Plexauridae	[12]	[10], [11]
Cnidaria	Anthozoa	Alcyonacea	Primnoidae	Primnoa	Primnoa resedaeformis	[12]	[10], [11]
Cnidaria	Anthozoa	Alcyonacea			Alcyonacea		
Cnidaria	Anthozoa	Antipatharia	Antipathidae	Stichopathes	Stichopathes	[12]	
Cnidaria	Anthozoa	Antipatharia	Schizopathidae	Stauropathes	Stauropathes arctica	[7]	
Cnidaria	Anthozoa	Antipatharia			Antipatharia	[12]	
Cnidaria	Anthozoa	Pennatulacea	Anthoptilidae	Anthoptilum	Anthoptilum		[13]
Cnidaria	Anthozoa	Pennatulacea	Funiculinidae	Funiculina	Funiculina		[13]
Cnidaria	Anthozoa	Pennatulacea	Funiculinidae	Funiculina	Funiculina quadrangularis	[7]	[13]
Cnidaria	Anthozoa	Pennatulacea	Halipteridae	Halipteris	Halipteris christii	[7]	[13]
Cnidaria	Anthozoa	Pennatulacea	Halipteridae	Halipteris	Halipteris finmarchica	[7]	[13]
Cnidaria	Anthozoa	Pennatulacea	Halipteridae		Halipteridae		[13]
Cnidaria	Anthozoa	Pennatulacea	Kophobelemnidae	Kophobelemnon	Kophobelemnon stelliferum	[12]	[13]
Cnidaria	Anthozoa	Pennatulacea	Pennatulidae	Pennatula	Pennatula		[13]
Cnidaria	Anthozoa	Pennatulacea	Pennatulidae	Pennatula	Pennatula aculeata	[7]	[13]
Cnidaria	Anthozoa	Pennatulacea	Pennatulidae	Pennatula	Ptilella grandis	[7] as *Pennatula grandis*	[13]
Cnidaria	Anthozoa	Pennatulacea	Protoptilidae	Distichoptilum	Distichoptilum	[12]	[13]
Cnidaria	Anthozoa	Pennatulacea	Protoptilidae	Distichoptilum	Distichoptilum gracile	[12]	[13]
Cnidaria	Anthozoa	Pennatulacea	Umbellulidae	Umbellula	Umbellula		[13]
Cnidaria	Anthozoa	Pennatulacea			Pennatulacea		[13]
Cnidaria	Anthozoa	Scleractinia	Caryophylliidae	Lophelia	Desmophyllum pertusum	[12]	[14]
Cnidaria	Anthozoa				Ceriantharia	[15]	[15]
Cnidaria	Hydrozoa	Leptothecata	Aglaopheniidae	Aglaophenopsis	Aglaophenopsis		[16]
Cnidaria	Hydrozoa	Leptothecata	Aglaopheniidae	Cladocarpus	Cladocarpus		[16]
Cnidaria	Hydrozoa	Leptothecata	Haleciidae	Halecium	Halecium		[16]
Cnidaria	Hydrozoa	Leptothecata	Laodiceidae	Staurostoma	Staurostoma mertensii		[16]

Cnidaria	Hydrozoa	Leptothecata	Sertularellidae	Sertularella	Sertularella	[7]	[16]
Cnidaria	Hydrozoa	Leptothecata	Sertulariidae	Abietinaria	Abietinaria		[16]
Cnidaria	Hydrozoa	Leptothecata	Sertulariidae	Sertularia	Sertularia cupressina		[16]
Cnidaria	Hydrozoa	Leptothecata	Sertulariidae	Thuiaria	Thuiaria carica		[16]
Cnidaria	Hydrozoa	Leptothecata	Sertulariidae	Thuiaria	Thuiaria thuja		[16]
Cnidaria	Hydrozoa	Leptothecata	Sertulariidae		Sertulariidae		[16]
Cnidaria	Hydrozoa	Leptothecata	Tiarannidae	Stegopoma	Ptychogena crocea		[16]
Cnidaria	Hydrozoa				Hydrozoa		[16]
Mollusca	Bivalvia	Mytilida	Mytilidae	Mytilus	Mytilus		[21]
Mollusca	Bivalvia	Mytilida	Mytilidae	Mytilus	Mytilus edulis		[21]
Porifera	Calcarea	Leucosolenida	Sycettidae		Sycettidae	[19]	
Porifera	Demospongiae	Astrophorida			Astrophorina		[22]
Porifera	Demospongiae	Axinellida	Axinellidae	Phakellia	Phakellia	[12]	
Porifera	Demospongiae	Axinellida	Axinellidae		Axinellidae	[23]	[23]
Porifera	Demospongiae	Poecilosclerida	Cladorhizidae	Chondrocladia	Chondrocladia	[12] as *Chondrocladia grandis*	
Porifera	Demospongiae	Poecilosclerida	Isodictyidae	Isodictya	Isodictya palmata	[12]	
Porifera	Demospongiae	Poecilosclerida	Mycalidae	Mycale	Mycale		
Porifera	Demospongiae	Polymastiida	Polymastiidae	Radiella	Polymastia hemisphaerica	[7]	
Porifera	Demospongiae	Polymastiida	Polymastiidae	Radiella	Radiella		
Porifera	Demospongiae	Polymastiida	Polymastiidae	Tentorium	Tentorium	[19]	
Porifera	Demospongiae	Polymastiida	Polymastiidae	Tentorium	Tentorium semisuberites	[19]	
Porifera	Demospongiae	Polymastiida	Polymastiidae		Polymastiidae	[19], [23]	[23]
Porifera	Demospongiae	Suberitida	Stylocordylidae	Stylocordyla	Stylocordyla	[19]	
Porifera	Demospongiae	Suberitida	Suberitidae	Rhizaxinella	Rhizaxinella	[19]	
Porifera	Demospongiae	Tetractinellida	Ancorinidae	Stelletta	Stelletta		[17]
Porifera	Demospongiae	Tetractinellida	Ancorinidae	Stryphnus	Stryphnus		[17]
Porifera	Demospongiae	Tetractinellida	Ancorinidae		Ancorinidae		[17]
Porifera	Demospongiae	Tetractinellida	Geodiidae	Geodia	Geodia	[23]	[17], [22], [23]

Porifera	Demospongiae	Tetractinellida	Geodiidae		Geodiidae		[17], [22]
Porifera	Demospongiae	Tetractinellida	Tetillidae	Craniella	Craniella	[7], [23]	[17], [23]
Porifera	Demospongiae	Tetractinellida	Tetillidae		Tetillidae		[17]
Porifera	Demospongiae	Tetractinellida	Theneidae	Thenea	Thenea	[7]	[17]
Porifera	Demospongiae	Tetractinellida	Theneidae	Thenea	Thenea levis		[17]
Porifera	Demospongiae	Tetractinellida	Vulcanellidae	Poecillastra	Poecillastra compressa	[19]	
Porifera	Demospongiae	Tetractinellida	Vulcanellidae		Vulcanellidae	[19]	
Porifera	Demospongiae	Tetractinellida			Astrophorina		[17]
Porifera	Hexactinellida	Amphidiscosida	Pheronematidae		Pheronematidae	[19]	
Porifera	Hexactinellida	Lyssacinosida	Euplectellidae		Euplectellidae	[19]	
Porifera	Hexactinellida	Lyssacinosida	Rossellidae	Asconema	Asconema		[17]
Porifera					Porifera	[19]	[17]

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Appendix 18. Invertebrate species Classified as Habitat Providers from the EU Surveys of NAFO Divisions 3LNO (see Table 1) with Associated Total Biomass, Number of Trawl Records and Mean Biomass/Trawl, ordered by Total Biomass. Row outlined in red indicates the last taxon contributing to 90% of the cumulative biomass in the catches. NAFO VME Indicator taxa are shaded in grey. Taxa in red at the bottom of the table were present in the survey but not present in the catches creating the KDE polygons for invertebrate habitat provision.

Phylum	Class	Order	Family	Genus	Scientific Name (WoRMS)	Total Biomass (Kg)	Number of Trawl Records	Mean Biomass per Trawl (Kg)
Porifera	Demospongiae	Tetractinellida	Geodiidae		Geodiidae	13698.580	52	263.434
Porifera	Demospongiae	Astrophorida			Astrophorina	11867.540	84	141.280
Porifera	Demospongiae	Tetractinellida	Geodiidae	Geodia	Geodia	5520.077	41	134.636
Porifera					Porifera	5398.496	397	13.598
Porifera	Hexactinellida	Lyssacinosida	Rossellidae	Asconema	Asconema	688.646	188	3.663
Porifera	Hexactinellida	Amphidiscosida	Pheronematidae		Pheronematidae	409.980	1	409.980
Porifera	Demospongiae	Tetractinellida	Ancorinidae	Stelletta	Stelletta	280.760	21	13.370
Chordata	Ascidiacea	Stolidobranchia	Pyuridae	Boltenia	Boltenia ovifera	162.692	30	5.423
Porifera	Demospongiae	Tetractinellida	Tetillidae		Tetillidae	141.636	120	1.180
Cnidaria	Anthozoa	Alcyonacea	Nephtheidae	Duva	Duva florida	117.967	348	0.339
Porifera	Demospongiae	Poecilosclerida	Mycalidae	Mycale	Mycale	75.980	37	2.054
Annelida	Polychaeta	Sabellida	Sabellidae		Sabellidae	75.843	148	0.512
Porifera	Demospongiae	Axinellida	Axinellidae		Axinellidae	56.262	55	1.023
Cnidaria	Anthozoa	Alcyonacea	Isididae	Keratoisis	Keratoisis	55.721	23	2.423
Porifera	Demospongiae	Polymastiida	Polymastiidae		Polymastiidae	45.342	209	0.217
Porifera	Demospongiae	Tetractinellida	Theneidae	Thenea	Thenea	44.231	62	0.713
Porifera	Demospongiae	Tetractinellida	Tetillidae	Craniella	Craniella	42.917	33	1.301
Cnidaria	Anthozoa	Alcyonacea	Paragorgiidae	Paragorgia	Paragorgia	41.193	3	13.731
Cnidaria	Anthozoa	Pennatulacea	Anthoptilidae	Anthoptilum	Anthoptilum	29.505	140	0.211
Bryozoa					Bryozoa	25.013	145	0.173
Porifera	Demospongiae	Tetractinellida	Ancorinidae	Stryphnus	Stryphnus	23.830	2	11.915
Cnidaria	Hydrozoa				Hydrozoa	17.491	296	0.059
Cnidaria	Anthozoa	Alcyonacea	Nephtheidae	Gersemia	Gersemia	17.113	50	0.342

Porifera	Demospongiae	Tetractinellida	Ancorinidae		Ancorinidae	13.160	3	4.387
Cnidaria	Anthozoa	Alcyonacea	Isididae	Acanella	Acanella arbuscula	7.612	87	0.087
Cnidaria	Anthozoa	Alcyonacea	Nephtheidae		Nephtheidae	7.428	185	0.040
Cnidaria	Anthozoa	Alcyonacea	Plexauridae		Plexauridae	5.924	5	1.185
Cnidaria	Anthozoa	Alcyonacea	Paragorgiidae	Paragorgia	Paragorgia arborea	5.137	3	1.712
Cnidaria	Anthozoa	Pennatulacea	Halipteridae	Halipteris	Halipteris finmarchica	4.622	51	0.091
Cnidaria	Anthozoa	Pennatulacea	Pennatulidae	Pennatula	Pennatula	4.452	38	0.117
Cnidaria	Anthozoa	Antipatharia	Schizopathidae	Stauropathes	Stauropathes arctica	3.941	5	0.788
Annelida	Polychaeta		Maldanidae		Maldanidae	3.544	14	0.253
Annelida	Polychaeta				Polychaeta	2.766	179	0.015
Porifera	Demospongiae	Polymastiida	Polymastiidae	Tentorium	Tentorium semisuberites	2.739	168	0.016
Porifera	Demospongiae	Polymastiida	Polymastiidae	Radiella	Polymastia hemisphaerica	2.611	38	0.069
Chordata	Ascidiacea	Stolidobranchia	Pyuridae	Boltenia	Boltenia	2.364	4	0.591
Porifera	Demospongiae	Poecilosclerida	Cladorhizidae	Chondrocladia	Chondrocladia	2.135	14	0.153
Cnidaria	Anthozoa	Alcyonacea	Acanthogorgiidae	Acanthogorgia	Acanthogorgia	1.552	13	0.119
Cnidaria	Anthozoa	Pennatulacea	Pennatulidae	Pennatula	Ptilella grandis	1.297	34	0.038
Porifera	Demospongiae	Tetractinellida	Vulcanellidae	Poecillastra	Poecillastra compressa	1.290	1	1.290
Porifera	Calcarea	Leucosolenida	Sycettidae		Sycettidae	1.256	2	0.628
Cnidaria	Anthozoa				Ceriantharia	1.062	2	0.531
Porifera	Demospongiae	Suberitida	Stylocordylidae	Stylocordyla	Stylocordyla	0.838	16	0.052
Cnidaria	Anthozoa	Alcyonacea	Anthothelidae	Anthothela	Anthothela grandiflora	0.716	2	0.358
Mollusca	Bivalvia	Mytilida	Mytilidae	Mytilus	Mytilus	0.581	3	0.194
Cnidaria	Anthozoa	Alcyonacea	Nephtheidae	Drifa	Drifa	0.571	16	0.036
Chordata	Ascidiacea	Stolidobranchia	Pyuridae		Pyuridae	0.545	4	0.136
Cnidaria	Anthozoa	Pennatulacea	Funiculinidae	Funiculina	Funiculina quadrangularis	0.522	25	0.021
Cnidaria	Hydrozoa	Leptothecata	Aglaopheniidae	Cladocarpus	Cladocarpus	0.362	16	0.023
Annelida	Polychaeta	Eunicida	Onuphidae	Nothria	Nothria	0.232	13	0.018
Cnidaria	Anthozoa	Pennatulacea	Halipteridae		Halipteridae	0.213	1	0.213
Cnidaria	Hydrozoa	Leptothecata	Sertulariidae	Thuiaria	Thuiaria thuja	0.207	44	0.005
Cnidaria	Anthozoa	Alcyonacea	Chrysogorgiidae	Radicipes	Radicipes	0.174	21	0.008

Cnidaria	Anthozoa	Pennatulacea			Pennatulacea	0.166	13	0.013
Cnidaria	Anthozoa	Pennatulacea	Funiculinidae	Funiculina	Funiculina	0.155	3	0.052
Cnidaria	Hydrozoa	Leptothecata	Aglaopheniidae	Aglaophenopsis	Aglaophenopsis	0.136	9	0.015
Porifera	Demospongiae	Suberitida	Suberitidae	Rhizaxinella	Rhizaxinella	0.126	7	0.018
Porifera	Demospongiae	Polymastiida	Polymastiidae	Tentorium	Tentorium	0.116	7	0.017
Cnidaria	Anthozoa	Pennatulacea	Umbellulidae	Umbellula	Umbellula	0.079	11	0.007
Porifera	Demospongiae	Polymastiida	Polymastiidae	Radiella	Radiella	0.070	2	0.035
Porifera	Demospongiae	Axinellida	Axinellidae	Phakellia	Phakellia	0.059	2	0.030
Porifera	Demospongiae	Tetractinellida	Theneidae	Thenea	Thenea levis	0.036	2	0.018
Cnidaria	Anthozoa	Pennatulacea	Protoptilidae	Distichoptilum	Distichoptilum gracile	0.035	11	0.003
Annelida	Polychaeta	Terebellida	Terebellidae		Terebellidae	0.033	10	0.003
Cnidaria	Hydrozoa	Leptothecata	Sertulariidae	Abietinaria	Abietinaria	0.030	3	0.010
Cnidaria	Anthozoa	Alcyonacea			Alcyonacea	0.021	4	0.005
Porifera	Hexactinellida	Lyssacinosida	Euplectellidae		Euplectellidae	0.020	1	0.020
Cnidaria	Hydrozoa	Leptothecata	Sertularellidae	Sertularella	Sertularella	0.014	3	0.005
Cnidaria	Anthozoa	Antipatharia			Antipatharia	0.011	2	0.006
Cnidaria	Anthozoa	Scleractinia	Caryophylliidae	Lophelia	Desmophyllum pertusum	0.011	2	0.006
Cnidaria	Anthozoa	Alcyonacea	Anthothelidae		Anthothelidae	0.005	1	0.005
Cnidaria	Anthozoa	Alcyonacea	Nephtheidae	Gersemia	Gersemia rubiformis	0.004	1	0.004
Annelida	Polychaeta	Eunicida	Eunicidae	Eunice	Eunice norvegica	0.002	1	0.002
Cnidaria	Anthozoa	Pennatulacea	Kophobelemnidae	Kophobelemnon	Kophobelemnon stelliferum	0.002	2	0.001
Annelida	Polychaeta	Sabellida	Serpulidae		Serpulidae	0.002	1	0.002
Cnidaria	Hydrozoa	Leptothecata	Laodiceidae	Staurostoma	Staurostoma mertensii	0.001	1	0.001
Cnidaria	Anthozoa	Alcyonacea	Isididae	Acanella	Acanella			
Cnidaria	Anthozoa	Pennatulacea	Protoptilidae	Distichoptilum	Distichoptilum			
Cnidaria	Anthozoa	Alcyonacea	Nephtheidae	Gersemia	Gersemia fruticosa			
Cnidaria	Hydrozoa	Leptothecata	Haleciidae	Halecium	Halecium			
Cnidaria	Hydrozoa	Leptothecata	Sertulariidae	Sertularia	Sertularia cupressina			
Cnidaria	Hydrozoa	Leptothecata	Sertulariidae		Sertulariidae			
Cnidaria	Hydrozoa	Leptothecata	Tiarannidae	Stegopoma	Ptychogena crocea			

Cnidaria	Anthozoa	Antipatharia	Antipathidae	Stichopathes	Stichopathes			
Cnidaria	Anthozoa	Alcyonacea	Clavulariidae	Telestula	Telestula septentrionalis			
Cnidaria	Hydrozoa	Leptothecata	Sertulariidae	Thuiaria	Thuiaria carica			
Mollusca	Bivalvia	Mytilida	Mytilidae	Mytilus	Mytilus edulis			
Porifera	Demospongiae	Poecilosclerida	Isodictyidae	Isodictya	Isodictya palmata			
Porifera	Demospongiae	Tetractinellida	Vulcanellidae		Vulcanellidae			

Appendix 19. Species Classified as Habitat Providers from the Canadian Surveys of NAFO Divisions 3LNO (see Table 1) with Associated Total Biomass, Number of Trawl Records and Mean Biomass/Trawl, ordered by Total Biomass. Row outlined in red indicates the last taxon contributing to 90% of the cumulative biomass in the catches. NAFO VME Indicator taxa are shaded in grey. Taxa in red at the bottom of the table were present in the survey but not present in the catches creating the KDE polygons for invertebrate habitat provision.

Phylum	Class	Order	Family	Genus	Scientific Name (WoRMS)	Total Biomass (Kg)	Number of Trawl Records	Mean Biomass per Trawl (Kg)
Porifera					Porifera	4071.845	349	11.667
Cnidaria	Anthozoa	Alcyonacea	Nephtheidae		Nephtheidae	209.187	293	0.714
Chordata	Ascidiacea	Stolidobranchia	Pyuridae	Boltenia	Boltenia	169.576	71	2.388
Cnidaria	Anthozoa	Alcyonacea			Alcyonacea	14.655	34	0.431
Annelida	Polychaeta				Polychaeta	14.099	60	0.235
Cnidaria	Anthozoa	Pennatulacea			Pennatulacea	13.766	40	0.344
Mollusca	Bivalvia	Mytilida	Mytilidae		Mytilidae	6.405	7	0.915
Cnidaria	Anthozoa	Antipatharia			Antipatharia	2.580	3	0.860
Bryozoa					Bryozoa	0.213	9	0.024
Cnidaria	Hydrozoa				Hydrozoa	0.046	4	0.011

Appendix 20. Species Classified as Habitat Providers from the EU Surveys of NAFO Division 3M (see Table 1) with Associated Total Biomass, Number of Trawl Records and Mean Biomass/Trawl, ordered by Total Biomass. Row outlined in red indicates the last taxon contributing to 90% of the cumulative biomass in the catches. NAFO VME Indicator taxa are shaded in grey. Taxa in red at the bottom of the table were present in the survey but not present in the catches creating the KDE polygons for invertebrate habitat provision.

Phylum	Class	Order	Family	Genus	Scientific Name (WoRMS)	Total Biomass (Kg)	Number of Trawl Records	Mean Biomass per Trawl (Kg)
Porifera	Demospongiae	Tetractinellida	Geodiidae		Geodiidae	26703.979	71	376.112
Porifera	Demospongiae	Astrophorida			Astrophorina	7742.265	49	158.005
Porifera					Porifera	2558.420	262	9.765
Cnidaria	Anthozoa	Alcyonacea	Nephtheidae	Duva	Duva florida	129.024	187	0.690
Cnidaria	Anthozoa	Pennatulacea	Anthoptilidae	Anthoptilum	Anthoptilum	54.473	141	0.386
Cnidaria	Anthozoa	Alcyonacea	Paragorgiidae	Paragorgia	Paragorgia	18.110	3	6.037
Porifera	Demospongiae	Polymastiida	Polymastiidae		Polymastiidae	12.672	52	0.244
Cnidaria	Anthozoa	Pennatulacea	Halipteridae	Halipteris	Halipteris finmarchica	9.398	97	0.097
Cnidaria	Anthozoa	Antipatharia	Schizopathidae	Stauropathes	Stauropathes arctica	9.258	48	0.193
Porifera	Demospongiae	Tetractinellida	Tetillidae		Tetillidae	8.102	13	0.623
Cnidaria	Anthozoa	Alcyonacea	Plexauridae	Paramuricea	Paramuricea	3.130	3	1.043
Porifera	Demospongiae	Suberitida	Stylocordylidae	Stylocordyla	Stylocordyla	3.037	5	0.607
Cnidaria	Anthozoa	Alcyonacea	Nephtheidae		Nephtheidae	2.717	47	0.058
Cnidaria	Anthozoa	Alcyonacea	Isididae	Acanella	Acanella arbuscula	1.733	58	0.030
Cnidaria	Anthozoa	Alcyonacea	Isididae		Isididae	1.028	9	0.114
Cnidaria	Anthozoa	Pennatulacea	Funiculinidae	Funiculina	Funiculina quadrangularis	0.886	48	0.018
Annelida	Polychaeta	Sabellida	Sabellidae		Sabellidae	0.780	18	0.043
Cnidaria	Anthozoa	Antipatharia			Antipatharia	0.597	15	0.040
Porifera	Demospongiae	Polymastiida	Polymastiidae	Radiella	Polymastia hemisphaerica	0.594	28	0.021
Annelida	Polychaeta				Polychaeta	0.577	58	0.010
Cnidaria	Hydrozoa				Hydrozoa	0.368	51	0.007
Cnidaria	Anthozoa	Alcyonacea	Acanthogorgiidae	Acanthogorgia	Acanthogorgia	0.355	14	0.025
Cnidaria	Anthozoa	Pennatulacea	Umbellulidae	Umbellula	Umbellula	0.336	29	0.012

Cnidaria	Anthozoa	Pennatulacea			Pennatulacea	0.248	3	0.083
Bryozoa					Bryozoa	0.219	23	0.010
Cnidaria	Anthozoa	Pennatulacea	Pennatulidae	Pennatula	Pennatula	0.185	17	0.011
Cnidaria	Anthozoa	Alcyonacea			Alcyonacea	0.147	5	0.029
Porifera	Demospongiae	Polymastiida	Polymastiidae	Tentorium	Tentorium	0.101	5	0.020
Cnidaria	Anthozoa	Pennatulacea	Pennatulidae	Pennatula	Ptilella grandis	0.098	10	0.010
Cnidaria	Anthozoa	Alcyonacea	Chrysogorgiidae	Radicipes	Radicipes	0.055	25	0.002
Cnidaria	Anthozoa	Pennatulacea	Halipteridae	Halipteris	Halipteris christii	0.038	4	0.010
Cnidaria	Anthozoa	Alcyonacea	Anthothelidae	Anthothela	Anthothela	0.027	1	0.027
Cnidaria	Anthozoa	Pennatulacea	Pennatulidae	Pennatula	Pennatula aculeata	0.014	4	0.004
Porifera	Demospongiae	Poecilosclerida	Cladorhizidae	Chondrocladia	Chondrocladia	0.010	1	0.010
Cnidaria	Anthozoa	Alcyonacea	Nephtheidae	Gersemia	Gersemia	0.010	2	0.005
Cnidaria	Anthozoa	Pennatulacea	Protoptilidae	Distichoptilum	Distichoptilum gracile	0.006	3	0.002
Cnidaria	Anthozoa	Pennatulacea	Kophobelemnidae	Kophobelemnon	Kophobelemnon stelliferum	0.003	3	0.001
Cnidaria	Anthozoa	Alcyonacea	Primnoidae	Primnoa	Primnoa resedaeformis			