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Recent DFO (Newfoundland & Labrador Region) studies of the Grand Banks benthos at small and large spatial scales

Récentes études conduites par le MPO (Région de Terre-Neuve-et-Labrador) sur l'échantillonnage du benthos des Grands Bancs a petites et grandes échelles Spatiales

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ABSTRACT

While acknowledged to be an important component of the Grand Banks ecosystem, our understanding of benthic communities on the Grand Banks is limited. In recent years, DFO NL has implemented sampling programs which sample benthos at large and small spatial scales over wide areas of the Grand Banks and Labrador Shelf. The DFO multispecies trawl surveys primarily provide information on large epifaunal benthos extending from the northern Labrador shelf to southern Grand Bank and from shallow shelf depths (~40 m) to deep continental slope areas (~ 1500 m). Preliminary observations on geographic trends in this dataset are discussed. As part of the NL NEREUS Ecosystem Research Initiative a benthic grab sampling program was designed and implemented during routine multispecies surveys. The benthic grab sampling program was developed to compliment other components of the NEREUS program. Objectives of the benthic program were to improve our understanding of benthic species assemblages and patterns of benthic biomass on the Grand Banks. Over the three-year period of the program (2008-2010), a total of 158 grab samples were collected and processed from 58 grab sample stations representing 25 survey strata and three NAFO Divisions (3LNO). Species assemblages and trophic composition characterizing grab sample sediment types are described. Benthic biomass recorded in the NEREUS program is compared with previous benthic grab sampling programs on the Grand Banks.

RÉSUMÉ

Bien que reconnu pour être un élément important de l'écosystème des Grands Bancs, notre compréhension des communautés benthiques des Grands Bancs est limitée. Ces dernières années, le MPO NL a mis en place des programmes d'échantillonnage du benthos, cet echantillonage est complété à petite et grande échelles spatiales sur de vastes zones des Grands Bancs et du plateau du Labrador. Les relevés du MPO au chalut multispécifique fournissent principalement des informations sur l'épifaune benthique de grande taille (macrofauna ?) s'étendant du plateau du Labrador nord au sud des Grand Bancs, des profondeurs peu profondes du plateau (~ 40 m) jusqu'aux zones profondes du talus continental (~ 1500 m). Les observations préliminaires sur les tendances géographiques de cet ensemble de données sont discutées. Dans le cadre de l'Initiative NL NEREUS une recherche sur l'écosystème un programme d'échantillonnage benthique a été conçue et mise en œuvre au cours des enquêtes de routine multispécifiques. Ce programme d'échantillonnage benthique a été développé pour compléter d'autres composantes du programme NEREUS. Les objectifs du programme benthique étaient d'améliorer notre compréhension des assemblages d'espèces benthiques et des modèles de la biomasse benthique sur les Grands Bancs. Au cours de la période de trois ans du programme (2008-2010), un total de 158 échantillons ont été collectées et traitées à partir de 58 stations d'échantillonnage d'appui représentant 25 strates et trois divisions de l'OPANO (3LNO). Les assemblages d'espèces et la composition trophique caractérisant les types de sédiments sont décrits. La biomasse benthique enregistrée dans le programme NEREUS est comparé avec d'autres programmes d'échantillonnage benthique utilisés sur les Grands Bancs.

INTRODUCTION

DEFINITION OF THE BENTHOS

Benthos is the community of invertebrates which live on, in, or very near the seabed. The latter are referred to as hyperbenthos. The term benthos comes from the Greek noun βένθος "depths of the sea". The majority of benthic community studies deal with the macro-and mega-fauna (organisms that are greater than 1 mm in size), thus excluding the meiobenthos which comprise organisms <1 mm in size. One reason for the exclusion of meiofauna in studies is due to the difficulty of effectively quantifying this size group with traditional sampling gears such as trawls, grabs and dredges.

RELEVANCE OF THE BENTHOS TO DFO ECOSYSTEM RESEARCH

The benthos of the Canadian east coast continental shelf and slope ecosystems constitutes a significant proportion of total species number, abundance and biomass within the marine ecosystem (Nesis 1970 (translation of Nesis 1965); Kenchington et al. 2001; Stewart and Hargrave 2001). Some of the highest benthic biomasses worldwide have been recorded from the Southeast Shoal on Grand Bank (Hutcheson and Stewart 1994). While it is generally acknowledged that the benthos on the Grand Banks represents a significant sink of biomass, it is unknown how this energy is being used in the system and by which pathways. As such, the benthos remains largely an undetermined term in current ecosystem models. It has long been known that certain benthos are important prey for demersal fishes (see Collie 1987; Link et al. 2002; Jaworski and Ragnarsson 2006). Also, the benthos has long been used as an indicator/monitoring tool for anthropogenic disturbance to seabed habitat. This includes Fisheries and Oceans Canada (DFO) trawling habitat impact research on the northeast Grand Bank carried out in the mid-1990s (see Gilkinson et al. 2006 and Gordon et al. 2006 for summaries). All of the above are highly relevant to DFO's ecosystem approach to fisheries management and habitat conservation objectives.

RECENT STUDIES OF THE BENTHOS BY DFO NEWFOUNDLAND & LABRADOR (NL) REGION

The scope of this research document is to present key results of two recent (post-2006) DFO research programs on the Grand Banks benthos which has added to our understanding of benthic assemblages over wide areas of the Grand Banks.

Sampling at Large Spatial Scales

While DFO NL multi-species trawl surveys, targeting fishes and commercial invertebrates, have been carried out since the 1950s, it was only in 2006 that standardized sampling protocols for non-commercial invertebrates (i.e. non-commercial benthos) were implemented in the surveys. However, standardized sampling protocols for cold-water corals were introduced to the surveys in 2005. Preliminary results of non-commercial benthos catch will be presented in this research document as minimal analyses have been carried out to date since the extent and quality of the data collected are currently being assessed. Results from the coral and sponge sampling program have been reported elsewhere (Wareham and Edinger 2007; Wareham 2009 *inter alia*).

Sampling at Small Spatial Scales

The NL region NEREUS (**N**L's **E**xpanded **R**esearch on **E**cosystem-relevant but **U**nder-surveyed **S**plicers) Program represents a DFO Ecosystem Research Initiative (ERI). Primary goals of NEREUS were: 1) To enhance the capability of NL surveys for providing information on ecosystem status and main trends by improving monitoring on forage fishes, non-commercial species, major benthic components and trophic interactions, and 2) To identify and track main pathways of energy in the NL system by integrating results from trophodynamic and statistical models with trends and patterns in ecosystem indicators.

While acknowledged to be an important component of the Grand Banks ecosystem, our understanding of benthic communities on the Grand Banks is limited, being both patchy and sporadic in space and time. In order to improve our knowledge of this ecosystem component, a benthic grab sampling program was developed for NEREUS. A description of this program and preliminary results are the primary focus of this research document. Key objectives of the benthic program were to acquire knowledge of benthic species assemblages and patterns in benthic biomass over a wide area of the Grand Banks, in particular:

- What species assemblages are found on the Grand Banks and how do these relate to environmental factors, e.g. depth and bottom type?
- What are the patterns in benthic biomass, including the faunal groups that contribute most to biomass?

OVERVIEW OF BENTHIC GRAB SAMPLING PROGRAMS ON THE GRAND BANKS

The first systematic, quantitative study of the benthos of the Grand Banks was carried out by Nesis (1970; translation of Nesis 1965). This was the first and only attempt, to map benthic communities or assemblages (bioceonoces) over the entire Grand Banks. However, given the level of grab sampling and the area of coverage, significant interpolation was required to produce faunal distribution maps. A list of the primary grab sampling programs that have been carried out on the Grand Banks since the 1960s are provided in Table 1. This is not a complete record as there may be some sources that are largely unpublished, such as grab sampling during Geological Survey of Canada (Bedford Institute of Oceanography) geological surveys on the Grand Banks during the 1970s. There is a substantial secondary literature associated with oilfield baseline surveys and subsequent Environmental Effects Monitoring Programs on the northeast Grand Banks. Most of the environmental assessment and monitoring reports are available on-line at the Canada-Newfoundland and Labrador Offshore Petroleum Board website (http://www.cnlopb.nl.ca). A very detailed compilation of grab sampling studies on the east coast of Canada, including the Grand Banks, can be found in Stewart et al. (2001). To date, there have been three studies (Nesis 1970; Hutcheson et al. 1981; this NEREUS program) which have attempted to quantify/characterize benthic communities over wide geographic areas of the Grand Banks. The remaining studies have been localized in spatial extent, *albeit* intense sampling in some cases (Fisheries and Oceans Canada 2000; Kenchington et al. 2001).

METHODOLOGY

MULTISPECIES TRAWL SURVEYS

Shipboard Sample Collections and Processing

Processing of non-commercial benthos catch is carried out similar to commercial species with the exception that certain additional measurements (e.g. lengths, reproductive state) are not recorded. Benthos are wet weighed by taxon and for those sets with large catches, a portion of the total catch volume is sampled and subsample weights are recorded and then converted to total weight based on the proportion of the subsample. The level of taxonomic resolution varies with the faunal group. A photographic guide of commonly captured benthos, along with sampling instructions, has been developed by the DFO NL Shellfish Section of the Aquatic Resources Division (Northwest Atlantic Fisheries Centre, St. John's). It is noted that, unlike the NEREUS grab sampling program (described below), processing of benthos is now part of the routine multispecies survey protocols.

NEREUS GRAB SAMPLING PROGRAM (2008-2010)

Shipboard Sample Collections and Processing

The addition of benthic grab sampling to the routine DFO multispecies surveys was challenging since trawlers are not designed to be scientific sampling platforms (i.e. in a non-trawling context). A major impediment is deck space limitation. As such, the first requirement was to design a functional shipboard sampling and processing deck layout that would not interfere with trawling operations. The second requirement was to train seagoing scientific staff that had no experience in benthic grab sampling/processing techniques. A one-day training exercise was carried out with sea-going staff before the start of the program (2008) at a near-shore location off St. John's.

Benthic sampling was carried out using a 0.1 m^2 Van Veen grab sampler. Initial sample processing was carried out on the DFO survey trawlers, CCGS *Wilfred Templeman* (2008) and *Alfred Needler* (2009, 2010). Grab sample stations were restricted to trawl set locations with depths ≤ 200 m in order to minimize time spent at a station. Grab stations were distributed over a wide range of survey strata to maximize geographic and bathymetric coverage. The shipboard processing involved two primary work stations on separate decks. The upper deck served as the grab sampling deployment/retrieval location with grab deployment from the hydrographics wire. From here, the retrieved samples (sediment + fauna) were transferred to a bucket which was taken to the lower trawl deck for processing. A stainless steel sieve table (1 mm mesh) and formalin carboy rack were set up adjacent the bulkhead outside the trawl deck area. A fish tub (4' x 4' x 4') was used to store the buckets of processed formalin-preserved samples. Details of the grab sampling protocol are provided in the Appendix.

Environmental Variables

Several environmental variables were quantified for each grab sample: sediment type, classified in terms of proportion (by volume) of sand, pebble, cobble and boulder; water depth and; pre-sieve sample volume. However, the latter can be considered more a 'sampling' variable. The successful performance of mechanical grab samplers such as the Van Veen is dependent on a number of factors affecting deployment and retrieval, including sea state, wind conditions, water depth and sediment type. As a result, although the surface area sampled by the grab is presumably less variable, there can be a considerable range in sample volumes taken during the course of a grab sampling program, reflecting variable depth of penetration into the sediment. This could potentially influence the biomass of benthos collected and species composition. Sample volumes of grab samples and the relationship to faunal biomass are rarely reported in the literature. In the present study, pre-sieve sample volumes were recorded for individual grab samples. The proportion of sediment classes in each sample were visually estimated after the sample was distributed on the sieve table and before washing the sample through the sieve. A ruler aided in measurement and assignment of the sediment types according to the Wentworth geological scale: sand and granules (0.125-4 mm), pebble (4 mm-6.4 cm), and cobble (6.4-25.6 cm).

Laboratory Sample Processing

Due to work commitments of the few commercial labs qualified to process and identify the entire suite of benthic invertebrates from grab samples, a different lab processed grab samples in each of the three years: Envirosphere Consultants Ltd. (2008), Arenicola Marine (2009) and the Atlantic Reference Centre (ARC) (2010). Each lab has extensive experience in processing and identifying benthic macrofauna from the Grand Banks. Each lab followed a standardized protocol. In order to assist in the standardization of nomenclature, labs were provided with the species lists from the previous years.

Sieving of Whole Sediments

Samples were shipped to the labs as whole samples in 4-L plastic buckets, pre-sieved on-board and preserved in 10% buffered formalin seawater solution. In the lab, samples (sediment and organisms) were washed through a 0.5 mm sieve. Samples with coarse material (gravel and shell) were elutriated and sieved by directing a flow of freshwater into the sample while tipping the bucket and catching the overflow on the 0.5 mm sieve. The flow suspended the less dense organisms (e.g. polychaetes). Elutriation continued until the water leaving the bucket was free of organisms. Larger non-elutriated organisms were separated manually as they were found. Encrusting organisms (e.g. barnacles) were scraped off rocks or shells.

Sorting and Identification

Organisms were sorted at 10X magnification under a stereomicroscope and grouped to higher taxonomic levels (e.g. polychaetes, amphipods, etc.) prior to more detailed identification. Taxonomic identifications were to the lowest level possible (usually species). Wet weight biomass and abundance was determined for each taxon after blotting to remove surface water. With the exception of 2010, biomass was recorded to 0.1 mg. In 2010, due to limitations of the equipment, weights were recorded to 1 mg. Each year, the relevant lab provided a reference collection of any species (preserved in 70% ethanol) not recorded by the previous lab.

Data Analyses

This report focuses on benthic biomass including patterns in total benthic biomass and trends in species assemblages based on environmental variables such as water depth and sediment type. Abundance data was also collected and will be reported elsewhere.

Data analyses/terminologies were carried out using PRIMER (Clarke and Gorley 2006).

Individual grab sample volumes varied (see results). Due to this, data was first standardized to proportional species biomass in an attempt to ameliorate any effects of differing sample volumes. Data were then transformed (4^{th} root) to down-weight the influence of biomass dominant taxa such as sand dollars. In order to compare results of this study with those of Nesis (1970), samples were grouped into two depth zones: mid-depth (>50m-100m) and deep (>100m-200m). Species assemblages were compared between these depth zones and sediment types.

Non-metric multi-dimensional scaling (MDS) ordination was then carried out on these groupings. Identification of significant differences between groupings was determined using the ANOSIM routine after transformation of data followed by the Bray-Curtis similarity index. Where significant differences occurred, the main species accounting for these differences were identified using the SIMPER routine.

Species accumulation curves were generated in PRIMER. Plots represent species-area curves, showing the cumulative number of different species observed as each new sample is added. The generated smoothed curves are averages based on 999 permutations of the order of addition of samples.

Linking Species Assemblage Patterns to Abiotic Variables

The 'BEST' routine for trend correlation in PRIMER was used to find the 'best' match between the multivariate (i.e. species) among-sample patterns and that from abiotic variables associated with those samples. The extent to which these two patterns match reflects the degree to which the chosen abiotic data correlate with the biotic pattern. The Global BEST match test was used to determine statistical significance. Five abiotic variables were used: depth, sample volume and percent sand, pebble and cobble-boulder. Because of cases of missing abiotic variables a subset of samples (140) were used. 'Draftsman' plots of abiotic variables (pairwise scatter plots) were generated and data was log-transformed to correct for skewed distributions. Data was then normalized due to different measurement units associated with the variables. Euclidean distance was used to generate similarity matrices for samples based on the abiotic data.

RESULTS AND DISCUSSION

MULTISPECIES SURVEY TRAWL BENTHOS CATCH

Average biomass of benthos per trawl set (i.e. tow) by year and Northwest Atlantic Fisheries Organization (NAFO) Division is shown in Fig. 1. The data is based on a random stratified design and has been grouped into higher level faunal groupings across five divisions extending from northern Labrador (NAFO Div. 2J) to the southern Grand Banks (NAFO Div. 3NO). The time series extends from 2006, when standardized sampling protocols were introduced, to 2010. It is noted that at the start of the standardized sampling program in 2006, a high proportion of benthic biomass was classified as 'unidentified invertebrates'. As taxonomic proficiency increased, this category was mostly eliminated in subsequent years. Although these are preliminary results, some geographic trends are apparent. Most notable is that a higher proportion of benthic biomass in northern areas (e.g. NAFO Div. 2J3K) is comprised of sponges and sea anemones, whereas on the southern Grand Banks (NAFO Div. 3NO) echinoderms dominate the catch. One of the goals behind this evolving dataset is to determine whether or not trawl-caught benthos can be used as an index of benthic biomass and biodiversity on the Grand Banks. A main impediment is determining trawl selectivity (‘catchability’) on different bottom types. Otter trawls capture primarily the larger epifaunal benthos, however successful capture will vary according to a number of factors, including bottom type. Accordingly, indices of benthic biomass have to be measured for different sediment types and bottom roughness. Arguably, the easiest seabed to measure trawl selectivity is a relatively flat, sandy bottom. In conjunction with the DFO Grand Bank trawling impact experiment, catches of benthos were compared between an epibenthic sled and an Engel 145 trawl (Prena et al. 1999). It was determined that, conservatively, the trawl captured ~ 0.5% of available benthic biomass, revealing the high inefficiency of bottom trawls for capturing benthos and a bias toward certain species.

NEREUS GRAB SAMPLING PROGRAM

Over the three-year study, a total of 158 grab samples were collected and processed from 58 stations (Fig. 2) covering 25 survey strata and three NAFO Divisions (3LNO). The majority of samples were collected from Divisions 3N and 3O during the spring multispecies survey. While a limited number of samples (12) were taken from more northern areas of Grand Bank (NAFO Div. 3L) during the fall survey, poor sea state and high winds at this time of year forced exclusion of the northern region of Grand Bank for the duration of the program. Since the main focus of the benthic program was directed at the shelf ecosystem, sampling depths for grab samples were restricted to $\leq$ 200 m. This also avoided the likelihood of lengthy station occupations at deep water locations, which would have significantly delayed the multispecies survey.

The distribution of successful grab samples by stratum and depth is shown in Fig. 3. The average number of samples collected per stratum was 6 $\pm$ 3 (SD) (range 1-13). The average sampling depth was 92 m (range 58-157 m). The proportion of grab samples by sediment type and depth zone is shown in Fig. 4. A total of 51% of all samples collected represented pure sand (i.e. gravel free). The majority (77%) of samples were collected from the mid-depth zone (> 50-100 m). Pure sand samples comprised 46% of all samples collected from this zone. This increased to 61% in the deep zone.

Sample Biomass vs. Sample Volume

Sample volumes ranged from < 1 L to approximately 12 L with a median value of 1.6 L. The wide range in sample volume was a reflection of the factors previously mentioned which determine the depth of penetration into the sediment by the grab. However, there was no correlation between sample volume and total sample biomass (r = 0.002, P = 0.983, n = 156) (Fig. 5). When the biomass dominant sand dollar, *Echinarachnius parma*, was excluded a lack of correlation between sample biomass and sample volume remained (r = 0.028, P = 0.738) (Fig. 5).

Faunal Composition

A total of 455 benthic macrofaunal taxa were identified from 22,000 specimens collected and processed over the three-year grab sampling program. Excluded from analyses were fish (primarily *Ammodytes* sp.), meiofaunal taxa, and unidentified categories listed as ‘fragments’ and ‘bits’. The unidentified categories were a minor component, recorded for 11 samples in 2009 and totaled 0.25 g. Meiofaunal taxa that were recorded in samples, but excluded from analyses, included: foraminiferans, nematodes, copepods, ostracods and nemerteans.

A total of 12 phyla were represented with three phyla, (Annelida, Arthropoda, and Mollusca) combining for 86% of all recorded taxa (Fig. 6). The Annelida was the most species rich phylum (39% of all species) with polychaetes accounting for 99% of all annelid taxa, amphipods for 60% of arthropod taxa while gastropods and bivalves accounted for 51% and 43%, respectively, of mollusc taxa. This pattern of dominance in species richness by these three phyla is typical of northwest Atlantic continental shelves dominated by sandy seabeds (see Gilkinson et al. 2005; Kenchington et al. 2001).

The Annelida and Arthropoda, which were dominant in terms of species richness, were minor components of total biomass whereas the species-poor Echinodermata dominated biomass (58% of the total), and the sand dollar, *E. parma* in particular (69% of total echinoderm biomass) (Fig. 6). The dominance of *E. parma* in terms of Grand Banks benthic biomass on sandy seabeds was first quantitatively recorded by Nesis (1970) following his 1959-1960 expedition to the Grand Banks. However, with a more recent deeper penetrating hydraulic grab sampler it is recognized that deep-burrowing bivalve molluscs are also an important contributor to benthic biomass on Grand Bank sandy seabeds resulting in significantly higher recent estimates of benthic biomass (see Kenchington et al. 2001).

Species Accumulation

Species accumulation curves for grab samples collected in each of the three divisions are shown in Fig. 7. This is a 'broad-brush' analysis as all samples combining all depths and sediment types have been included. Based on sample number, only NAFO Div. 3N and 3O can be compared although it is noted that, over 12 samples, Div. 3L has a similar initial trajectory as Div. 3O. It is apparent that species are accumulating more rapidly in Div. 3O than in Div. 3N. At 50 samples, Div. 3O has approximately 35 more species than Div. 3N. However, given the sampling effort relative to the total area of the divisions, these results are difficult to interpret without additional sampling. It is also obvious that the curves have not reached their asymptote, indicating that potentially more species could be added with additional sampling.

Trends in Benthic Biomass

Average benthic biomass recorded within each NAFO Division is shown in Fig. 8. Average biomass ranged from approximately 26 g/0.1 m^2 in Div. 3L and 3N to 14 g/0.1 m^2 in Div. 3O. Average biomass did not differ significantly between divisions (ANOVA, $F_{(2,158)} = 2.5$, $P = 0.085$). There were no significant correlations between water depth and total sample biomass ($r = -0.121$, $P = 0.133$) and water depth and sample biomass excluding the biomass-dominant *E. parma* ($r = -0.107$, $P = 0.184$).

Species Assemblages

Environmental Linkages to Species Assemblage Patterns

The structure of benthic invertebrate assemblages is influenced by numerous environmental factors such as sediment type, amongst others. A test was undertaken to determine the 'best' match between the multivariate among-sample patterns of the Grand Bank species assemblages and that from the abiotic variables associated with the samples. The degree to which the two patterns match reflects the degree to which the chosen abiotic data in this study correlates with the biotic pattern.

The test for concordance between abiotic and biotic explanatory variables indicated a significant, although not an overly strong relationship (PRIMER BEST, ρ = 0.216, P = 0.01). The combinations of abiotic variables and their correlations behind the species assemblage pattern are shown in Table 2. The combination of variables showing the highest correlation was sample volume, water depth and percent volume of pebbles.

Characteristic Species Assemblages and Trophic Groups on Grand Bank Substrates

The PRIMER BEST analysis indicated that percent volume of pebbles in grab samples was an explanatory variable for the associated species patterns. In an attempt to identify distinct species associations with varying concentrations of sand and gravel (i.e. pebbles), an iterative approach was undertaken by grouping samples by increasing volumes of pebbles. The basis for comparison was the dominant pure sand category which was devoid of any gravel. Since depth was also identified as an influencing variable, only samples from the same depth zone were compared. Based on these criteria, a sufficient number of samples for comparison were available from NAFO Div. 3O in the mid-depth zone (> 50-100 m). Samples grouped by ≥ 45% pebbles showed a strong trend towards separation from the pure sand samples although the ANOSIM test was not significant (R = 0.122, P = 0.09) (Fig. 9). Comparison of sample groupings at lower and higher proportions of pebbles (45% ≥ pebbles ≥ 60%) did not improve the degree of separation. However, it is noted that sample sizes were low for combinations of sand with gravel where gravel comprised ≥ 45% and ≥ 60% of sample volume.

A total of 80 taxa combined for 75% of the average dissimilarity between the two sediment types; of these, 46 taxa combining for 60% of the cumulative dissimilarity are listed in Table 3. The carnivorous/subsurface deposit feeding polychaete, *Glycera capitata*, contributed most to between-group dissimilarity, having greater proportional biomass on sand with gravel. Fourteen taxa were unique to either pure sand or sand + pebbles sediment types (Table 3). Notable differences between the two sediment groupings were the decrease or loss of infaunal suspension feeding bivalves such as *Antalis entalis*, *Liocyma fluctuosa*, *Arctica islandica,* and *Cyrtodaria siliqua* on sand + pebbles. Surface-dwelling suspension feeding bivalves appearing only on the more gravelly sediments included *Chlamys islandica* and *Crenella decussata* which require a hard surface on which to bysally attach. Predictably, the sand dollar, *E. parma,* which was a biomass dominant on pure sand, had a reduced biomass on the coarser sediment.

COMPARISON OF BENTHIC BIOMASS FROM GRAND BANKS STUDIES

Since the late 1950s there have been numerous surveys on the Grand Banks which have provided estimates of benthic biomass (Fig. 10). The variance associated with these estimates is typically high. In addition to the NEREUS program, two other studies are based on wide geographic coverage of the Grand Banks (Nesis 1970; Hutcheson et al. 1981). Some of the other studies were very localized in nature and were focused on oil field monitoring programs (Jacques Whitford Environment Ltd. 1997, 1999; Envirosphere 1995) and a trawling impact experiment (Fisheries and Oceans 2000; Kenchington et al. 2001). With two exceptions, all estimates were based on samples collected with a 0.1 m^2 Van Veen grab sampler. The samples collected by Nesis were taken with a 0.25 m^2 Ocean-50 bottom scoop which is also a mechanical grab. The average biomass of approx. 1 kg/m^2 recorded on the northeast Grand Bank (1993-1995) during the fishing impact experiment (Fisheries and Oceans Canada 2000; Kenchington et al. 2001) can be considered the bench mark for benthic biomass on sandy seabeds. The sampler used was the Bedford Institute of Oceanography 0.5 m^2 hydraulic grab sampler. This grab has a maximum sediment penetration depth of 25 cm on sandy seabeds. It therefore captures deeper burrowing large bivalve molluscs such as the propeller clam *Cyrtodaria siliqua* which typically reside below the penetration depth of mechanical grabs such as the Van Veen. Details of this hydraulic grab sampler can be found in Rowell et al.,(1997). It is noted that the overall average biomass of 228 g/m^2 recorded in the NEREUS program is within a similar range to a number of previous studies. If one includes one anomalous sample with a biomass of 5 kg/m^2 for the clam *Macoma calcarea*, average biomass increases to 236 g/m^2. While the average biomass recorded by Nesis is a factor of two greater than the present study, this author gives no indication of the variance associated with this estimate.

One of the valuable aspects of grab sampling programs such as NEREUS is that it affords the opportunity to assess and monitor benthic biomass and species assemblages over broad areas. The NEREUS grab sampling program was undertaken five decades after the survey by Nesis (1970). While it is not possible to make an accurate comparison of results from the two studies given differences in some of the sampling locations and different grabs used, some broad trends can be examined. Average benthic biomass recorded in mid-depth (> 50-100 m) and deep-water (> 100-200 m) zones in the two studies are shown in Fig. 11. While the NEREUS program had a higher level of sampling effort in both depth zones for the Grand Bank, it is noteworthy that average biomass in the deep zone was similar in both studies. Given the difference in sampling effort in the deep zone, and the lack of information on variance in the Nesis data, it is unknown how representative the approximate two-fold higher biomass recorded in the mid-depth zone by Nesis is.

CONCLUDING REMARKS

The objectives outlined in the Introduction could only be partially addressed, since a long-term field program would be required. Funding for the benthic grab sampling component of the NEREUS program was discontinued after three years. However, it is noted that costs associated with carrying out this benthic program were high with the majority of expenditures devoted to laboratory sample processing and taxonomic identifications. DFO NL does not have the in-house capacity to perform the full-suite of processing/identifications of all benthos collected in grab samples. In addition, there are few commercial labs providing benthic taxonomic services making it difficult to standardize across years.

The level of support from seagoing staff was exceptional. The conditions (sea state, winds) encountered at times during the survey were harsh and were compounded by the necessity of using a relatively light grab sampler on a trawler with very limited deck space. It is also noted that records were taken of operational grab sampling at each station. Based on this, average time spent at each grab station (i.e. trawl set location) was approximately one hour which represents a significant investment of time. Given the above, it is questionable whether a long-term grab sampling program is feasible at this point using existing survey trawlers combined with available financial resources.

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REFERENCES

Clarke, K.R. and Gorley, R.N. 2006. PRIMER v6: User Manual/Tutorial. PRIMER-E: Plymouth.

Collie, J.S. 1987. Food consumption by yellowtail flounder in relation to production of its benthic prey. Mar. Ecol. Prog. Ser. 36: 205-213.

Envirosphere Consultants Limited. 1995. Report on taxonomic and ecological analysis of seabed organisms from the vicinity of the Hibernia Production Site. Hibernia Management and Development Company Ltd. St. John's, Newfoundland. *In* Stewart, P.L., H.A. Levy and B.T. Hargrave. 2001. Database of benthic macrofaunal biomass and productivity measurements for the eastern Canadian continental shelf, slope and adjacent area. Can. Tech. Rep. Fish. Aquat. Sci. 2336: vi + 31p + A1-6.

Fisheries and Oceans Canada. 2000. Raw data from Northeast Grand Bank, obtained from trawling impact studies in 1993-1995. Kevin MacIsaac, pers. Comm.. *In* Stewart, P.L., H.A. Levy and B.T. Hargrave. 2001. Database of benthic macrofaunal biomass and productivity measurements for the eastern Canadian continental shelf, slope and adjacent area. Can. Tech. Rep. Fish. Aquat. Sci. 2336: vi + 31p + A1-6.

Gilkinson, K.D., Gordon, D.C., Jr., MacIsaac, K., McKeown, D.L., Kenchington, E.L.R., Bourbonnais, C., and Vass, W.P. 2005. Immediate impacts and recovery trajectories of macrofaunal communities following hydraulic clam dredging on Banquereau, eastern Canada. ICES J. Mar. Sci. 62: 925-947.

Gilkinson, K., Dawe, E., Forward, B., Hickey, B., Kulka, D., and Walsh, S. 2006. A review of Newfoundland and Labrador Region research on the effects of mobile fishing gear on benthic habitat and communities. DFO Can. Sci. Advis. Sec. Res. Doc. 2006/055, iv + 26 p.

Gordon, D.C. Jr., Kenchington, E.L.R., and Gilkinson, K.D. 2006. A review of Maritimes Region research on the effects of mobile fishing gear on benthic habitat and communities. Can. Sci. Advis. Sec. Res. Doc. 2006/056, ii + 41 p.

Hutcheson, M.S., and Stewart, P.L. 1994. A possible relict population of *Mesodesma deauratum* (Turton): Bivalvia (Mesodesmatidae) from the Southeast Shoal, Grand Banks of Newfoundland. Can. J. Fish. Aquat. Sci. 51: 1162-1168.

Hutcheson, M.S., Stewart, P.L., and Spry, J.M. 1981. The biology of benthic communities of the Grand Banks of Newfoundland (including Hibernia area). Vol. 7. Grand Banks Oceanographic studies. Report for Mobil Oil Canada Ltd., St. John's, Newfoundland, by MacLaren Plansearch Ltd. 138 p.

Jacques Whitford Environment Limited. 1997. Raw data for Terra Nova Environmental Effects Monitoring Program. *In* Stewart, P.L., H.A. Levy and B.T. Hargrave. 2001. Database of benthic macrofaunal biomass and productivity measurements for the eastern Canadian continental shelf, slope and adjacent area. Can. Tech. Rep. Fish. Aquat. Sci. 2336: vi + 31p + A1-6.

Jacques Whitford Environment Limited. 1999. Hibernia Production Phase Environmental Effects Monitoring Report for 1998. Report to Hibernia Development and Management Company Limited. *In* Stewart, P.L., H.A. Levy and B.T. Hargrave. 2001. Database of benthic macrofaunal biomass and productivity measurements for the eastern Canadian continental shelf, slope and adjacent area. Can. Tech. Rep. Fish. Aquat. Sci. 2336: vi + 31p + A1-6.

Jaworski, A. and Ragnarsson, S.A. 2006. Feeding habits of demersal fish in Icelandic waters: a multivariate approach. ICES J. Mar. Sci. 9: 1682-1694.

Kenchington, E.L.R., Prena, J., Gilkinson, K.D., Gordon, D.C., Jr., MacIsaac, K., Bourbonnais, C., Schwinghamer, P., Rowell, T.W., McKeown, D.L., and Vass, W.P. 2001. Effects of experimental otter trawling on the macrofauna of a sandy bottom ecosystem on the Grand Banks of Newfoundland. Can. J. Fish. Aquat. Sci. 58: 1043-1057.

Link, J.S., Bolles, K., and Milliken, C.G. 2002. The feeding ecology of flatfish in the Northwest Atlantic. J. Northw. Atl. Fish. Sci. 30: 1-17.

Nesis, K.N.N. 1965. Biotsenozy I biomassa bentosa N'yufaundlendskogo-Labradorskogo raiona. Trudy Vsesoyuznogo Nauchno-Issledovatel'skogo Institua Morskogo Rybnogo Khozyaistva I Okeanografii (VNIRO) 57: 453-489.

Nesis, K.N.N. 1970. Biocoenoses and biomass of benthos of the Newfoundland-Labrador region. Fisheries Research Board of Canada Translation Series No. 1375. Translated by the Translation Bureau Foreign Languages Division, Department of the Secretary of State of Canada.

Prena, J., Schwinghamer, P., Rowell, T.W., Gordon, D.C., Jr., Gilkinson, K.D., Vass, W.P., and McKeown, D.L. 1999. Experimental otter trawling on a sandy bottom ecosystem of the Grand Banks of Newfoundland: analysis of trawl bycatch and effects on epifauna. Mar. Ecol. Prog. Ser. 181: 107-124.

Rowell, T.W., Schwinghamer, P., Gilkinson, K., Gordon, D.C., Jr., Hartgers, E., Hawryluk, M., McKeown, D.L., Prena, J., Vass, W.P., and Woo, P. 1997. Grand Banks otter trawling impact experiment: III. Sampling equipment, experimental design and methodology. Can. Tech. Rep. Fish. Aquat. Sci. 2190.

Stewart, P.L., Levy, H.A., and Hargrave, B.T. 2001. Database of benthic macrofaunal biomass and productivity measurements for the eastern Canadian continental shelf, slope and adjacent area. Can. Tech. Rep. Fish. Aquat. Sci. 2336: vi + 31p + A1-6.

Wareham, V.E. 2009. Updated on deep-sea coral distributions in the Newfoundland Labrador and Arctic regions, Northwest Atlantic. *In* The ecology of deep-sea corals of Newfoundland and Labrador waters: biogeography, life history, biogeochemistry, and relation to fishes. *Edited by* K. Gilkinson and E. Edinger. Can. Tech. Rep. Fish. Aquat. Sci. 2830. pp. 4-22.

Wareham, V.E. and Edinger, E.N. 2007. Distributions of deep-sea corals in Newfoundland and Labrador waters. Bull. Mar. Sci. 81(Supp. 1): 289-311.

TABLES AND FIGURES

Table 1. Studies presenting biomass of benthic macrofaunal invertebrates from the Grand Banks.[1]

Location	Sampling Date(s)	Depth (m)[2]	Source
Grand Bank (entire)	1959-1960	To 300 m	Nesis 1970[3]
NW Grand Bank	1980	183	Hutcheson et al. 1981
Hibernia	1980	75-102	Hutcheson et al. 1981
St. Pierre Bank	1980	77	Hutcheson et al. 1981
Central Grand Bank	1980	77	Hutcheson et al. 1981
SE Shoal	1980	51	Hutcheson et al. 1981
NE Grand Bank	1993-1995	120-146	Fisheries and Oceans Canada 2000[4]
NE Grand Bank (Hibernia & approaches)	1994	80	Envirosphere 1995
NE Grand Bank (Terra Nova baseline)	1997	87-99	Jacques Whitford Env. Ltd. 1997
NE Grand Bank (Hibernia baseline)	1999	75-84	Jacques Whitford Env. Ltd. 1999
Grand Bank (Div. 3LNO)	2008-2010	52-157	Fisheries & Oceans Canada, (Unpubl. data- NEREUS)

1. Adapted from Stewart et al. 2001
2. Data from deeper water (e.g. slope depths) are excluded with a focus on the continental shelf.
3. The English translation is dated 1970; the original document in Russian is dated 1965.
4. Raw data provided by K. MacIsaac, DFO Maritimes, and extracted from Stewart et al. 2001 (Table A6). Note: these data are in connection with a fishing impact experiment and for the present study only data from control stations or ‘before trawling’, i.e. non-impacted, are included.

Table 2. Results of 'BEST' test (PRIMER) for among-sample match between abiotic variables and species assemblages. The five log-transformed variables used in the analysis are listed along with the ranking of variable combinations that best correlate with the species associations.

Variables

1 log(Sample Volume (L)+1)
2 log(Water Depth (m)+1)
3 log(% sand+1)
4 log(% pebbles+1)
5 log(%boulder-cobble+1)

Best results

No.Vars	Corr.	Variable Combinations
3	0.216	1,2,4
3	0.213	1-3
4	0.210	1-4
2	0.207	2,3
2	0.191	2,4
2	0.188	1,2
1	0.186	2
3	0.184	2-4
5	0.157	All
4	0.155	1,2,4,5

STATISTICAL TEST FOR BIO-ENV

Global Test

Sample statistic (Rho): 0.216
Significance level of sample statistic: 1%

Table 3. SIMPER analysis for taxa contributing most to average dissimilarity between pure sand (S) (n = 41) and sand + ≥ 45% Pebble (P45)(n = 11) categories in NAFO Div. 3O; mid-depth zone (> 50m-100 m). E = Echinodermata; SIPUN = Sipunculida; M = Mollusca; ANN = Annelida; AR = Arthropoda. (based on standardized (proportional) 4th root transformed biomass values). Taxa unique to one of the sediment types are in bold.

Average dissimilarity =92.95

Species	Phylum	Trophic Group	S Av.Biom	P45 Av.Biom	Av.Diss	Diss/SD	Contrib%	Cum.%
Glycera capitata	ANN	Carn./Subsurface deposit	0.24	0.93	3.4	0.64	3.66	3.66
Ophiura sarsii	E	Carnivore	0.92	0.66	3.19	1.02	3.44	7.09
Echinarachnius parma	E	Carnivore/Surface deposit	0.68	0.26	3.15	0.52	3.39	10.48
Hyas coarctatus	**AR**	**Carnivore**	**0**	**0.77**	**2.83**	**0.57**	**3.05**	**13.53**
Unciola irrorata	AR	Surface deposit	0.19	0.89	2.81	0.89	3.03	16.55
Phascolion strombus	SIPUN	Deposit	0.61	0.36	2.45	0.82	2.63	19.19
Cnemidocarpa mollis	CHORD	Suspension	0.06	0.28	1.63	0.32	1.75	20.94
Prionospio steenstrupi	ANN	Surface deposit	0.18	0.32	1.58	0.66	1.7	22.64
Terebellides stroemi	ANN	Surface deposit	0.12	0.42	1.53	0.51	1.64	24.28
Nothria conchylega	ANN	Omnivore	0.22	0.48	1.53	0.92	1.64	25.93
Antalis entails	**M**	**Suspension**	**0.46**	**0**	**1.52**	**0.5**	**1.64**	**27.57**
Crenella decussate	M	Suspension	0.03	0.46	1.42	0.67	1.53	29.09
Ampharete sp	ANN	Surface deposit	0.06	0.45	1.39	0.64	1.5	30.59
Arctica islandica	**M**	**Suspension**	**0.36**	**0**	**1.35**	**0.34**	**1.45**	**32.04**
Pectinaria granulate	ANN	Subsurface deposit	0.21	0.31	1.26	0.66	1.36	33.4
Liocyma fluctuosa	**M**	**Suspension**	**0.24**	**0**	**1.12**	**0.29**	**1.21**	**34.61**
Unciola leucopis	AR	Surface deposit	0.05	0.24	1.03	0.43	1.11	35.72
Chlamys islandicus	**M**	**Suspension**	**0**	**0.28**	**0.99**	**0.31**	**1.07**	**36.78**
Pholoe minuta	ANN	Carnivore	0.15	0.25	0.95	0.84	1.02	37.81
Dipolydora socialis	ANN	Suspension/Surface deposit	0.05	0.21	0.94	0.46	1.01	38.81
Ophelia limacine	ANN	Subsurface deposit	0.15	0.19	0.93	0.48	1	39.81
Anemone unid juv	**CNID**	**Carnivore**	**0**	**0.29**	**0.91**	**0.5**	**0.98**	**40.79**
Diastylis sculpta	AR	Suspension/Grazer	0.06	0.22	0.88	0.61	0.95	41.74
Ampelisca macrocephala	**AR**	**Susp./Surface deposit**	**0.24**	**0**	**0.85**	**0.46**	**0.92**	**42.66**
Nephtys ciliata	**ANN**	**Carnivore**	**0.27**	**0**	**0.84**	**0.37**	**0.9**	**43.56**
Exogone hebes	ANN	Carnivore/Surface deposit	0.07	0.27	0.83	1.09	0.9	44.46
Tiron acanthurus	**AR**	**Surface deposit**	**0**	**0.25**	**0.81**	**0.41**	**0.87**	**45.33**
Colus cf. stimpsoni	**M**	**Carnivore**	**0**	**0.28**	**0.81**	**0.31**	**0.87**	**46.2**
Ampharete lindstroemi	ANN	Surface deposit	0.12	0.18	0.81	0.5	0.87	47.07

Species	Phylum	Trophic Group	S Av.Biom	P45 Av.Biom	Av.Diss	Diss/SD	Contrib%	Cum.%
Scoloplos armiger	ANN	Subsurface deposit	0.15	0.15	0.79	0.5	0.85	47.92
Tubularia sp	CNID	Suspension	0.01	0.19	0.75	0.33	0.81	49.57
Goniada maculate	**ANN**	**Carnivore**	**0.22**	**0**	**0.72**	**0.52**	**0.78**	**50.35**
Lumbrineris fragilis	ANN	Carnivore	0.11	0.18	0.72	0.47	0.78	51.13
Oligochaete unid	ANN	SubsurfaceDeposit	0.09	0.22	0.72	0.77	0.77	51.91
Mediomastus ambiseta	ANN	SurfaceDeposit	0.05	0.12	0.7	0.34	0.75	52.66
Margarites groenlandicus	M	Omnivore	0.09	0.18	0.68	0.4	0.73	53.39
Ctenodiscus crispatus	**E**	**Carnivore**	**0.21**	**0**	**0.68**	**0.35**	**0.73**	**54.12**
Cyrtodaria siliqua	M	Suspension	0.17	0.06	0.67	0.33	0.72	54.85
Chone duneri	**ANN**	**Susp./Surface deposit**	**0**	**0.27**	**0.67**	**0.44**	**0.72**	**55.57**
Spionidae unid	ANN	SurfaceDeposit	0.1	0.12	0.67	0.47	0.72	56.28
Euclymene zonalis	ANN	SubsurfaceDeposit	0.03	0.23	0.66	0.51	0.71	56.99
Ascidia callosa	CHORD	Suspension	0.04	0.2	0.63	0.5	0.67	57.66
Phoxocephalus holbolli	AR	SurfaceDeposit	0.14	0.05	0.61	0.44	0.66	58.32
Sternapsis scutata	**AR**	**??**	**0.19**	**0**	**0.61**	**0.36**	**0.66**	**58.98**
Astarte borealis	M	Suspension	0.11	0.07	0.61	0.31	0.66	59.64
Paradoneis lyra	ANN	Subsurface/Surface Deposit	0.11	0.13	0.6	0.59	0.65	60.28

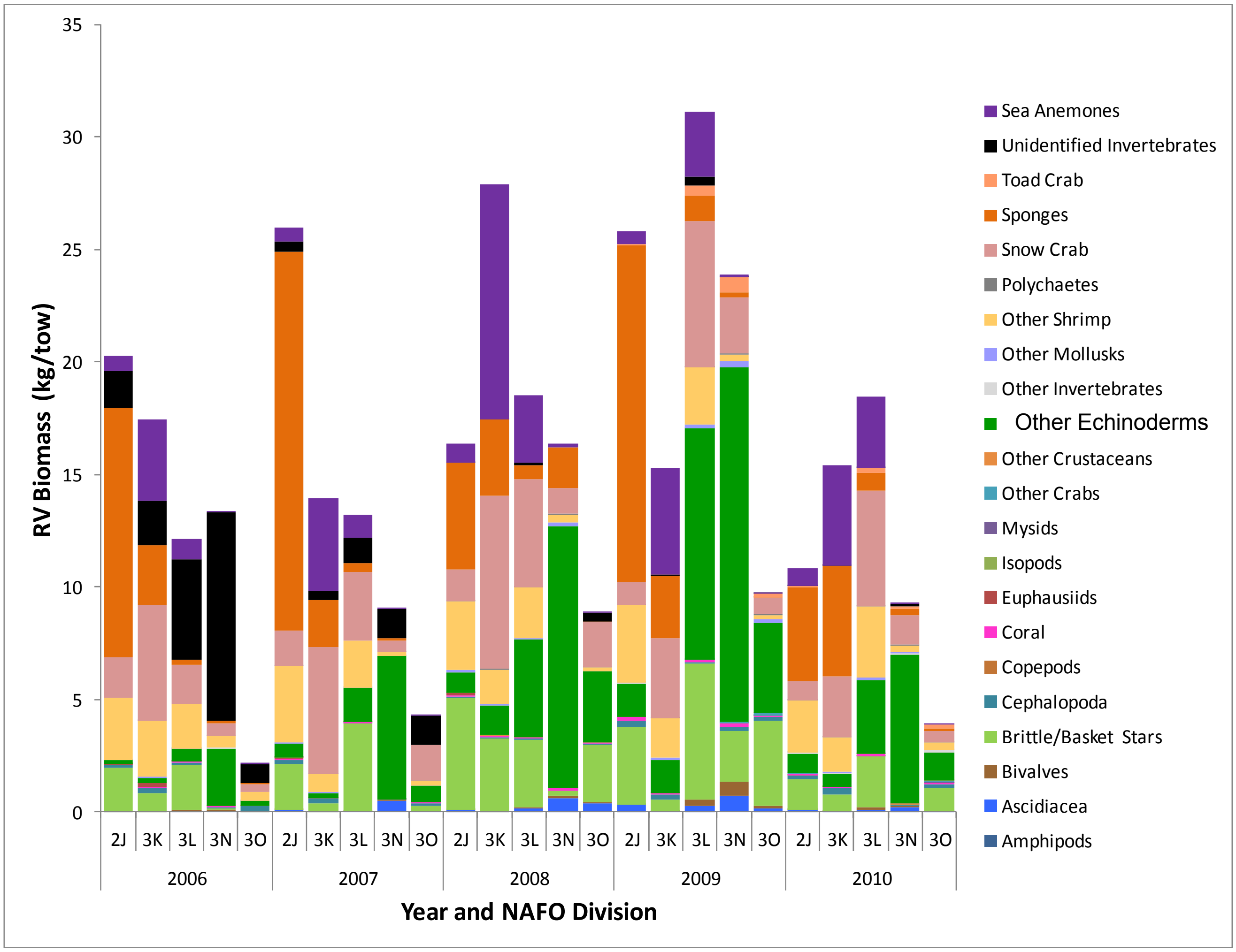


Figure 1. DFO research vessel average trawl-caught benthos biomass by year and NAFO Division. (Figure courtesy of Mariano-Koen Alonso).

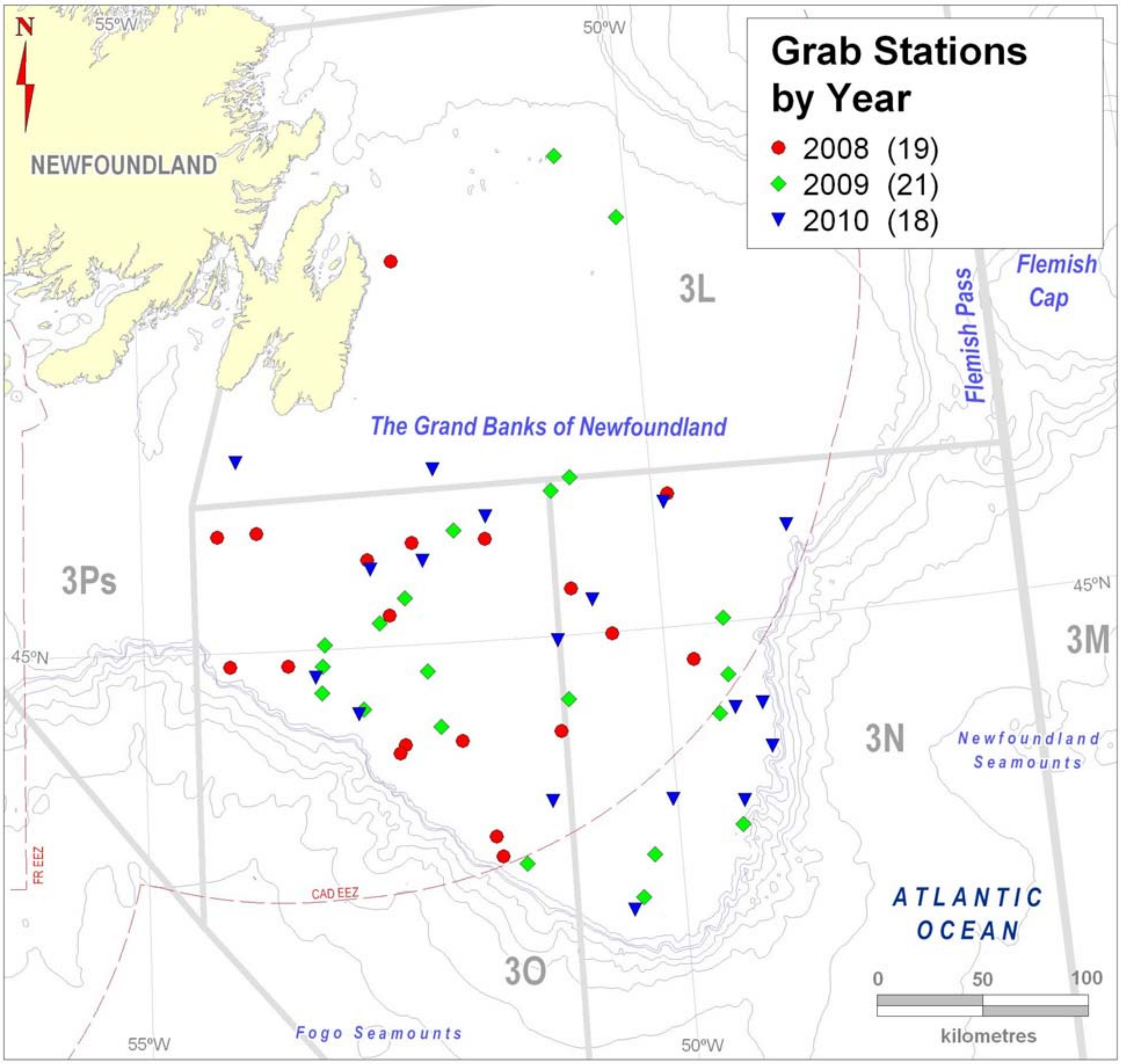


Figure 2. Location of NEREUS grab sample stations (2008-2010) (courtesy of Vonda Wareham).

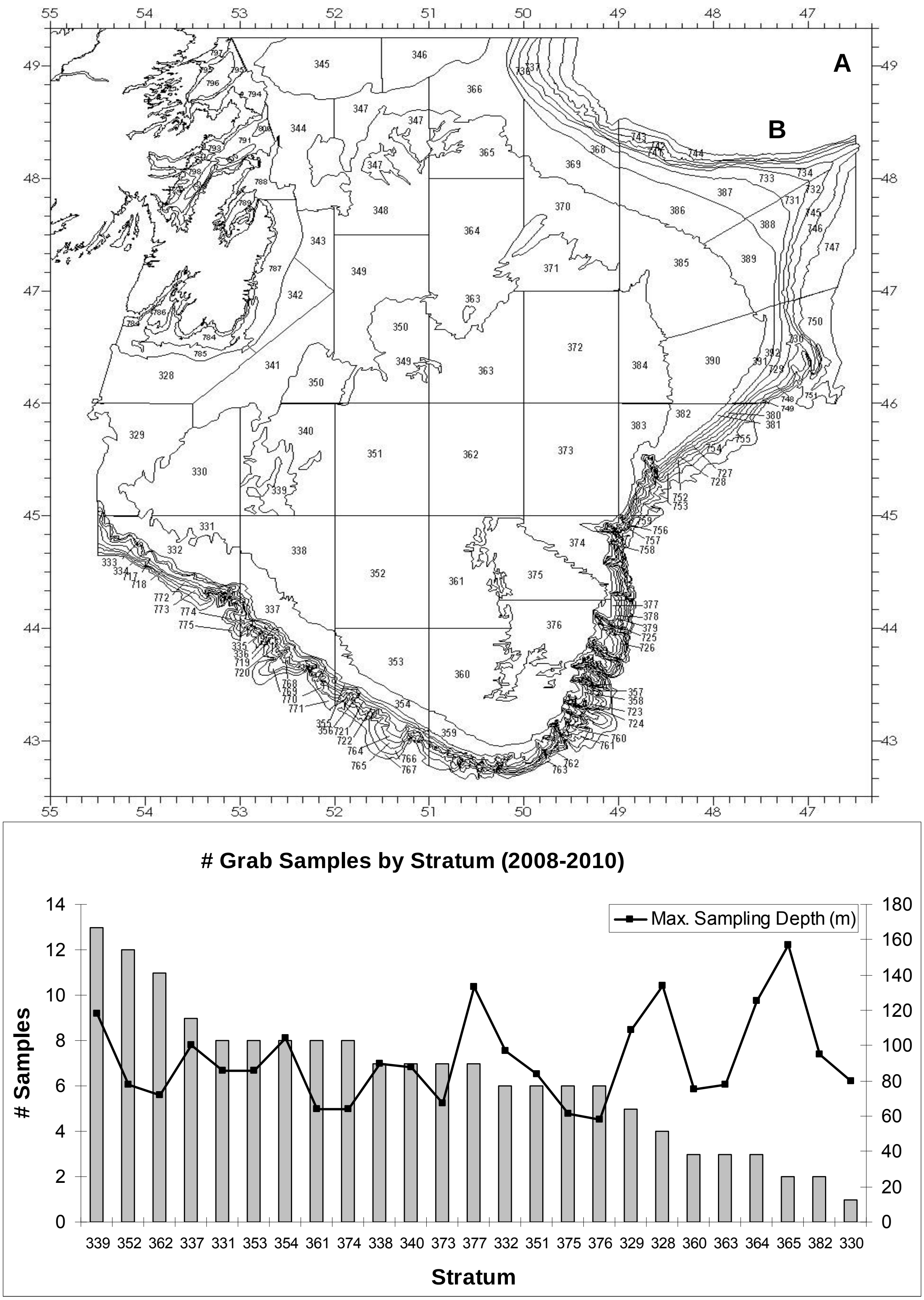


Figure 3. (Upper Panel) DFO Grand Bank strata map. (Bottom Panel) Distribution of grab samples by DFO survey stratum and maximum sampling depth.

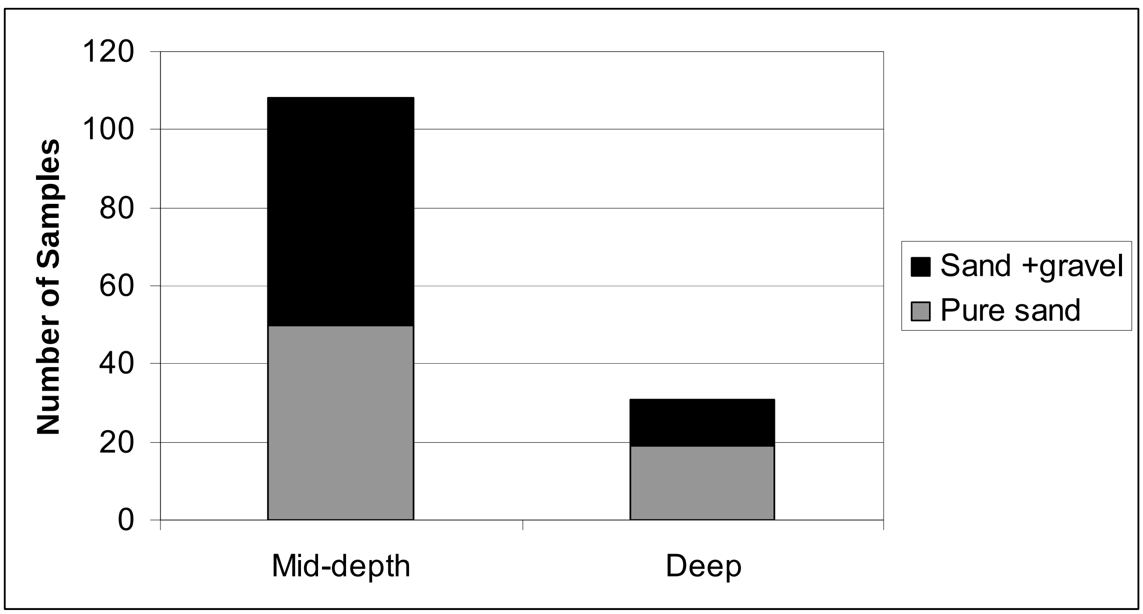
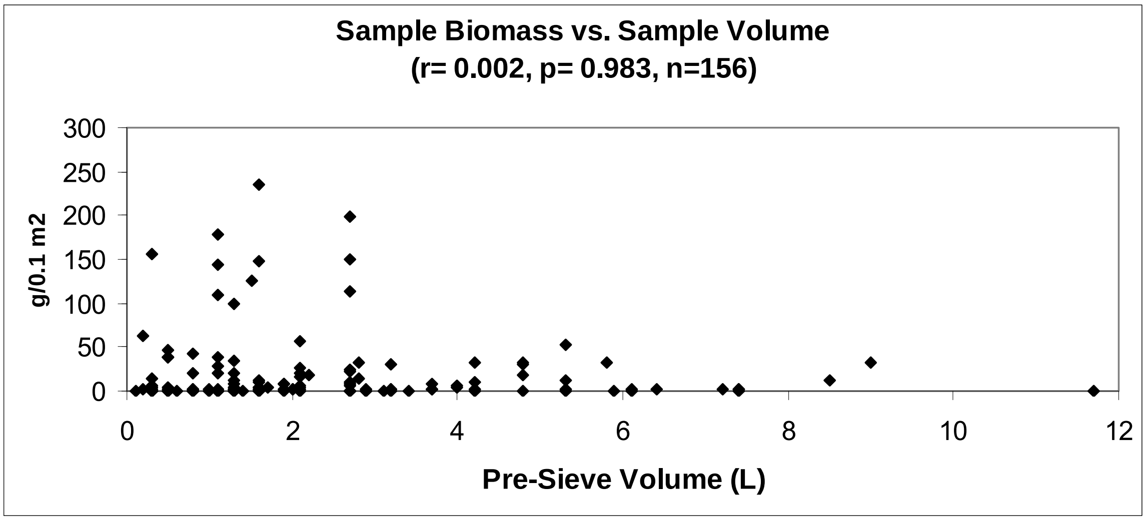


Figure 4. Proportion of all grab samples collected by depth zone and sediment type. Mid-depth (> 50-100 m); deep (> 100m-200 m). Gravel = pebbles and/or cobble.



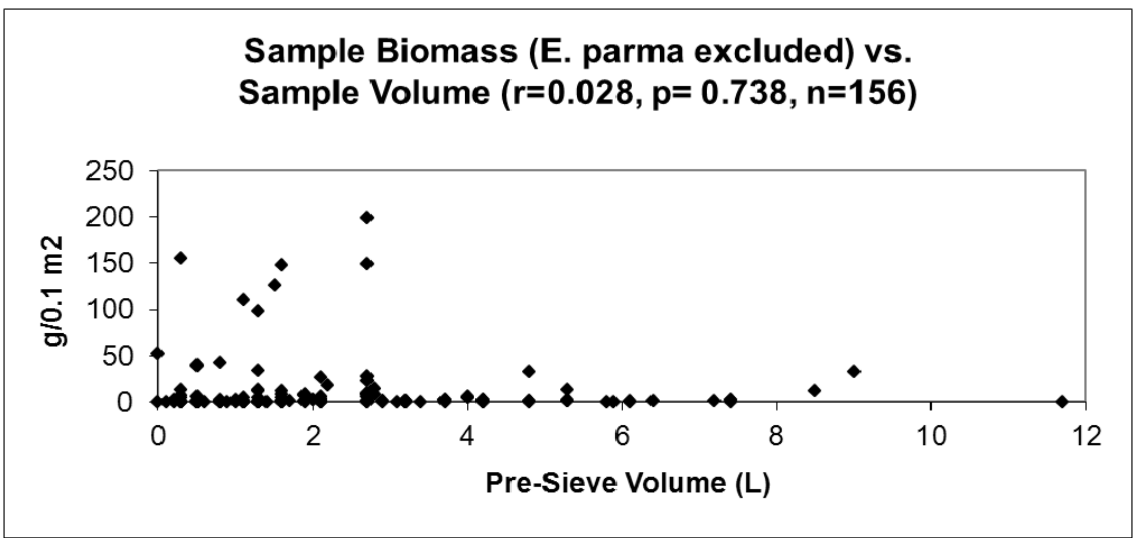


Figure 5. Pre-sieve sample volume vs. total sample biomass (upper panel) and sample volume vs. biomass excluding sand dollars (E. parma*) (lower panel). Note: one outlying sample (560 g, 4 L) excluded from both graphs.*

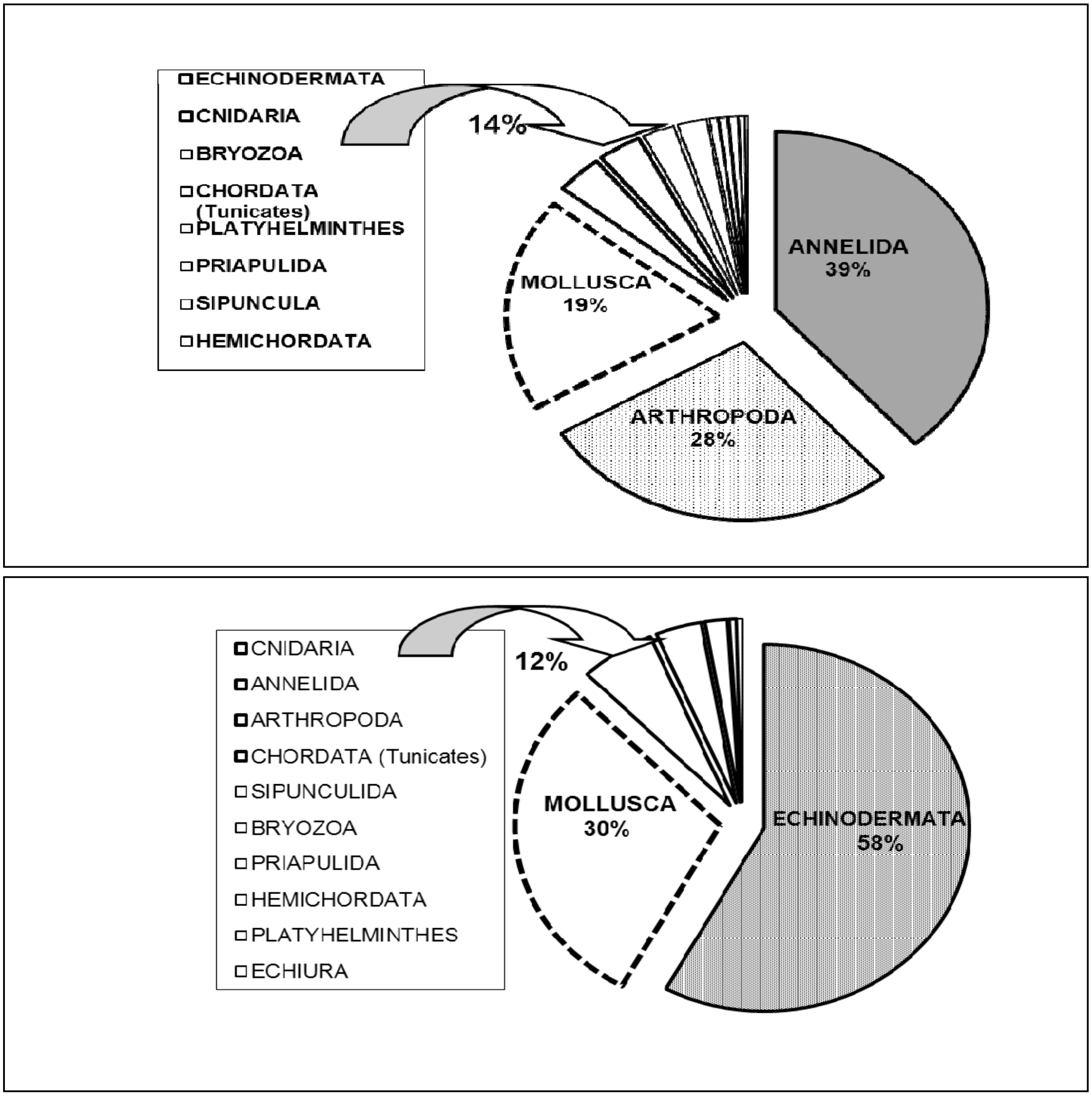


Figure 6. Upper Panel: Proportion of total number of macrofaunal species (455) by phylum collected during the NEREUS grab sampling program (2008-2010). Inset shows total contribution to species number by 8 non-dominant phyla. Lower panel: Proportion of total biomass by phyla. Inset shows total contribution to biomass by 10 non-dominant phyla.

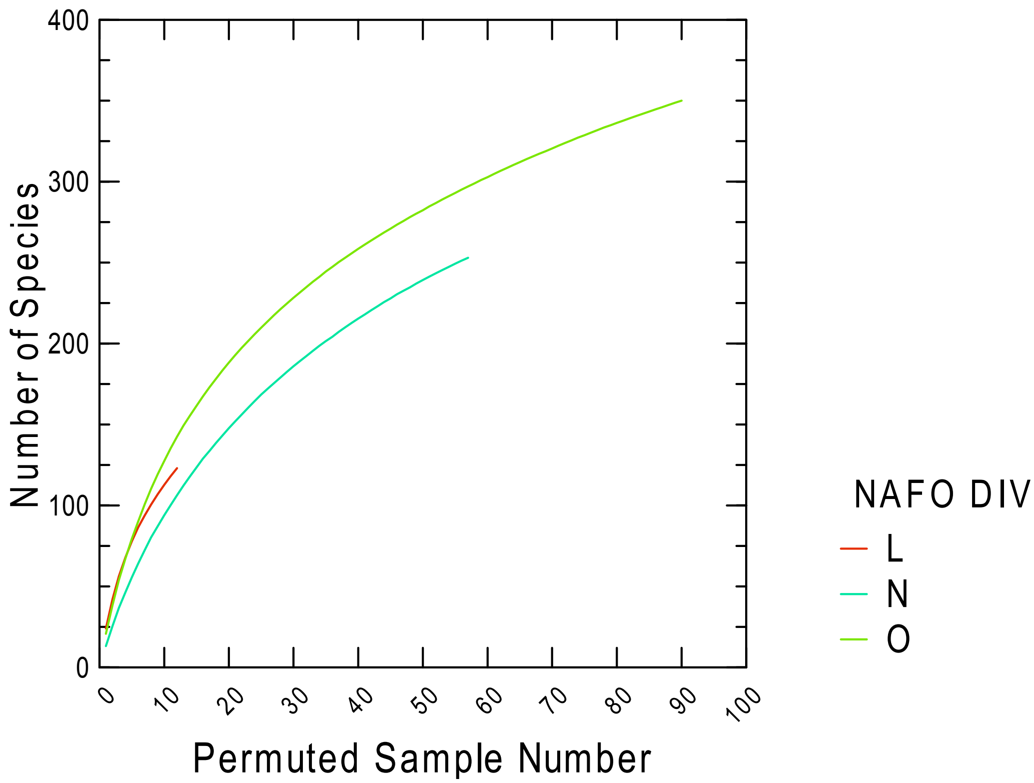


Figure 7. Species accumulation curves for samples collected in NAFO Div. 3LNO

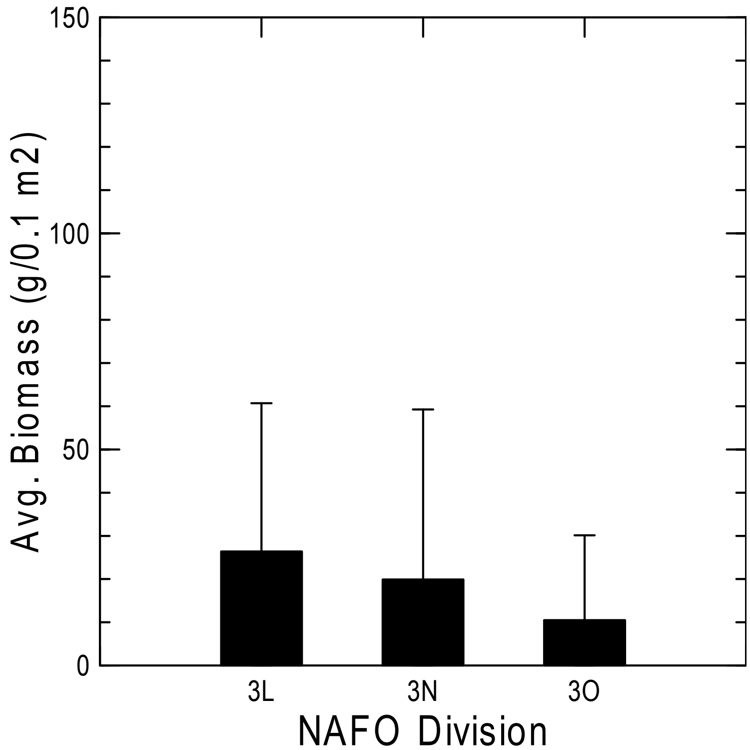


Figure 8. Average biomass of grab samples collected in each NAFO Division (± 1 SD)

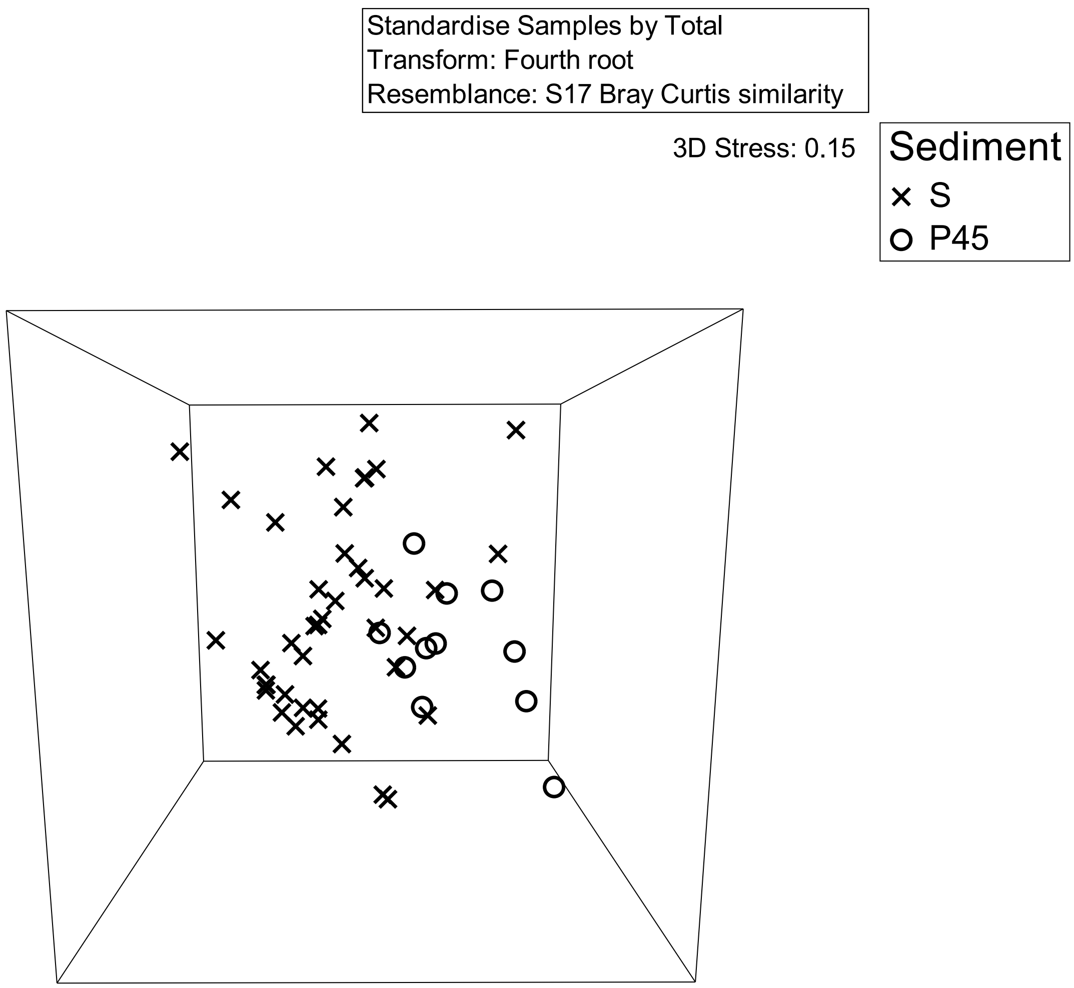
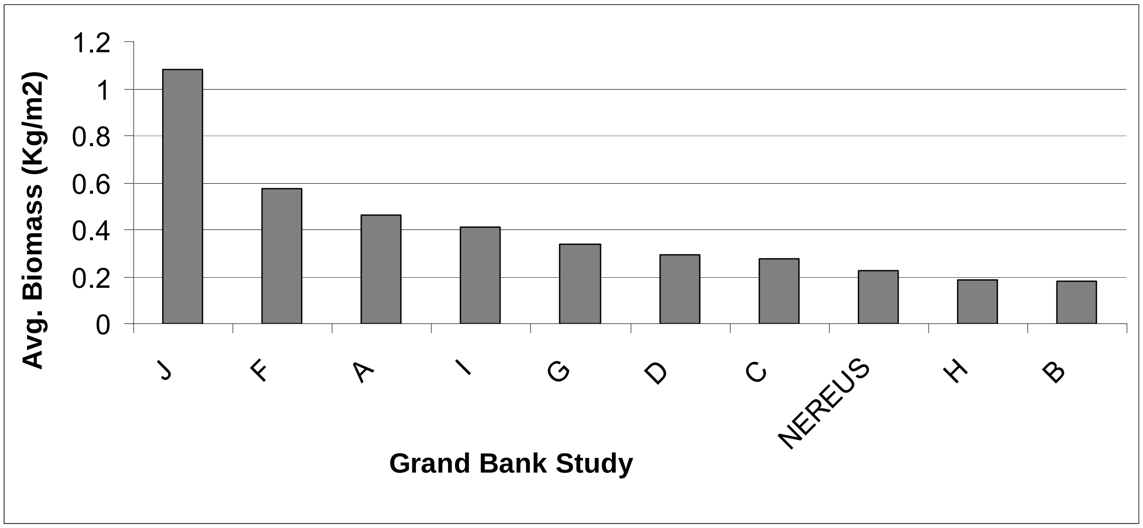


Figure 9. 3-D MDS plot of samples taken from NAFO Div. 3O and the mid-depth zone (> 50-100 m). S = pure sand (n = 41); P45 = sand + ≥ 45% pebble by volume (n = 11).



Source	Location	Depth (m)	Study	Avg Biom $(g/m^2)^1$	SD	n
Nesis 1965	Grand Banks	to 300m	A	461		29
Hutcheson et al. 1981	NW Grand Banks	183	B	181	169	169
	St. Pierre Bank	77	C	277	313	13
	Central Grand Bank	77	D	292	281	11
	SE Shoal (1)	44-51	E	7337	17007	17
	Hibernia	75-102	F	576	509	127
Jacques Whitford Env. Ltd. 1997	NE Gand B. (Terra Nova)	87-99	G	339	259	108
Jacques Whitford Env. Ltd. 1999	NE Grand Banks (Hibernia)	75-84	H	186	209	22
Envirosphere 1995	NE Grand Banks (Hibernia)	80	I	410	470	13
Fisheries and Oceans Canada, 2000.	NE Grand Banks	120-146	J	1083	264	82
Fisheries and Oceans Canada, unpubl. Data	Grand Banks (Div. 3LNO)	52-157	NEREUS	228	585	158

1. wet weight

Figure 10. Average biomass of benthos recorded in surveys carried out on the Grand Bank (1959-2010).
__Note:__ Study E (Hutcheson et al. 1981), which was a survey of SE Shoal, was excluded from the graph. This is a unique location based on the extremely high biomass of Turton's wedge clam Mesodesma deauratum *(Hutcheson and Stewart 1994).*

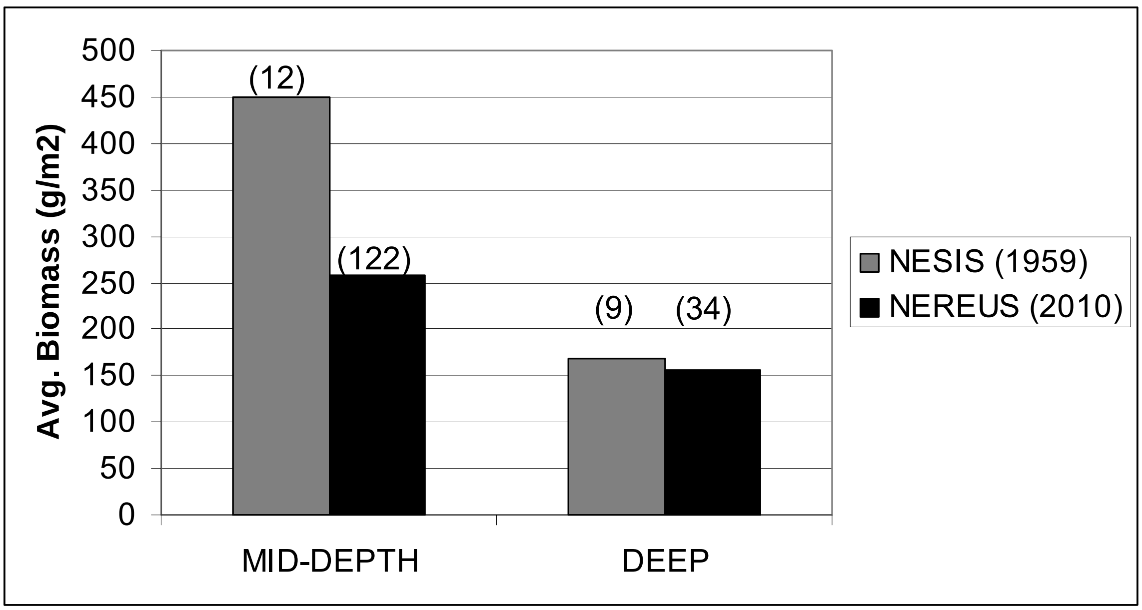


Figure 11. Average benthic biomass recorded by two benthic surveys separated in time by five decades. Geographic area of coverage: Nesis- Grand Bank except NW Slope; NEREUS - NAFO Div. 3LNO. Mid-depth (> 50-100 m); Deep (> 100-200 m). Numbers above bars aresample numbers.

APPENDIX

SHIPBOARD GRAB SAMPLING PROTOCOLS

Shipboard Benthic Grab Sampling Procedures

Stations

1. Benthic strata are listed in a separate Table (to be completed). Benthic sampling should be conducted at the first fishing station in a stratum (or substratum), at depths < 200 m, where sea conditions permit. Sampling will be carried out at one station (if successful) per stratum.
2. Benthic sampling should be conducted **prior** to fishing activity at the station.
3. A Bridge card will be requested for each station and attached to sample log sheet. Station waterproof log sheets will be provided. Log sheet recording to be done with pencil.
4. Multiple grab attempts will be conducted at each station. Data must be recorded for each attempt.
5. 4 grabs (any combination of successful and partially successful), to a maximum of 7 grab attempts will be taken at each station. Head of watch may reduce number of grab attempts in situations where the probability of success is low (e.g. excessive boat movement causing premature tripping of grab)
6. The vessel shall be allowed to drift while grab attempts are made (no station keeping required), but vessel should remain within stratum bottom depth boundaries.
7. Final grab location will be requested from Bridge and recorded on Station log sheets.

Grab Deployment and Retrieval (2 staff, one to record, one to receive grab)

1. Obtain bottom depth reading from bridge and record.
2. Reset metering block to zero at surface.
3. Deploy Van Veen grab at slow to moderate speed, speeding up 10 m from the bottom.
4. When bottom is reached, watch for signs of 'slack' wire indicating grab is on-bottom. Let out an extra 30-40 feet of wire relative to sea conditions.
5. Allow grab to settle into sediment for a few seconds. Manually pull in slack until wire is taut (give 3-4 tugs on wire to ensure grab has tripped).
6. Start to take back dead slow so that grab will close while in the substrate.
7. After first couple meters retrieve grab at a slow to moderate **steady** rate. Communicate to winch operator when grab is **sighted** and when at **surface.**

Grab Sample Assessment and Processing (2 staff trawl deck)

NOTE: On the *Needler*, steps 1 & 2 will be performed on the upper deck where the grab is deployed/retrieved and remaining steps will be performed at the sieve table on the trawl deck.

1. Lower grab into large crab box (black) and dump contents; rinse inside of grab with hose into box. Based on this, and visuals as the grab was retrieved, assess whether the grab was successful, partially successful or unsuccessful and record category on station log sheet.
   - **Successful** grabs have closed jaws and contain sediment. These samples will always be kept (i.e. processed)
   - **Partially successful** grabs occur when the grab is retrieved with the jaws not quite closed due to small rocks or pebbles jammed in the jaws. Partially successful grabs will be processed **if** the combined contents (rocks and/or sand/mud) of the grab is at least 10% of potential grab volume.
   - **Unsuccessful** grabs are retrieved with jaws open (failure to trip), closed but devoid of sediment (water hauls) or with large rock holding jaws open and no sediment in the grab.

2. Transfer sample **(sediment and water)** from crab box to 5 gal. bucket and seal with lid. **Record station # and attempt # and other information on water proof labels and place in bucket on top of sediment.** Carry bucket to trawl deck where sieve is set up for processing.

3. Pour excess water from 5 gal. bucket through sieve. Smooth down surface of sediment in the bucket(s) and record depth of sediment by inserting ruler (provided) to bottom of bucket.

4. Collect one **sample of sediment in 20 ml glass scintillation vial** for analysis of Carbon, Nitrogen and Hydrogen. Only sand or mud should be collected. Affix station information on outside of vial (use pencil on tape and a sharpie to record station # and attempt # on vial cap). **Do not place labels inside the vials.** Freeze vials ASAP.

5. Transfer sediment in bucket onto 1 mm mesh sieve placed on table using the plastic scoops. **IMPORTANT: before washing sediment through sieve estimate the % of total volume in each size category according to the table below. If required, use the ruler provided.**

	% of total sample
Boulder (> 25.6 cm)	
Cobble (6.4-25.6 cm)	
Pebbles (0.4-6.4 cm)	
Sand and Mud (<0.4 cm)	

6. Using hose, wash sediment through sieve until no more sediment appears to be passing through. Using hose, wash remaining sediment and organisms retained on sieve to beveled end and scoop into empty 5 L buckets using plastic shovels. Do not fill individual buckets beyond ¾ full. If necessary use more than one bucket per grab sample.

7. **Ensure station water proof label is transferred from 5 gal. bucket to 5 L bucket.** Record the same information on the outside of the bucket using a sharpie.

8. Fix the sample using the pre-mixed buffered 10% formalin solution provided dispensed from the carboys (located in aluminum racks). Ensure that the level of liquid rises to overlie the surface of the sediment by ~ 2 inches.

9. Thoroughly seal the lid(s) on the bucket(s) using the rubber mallet. Next, invert the bucket several times to ensure mixing of the formalin throughout the sediment.

10. Before processing the next grab sample wash the sieve as thoroughly as possible. To minimize clogging of the sieve periodically scour the sieve with the wire brush.

11. Store & Secure the bucket(s) on deck in the large blue fish tub.

Example - Grab Log Sheet
Station information

Vessel	Trip	Station	Date(ddmmyyy)	Time Started	Time Ended
WT	823	430	15/10/2008	1500	Fill in when last sample taken
Start Lat	Start Long	End Lat	End Long	Associated Fishing Set	
4753.5	5324.8	Complete in when last sample taken		110	

Grab attempts

Attempt Number	Bottom Depth	Time (hhmm – local time)				Success (yes/no/partially)
		In water	On bottom	On deck	Proc. complete	
1	75	1510	1517	1525	1548	Yes
2	78	1530	1537	1544	1544	No
3	67	1549	1556	1605	1620	Partially
4						
5						
6						
7						

Continue grabs until 4 samples are collected or 7 attempts made.

Sample collection

Attempt Number	% Total volume				Depth (cm) in 2.5 gallon bucket	Shell Material	
	Boulder >25 cm	Cobble 6.4-25.6 cm	Pebbles 0.2-6.4 cm	Sand <0.2 cm		Whole shells? (Yes/No)	Fragments (Yes/No)
1	**0**	**10**	**10**	**80**	**5**	**No**	**No**
3	**0**	**20**	**20**	**60**	**3**	**No**	**Yes**

Grab Station Equipment and Supplies List

Grab Deployment and Retrieval (upper deck)

1. deployment/retrieval log sheets in binder (when not recording to be stored in hydrographics lab)
2. copy of grab sampling instructions
3. Van Veen grab (with arms secured in extended position)(spare grab on-board)
4. black crab box (2)
5. 2.5 gal buckets (2)
6. water proof sample labels to be placed in buckets (stored in Rubbermaid container-provided)
7. plastic scoop (2) **IMPORTANT- secure to railing with twine.**
8. garden hose with spray nozzle (connected to seawater)
9. walkie-talkie for bridge communication
10. pencils

Grab Sample Assessment and Processing (trawl deck)

1. sample assessment/processing log sheets in binder
2. copy of grab sampling instructions
3. sieve- set on table (spare sieve stored to side)
4. metal ruler (2) (stored in plastic storage container-provided)
5. scintillation vials (stored in plastic storage container-provided)
6. plastic scoop (2) **IMPORTANT- secure to sieve table with twine.**
7. wire brush (1) to be left on sieve (with spare in plastic storage container-provided)
8. 5 litre plastic buckets + lids
10. rubber mallet (spare in plastic storage container-provided)
11. 20 litre carboys filled with 10% formalin-seawater solution.
12. garden hose with spray nozzle (connected to seawater)
13. pencils and sharpies (stored in plastic storage container-provided)
14. MSDS sheets, gloves, goggles