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Improving benthic monitoring by combining trawl and grab surveys

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ABSTRACT

Environmental monitoring is performed on seafloor communities since these organisms are relatively stationary and integrate the environmental conditions over many years. Standard practices involve sampling by grab. Epifaunal taxa, often missed by grab sampling, are likely to have different ecological functions. We investigate how current environmental assessments represent the benthic community as a whole by comparing taxonomic and functional components sampled by grabs and epibenthic trawls. Faunal communities sampled by trawl (filtrating or predator, epifauna) and grab (infaunal, detrivore) differs widely by sampling distinct functional components, and these may be expected to respond to different human-induced stressors. Neither component appears to be a good surrogate for the community as a whole. We suggest a benthic monitoring by combining both techniques. Sustainable ecosystem functioning is intimately tied to the health of both components of the benthic community, and is recognized as an important goal by signatories of the Convention on Biological Diversity.

1. Introduction

Environmental monitoring is a necessary step towards preserving biodiversity and maintaining ecosystem function in the face of increased pressure from human activities in marine habitats. New technologies and increasing activity in areas such as the Arctic present new challenges for how impacts of fishing, petroleum development, and other seafloor activities can be identified and minimized. They also provide opportunities for rethinking current practices designed to ensure that international agreements, such as the OSPAR (Oslo–Paris Convention) Biological and Ecosystems Strategy (OSPAR, 2003) and the Convention on Biological Diversity (http://www.cbd.int/convention/convention.shtml), are upheld. It is well understood that maintaining healthy marine ecosystems is vital for environmental, economic, and social benefits at both national and international levels.

Many of the expected responses to human activities in the marine environment may best be monitored at the seafloor, in physical and chemical constituents and in benthic communities. Benthic communities in particular have been monitoring targets as constituent organisms are generally stationary, long-lived, and integrate ecological processes over long periods. Further, numerous conceptual models exist by which changes in community structure can be interpreted (e.g., Pearson and Rosenberg, 1978; Borja et al., 2003). In this way, both the short-term and long-term effects on the environment expected from many human activities (Peterson et al., 2003) can be assessed. In many cases, methods have been standardized, at national and international levels, as appropriate, for quality assurance and to maximize comparability.

Sea-floor environmental monitoring, including benthic faunal analyses, has become standard practice for assessing impacts of discharges from the petroleum industry. Although anchoring and pipeline installation can cause local seafloor disturbance, most of the monitoring effort focuses on regulated discharges of particulate matter from drilling activities, associated chemicals, where present, as well as accidental discharges into the marine environment. In Norway, governmental and industry representatives have established an ambitious monitoring program designed to identify impacts, and modified both industry practices and monitoring schemes based on scientific results of this work (Gray et al., 1999, and discussion in Renaud et al. (2008)). The industry has remained responsive and interested in developing more accurate assessment methods as it enters new areas of activity (e.g., Myhrvold et al., 2004).

Any type of sampling methodology has its advantages as well as biases. Biological monitoring of benthic communities for both the Norwegian offshore petroleum industry and Norwegian aquaculture facilities (FKD, 2004; SFT, 2010) is largely restricted to infaunal sampling by grabs and box corers, in accordance with International Organization for Standardization (ISO) guidelines (ISO 16665). Replicated sampling with these techniques is repeatable with good control of sample area (usually 0.05–0.25 m^2). Infauna collected in this manner generally show high biodiversity per unit area (e.g., Renaud et al., 2008). These techniques, however,

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are difficult or impossible to use in coarser sediments where stones prevent adequate closure of the grab. Furthermore, larger and/or more sparsely distributed organisms, including most epifauna, are not well assessed with this method. Trawling (a wide variety of trawl designs exist and have been used) can provide an alternative for describing distributions and abundances of these organisms, although area sampled and efficiency of capture can limit some interpretation. Still, the epifaunal component of the benthos includes organisms of high biomass and potentially of high ecosystem importance as they provide habitat structure, and potentially different functional components of the community. Other techniques, such as video and still photography, have also been used to evaluate epifauna with greater control of area sampled, but poorer ability to identify organisms to lowest taxonomic levels.

Incorporating epifauna sampling into regular monitoring regimes may provide valuable data on ecosystem state and potential impacts but also increase the number of species when added to the grab faunal list. Bottom fisheries mechanically remove individuals from more than 300 different epifaunal species (Anisimova et al., 2010). Generally trawling gear removes large-bodied fauna, damages species with fragile shells and tests, and removes and injures large bivalves (Kaiser et al., 2000). Larger fauna often represent long-lived and slowly reproducing species that are more prone to decline if mortality is increased due to fishing, e.g., *Arctica islandica*. (Callaway et al., 2007; Witbaard and Klein, 1994), but also significant amounts of habitat-forming biota (e.g., corals, sponges, bryozoans, bivalve beds, tube-building organisms) (Auster et al., 1996; Auster and Langton, 1999; Collie et al., 2000; Fosså et al., 2002). These biogenic structures are home to other organisms and increase the structural heterogeneity and regional biodiversity considerably, and are considered critical habitat in many national management plans (US Dept. Commerce, 2007; Det Kongelige Miljøverndepartementet, 2006). Furthermore, it is likely that many epifaunal species feed directly on sinking material or the most recently deposited organic matter on the sediment surface. This suggests that they may be more sensitive indicators of recent chemical contamination, and perhaps respond in difference manners and on different (faster) time scales than infauna. The importance of monitoring diversity and persistence of epifaunal organisms, then, reflects their functions in the ecosystem and, potentially, their values as sentinel species indicating human impacts.

Based on this information, it is important to assess how well infaunal monitoring represents the taxonomic and functional biodiversity of the benthic community as a whole. The goal of this study is *not* to provide a detailed description of the communities at these locations, or what factors may be responsible for community patterns. Instead, we conduct focused sampling at different spatial scales in the Barents and North Seas and investigate community structure, taxonomic distribution, and functional roles of infaunal versus epifaunal species. These studies will help address: (1) How similar are infaunal and epifaunal communities? (2) Are functional roles and sensitivity to human activities similar? and (3) Do current monitoring regimes need to be revised to better insure sustainable use of marine ecosystems and their biodiversity?

2. Materials and methods

2.1. Study area

Benthic fauna were sampled from three locations at two different scales: North Sea and North Cape Bank/Bear Island Channel stations are 10 s of km apart, whereas replicate stations at the Nucula site are all within a 10 × 10 km area (Fig. 1 and Table 1).

The south western part of the Barents Sea is characterized by an inflow of relatively warm Atlantic water, and coastal water from the west. Most of the North Cape Bank is covered by a coarse sediment while fine-grained sediment prevails in the deeper Bear island Channel. The shallow bank areas (<300 m) are mainly inhabited by diverse warm-water fauna brought in by the Atlantic waters (Zenkevitch, 1963), while the deeper channel (400–500 m) receive species from the colder North Atlantic water. Though the Barents Sea is topographically uniform the bottom temperatures vary over short distances as the warmer Atlantic water meets the cold Arctic currents (Loeng, 1991). A sharp gradient from above-zero to subzero temperatures is displayed along the Polar Front, which runs roughly diagonally from south-east to north-west across the area.

The northwestern North Sea is strongly influenced by the inflow of warm Atlantic water from between the Orkney and Shetland Islands. Mean depth is of 90 m. The only exception is the deep (725 m) Norwegian trench which extends parallel to the Norwegian shoreline. The average temperature in summer is 17 °C (63 °F) and 6 °C (43 °F) in the winter. Most of the species belong to the Atlantic fauna. Observed differences between northern and southern North Sea faunal assemblages were best explained by temperature variation (Jennings et al., 1999) and by the influence of different water masses (Frauenheim et al., 1989). As a shelf sea in temperate regions, the North Sea, is characterized by strong seasonal fluctuations of temperature and salinity (Otto et al., 1990). Also primary production and, thus, the food supply for the benthic fauna is determined by annual cycles of temperature, nutrient input, and light availability (Colijn and Cadée, 2003). Overall, temperature is believed to be a main factor to trigger spatial as well as temporal changes in benthic communities (Callaway et al., 2002).

2.2. Field sampling

All benthic data were collected in 2003 and 2004 (North Sea data), and 2006–2007 (Nucula and other Barents Sea data) between August and September for both epifauna and infauna.

In attempting to describe the epifaunal community in terms of its composition and diversity, it is important to take account of the restrictions that the sampling procedure has on the community being represented. The impressions of the epibenthic community gained from the analysis of the sample data is not that of the actual epifaunal community present at each sampled location, but that rather it is a view of the community biased by the differential selectivity of the sampling gear for each species present at each location. No trawl gear ever samples all the individuals present in the path of the net. Trawling is a selective process because the catch rates of different species in any given fishing gear vary considerably, both between species and between size classes of the same species. Many factors can be involved. Although many of the epibenthic species sampled are less motile than the fish species it is likely that a proportion of the more mobile species can move out of the way of the gear. Also, some of the species live partially submerged in the sediment during certain times of the day and these too may not be sampled well by a towed trawling gear. In fact it is likely that catchability of the epibenthic community in the 2-m beam trawl varies as a result of a number of factors including motility, size, and living position on/within the seafloor. Because there have been few large-scale epibenthic surveys to date, there is little information available to account for catchability issues (but see Reiss et al., 2006).

The epifauna were sampled with a 2-m beam trawl (4 mm mesh size in cod-end) (Jennings et al., 1999) with a Scanmar indicating the contact with the sea-bed. The towing time was 5 min with a tow speed of 1.5 knots over ground. All animals retained on a 5 mm sieve were identified to the lowest taxonomic level, counted

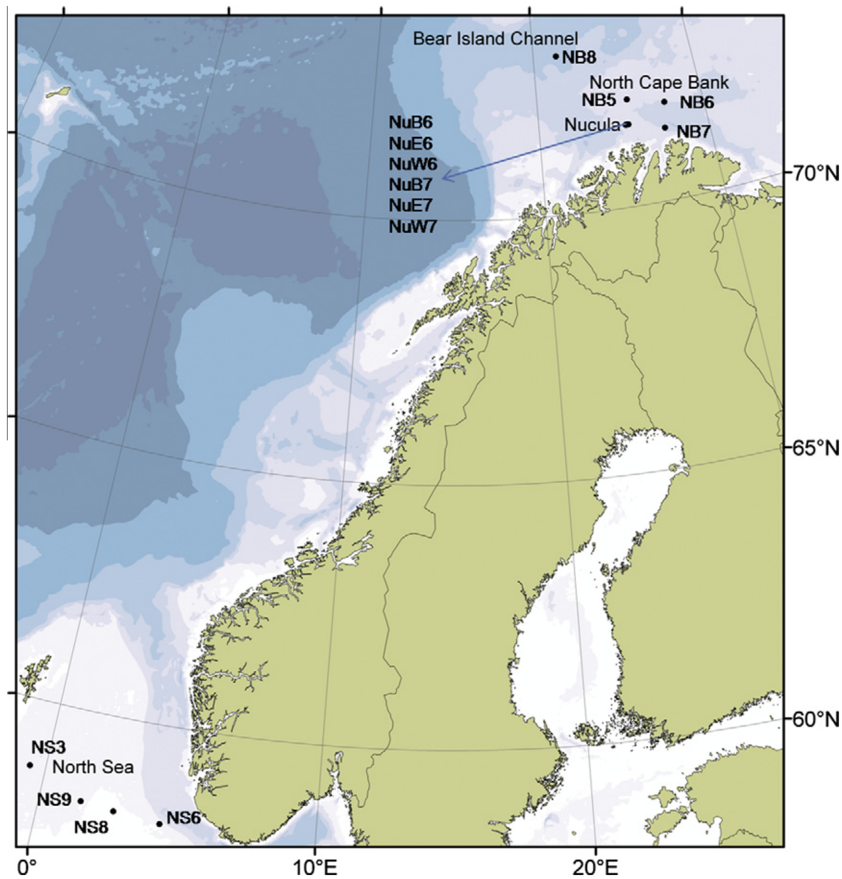

Fig. 1. Grab and beam trawl taken at stations (black dots) in the North Sea and in the Barents Sea (North Cape Bank/Bear Island Channel and the Nucula site).

Table 1
Station information, sediment type, and sampling effort in the areas covered in this study. NC Bank, North Cape Bank; BI Trench, Bear Island Trench.

Station	Lat. (N)	Long. (E)	Depth (m)	Date	Sediment	Grabs (0.1 m^2)	Beamtrawl
North Sea							
3	58°44.48	00°34.16	127	21/9 2004	Mud	5	1
6	58°90.00	04°24.80	140	25/9 2004	Mud	5	1
8	58°13.80	02°42.80	73	26/9 2004	Sandy-mud	5	1
9	58°17.73	01°29.98	111	26/9 2004	Mud	5	1
North Cape Bank							
5	72°01.08	25°29.69	245	16/8 2007	Mud	5	1
6	71°50.48	27°41.26	285	17/8 2007	Mud	5	1
7	71°21.84	27°25.38	345	18/8 2007	Gravel mud	1 (0.25 m^2)	1
Bear Island Channel							
8	73°00.34	21°28.26	440	24/8 2007	Mud	5	1
Nucula							
B6	71°33.06	25°14.10	292	27/8 2006	Sandy-mud	5	1
E6	71°32.91	25°17.37	290	26/8 2006	Sandy-mud	5	1
W6	71°32.69	25°10.33	291	27/8 2006	Sandy-mud	5	1
E7	71°32.87	25°20.10	294	19/8 2007	Sandy-mud	5	1
W7	71°32.74	25°09.84	293	19/8 2007	Sandy-mud	5	1
B7	71°33.06	25°14.10	292	19/8 2007	Sandy-mud	5	1

and weighed (blotted wet weight). The infauna was sampled with five replicate 0.1 m^2 Van Veen grabs. Material collected was washed through 1 mm sieve and identified to the lowest taxonomic level, counted and weighed (blotted wet weight). Infauna from one station in the North Cape/Bear Island Channel (st. 7) was sampled with only one replicate of a 0.25 m^2 grab due to coarse sediment (Table 1). A total of 14 stations (four in the North Sea, six at Nucula, and four in the North Cape/Bear Island Channel) were sampled with beam trawl and grab.

2.3. Data analyses

Numbers and biomass (blotted wet weight) were standardized to densities per 100 m^2 for each gear. For epifauna, the sampled area (swept area) were itself calculated by multiplying the total track fished by the width of the two meter beam trawl (mean speed (m/h) $*$ time (h) on the seabed $*$ beam trawl width (m)).

For infauna the area sampled by an individual grab was 0.1 m^2 (except in one case described above in Section 2.2). Species were coded by their feeding type (predator/scavenger, deposit feeder, filter/suspension feeder), position in the sediment (infauna, epifauna) and mobility (sessile/tupedwelling/motile) according to a variety of references (Enequist, 1949; Fauchald and Jumars, 1979; Barnes, 1987; Pechenik, 2000; Cochrane et al., submitted for publication). All species was grouped into following groups "Polychaeta", "Crustacea", "Mollusca", "Echinodermata", and "others". "Others" includes Cnidaria, Nemertini, Nematoda, Sipunculida, Priapulida, Bryozoa, Phoronida, Brachiopoda, Tunicata, and Vertebrates. An ANOVA test in SYSTAT version 13 was used to test whether there was an effect of equipment (trawl versus grab) on abundance and biomass per area. The fauna similarities between stations, based on lowest possible taxon, were analyzed in PRIMER 6.1.9 by a hierarchical cluster analysis using the Group Average Method on a Bray-Curtis resemblance matrix of the raw data (not shown). The relative distribution of the coded data (functional traits) across animal-groups was analyzed in XLSTAT (version 2007.6) by using a Agglomerative hierarchical clustering with a Pearson Correlation Coefficient and Weighted Pair-Group Average (not shown) and by a Correspondence Analysis (Greenacre, 2010 for this method).

3. Results

3.1. Faunal communities

Overall, the mean density of individuals sampled by grab was close to 400 times higher (mean ~123,300; min. ~17,800; max. ~248,800 ind. 100 m^{-2}) than for trawl (mean ~330; min. 8, max. 2347 ind. 100 m^{-2}). Mean overall biomass was 200 times higher from grab samples (mean ~67,680; min. 641; max. 184,600 g 100 m^{-2}) than from the trawl (mean ~338; min. 12, max. 2976 g 100 m^{-2}).

The number of individuals collected in grabs were 2 and close to 5 times higher in the North Cape Bank/Bear Island Channel (mean 87,700 ind. 100 m^{-2}) and Nucula (mean 201,433 ind. 100 m^{-2}) sites, respectively, compared to the North Sea (mean 41,700 ind. 100 m^{-2}), whereas densities from trawls were 18 and 4 times higher in the North Cape Bank/Bear Island Channel (mean 809 ind. 100 m^{-2}) and Nucula (199 ind. 100 m^{-2}), respectively, than in the North Sea (46 ind. 100 m^{-2}) (Fig. 2). Although the number of stations was too low to give a statistical robustness, the analysis of variance clearly demonstrated that trawl was different from grab ($p < 0.001$).

Grab biomass was 4 times lower in the North Sea (mean 217 g 100 m^{-2}) compared to North Cape Bank/Bear Island Channel (mean 835 g 100 m^{-2}).

Mean species richness in grab samples from Nucula (123 taxa) was higher than in the North Sea (67 taxa) and North Cape Bank/Bear Island Channel (81 taxa). Trawls from Nucula exhibited the highest number of taxa (103), but this is likely due to better taxonomic expertise within the Porifera (55 taxa) than for trawls from the North Sea (5 taxa) and the North Cape Bank/Bear Island Channel (9 taxa). This did not affect the main purpose of this work, which is to study the faunal difference between grab and trawl considering the large animal groups and their broad functional groups where all the Porifera taxa was lumped, and marked as sessile, filtrating epifauna. Values for North Cape Bank/Bear Island Channel (26 taxa) and the NS (30 taxa), therefore, represent minimum values only (Table 2). Due to uncertainty about identifications at the other two sites, statistical comparisons were not performed. Only 12 and 13 taxa were collected by both gears in the North Sea and North Cape Bank/Bear Island Channel, respectively, whereas 78 taxa were common to the two gears at the Nucula-site.

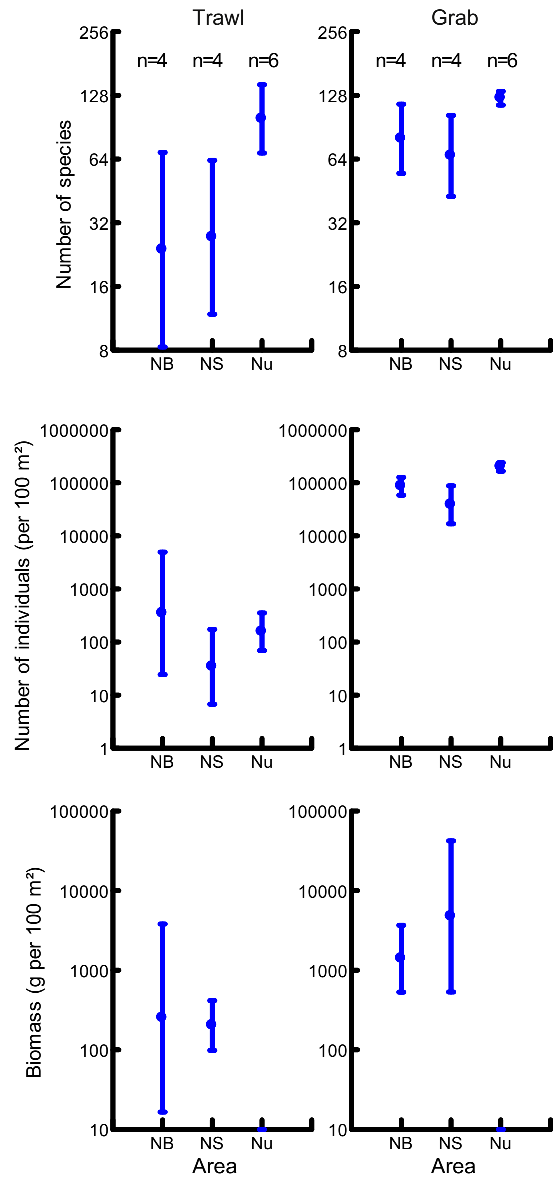

Fig. 2. Abundance and weight per 100 m^2 (log transformed) and species richness of trawl (left) and grab (right) samples presented as mean value and SD in the North Sea (upper), at the Nucula site (middle, no data for weight) and in the NC/BI (lower).

Community structure of grab and trawl catches differed substantially in all three sampling sites. Trawl and grab assemblages exhibited nearly 0% similarity at all three sites; and replicate grab stations were generally more similar than replicate trawl sites. The six grab stations within 10 km of each other were at least 70% similar, but trawl stations also at this scale were only 30–50% similar (not shown).

3.2. Functional and taxonomic groups

Grab and trawl samples from the stations visited in the North Sea, at the Nucula field and at the North Cape Bank/Bear Island Channel were characterized in terms of the animal groups present and their broad functional traits (Figs. 3 and 4). In terms of numerical abundance, the grab samples tended to be most similar (80–90% similarity level) to each other and markedly dissimilar (18–38% similarity level) from the trawl samples. For all three sites, grab stations clustered in areas of the biplots due to the high importance of detrivorous infaunal Polychaeta (upper left corner

Table 2
Mean values (±1 SD) per 100 m^2 for density (d), biomass (grams wet weight, B) and mean and total species richness (S) from the three study areas for grab and beam trawl. No weight data were obtained from the Nucula field. * represents minimum estimates of species richness from trawls at these two sites due to lower taxonomic expertise in analyzing these samples.

	Grab				Beam trawl			
	d	*B* (g ww)	*S*	*S* (total)	*d*	*B* (g ww)	*S* (mean)	*S* (total)
North Sea	44,550(16,196)	11,635(17,269)	67(16)	187	44(31)	217(86)	30*(17)	84*
NC/BI	102,900(19,412)	1750(881)	81(18)	156	809(1055)	835(1428)	26*(13)	67*
Nucula	201,433(34,547)	–	123(9)	233	199(159)	–	103(38)	276

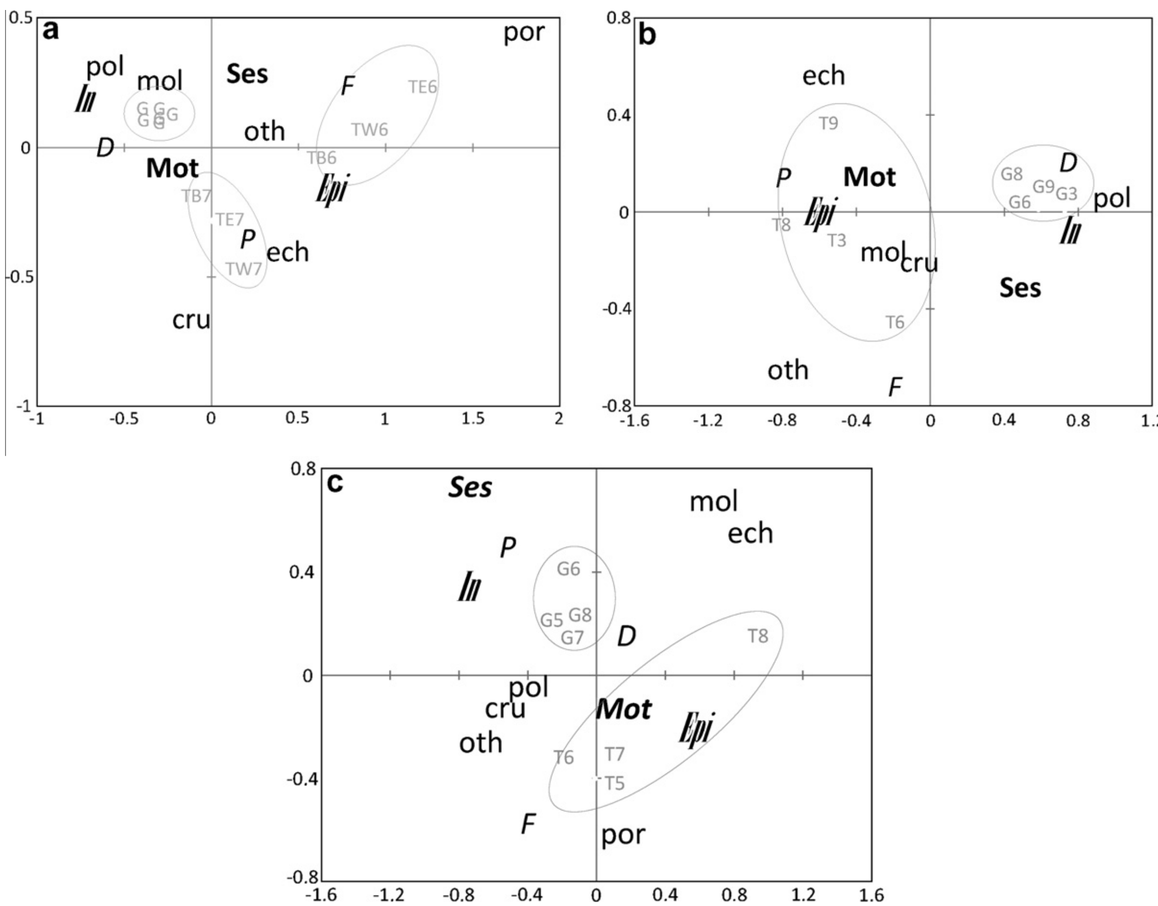

Fig. 3. Biplots from correspondence analyses (CA) of abundance data from the (a) Nucula (b) North Sea, and (c) North Cape/Bear Island Channel areas. Station names (Table 1) are abbreviated to G and T, indicating grab and trawl stations, and the station number (in "b" are the grabs not added station numbers due to lack of space). Circles enclose stations with more than 70% (a) or 50% (b and c) faunal similarity. Plotted with the stations are the functional variables that determine the relative positions of the stations. Por (Porifera), pol (Polychaeta), cru (Crustacea), mol (Mollusca), ech (Echinodermata), oth (other groups), P (predators), D (detrivores), F (filter feeders), "In" (infauna), "Epi" (epifauna), Ses (sessile), Mot (motile).

in Fig. 3a and c, lower left corner in Fig. 3a), with mollusks also contributing to station dispersal at Nucula. Conversely, epifaunal predators (crustaceans and echinoderms in Nucula and the North Sea, Fig. 3a and b) and filtrating Porifera (Nucula and North Cape Bank/Bear Island, Fig. 3a and c) appeared to determine similarities among trawl stations.

In terms of biomass, the grab and trawl samples showed similar functional trait composition, even though the species responsible for the functional traits were not necessarily the same (Fig. 4a). The North Sea samples, pooled by 60% faunal similarity, showed two grabs (G6 and G8) that were characterized by their detrivorous Mollusca fauna (upper left corner of Fig. 4a). One grab "G3" was similar to trawl sample T3, T8, and T9 due to motile echinoderms (*Brissopsis lyrifera*) in the grab. One grab (G9) and one trawl (T6) were dissimilar from the rest of the samples. G9 was characterized by infaunal Polychaeta, and T6 by filtrating, sessile Porifera.

The North Cape Bank and Bear Island Channel separated well by biomass between grabs and trawls at the 50% similarity level (Fig. 4b). The trawl stations were clustered together in Fig. 4b due to epifaunal, fitrating, sessile Porifera, and motile Echinodermata and predatory crustaceans. The pool of grabs (right lower corner of Fig. 4b) plotted together due to common infaunal, detrivorous Polychaeta and Mollusca. A single grab sample (G8 in the Bear Island Channel) was characterized by a group of an "Other" filtrating fauna (Brachiopoda and Bryozoa).

4. Discussion

Grab and trawl estimates of benthic communities in the Barents and North Seas were considerably different in taxonomic and functional characteristics. This study was not intended to estimate total

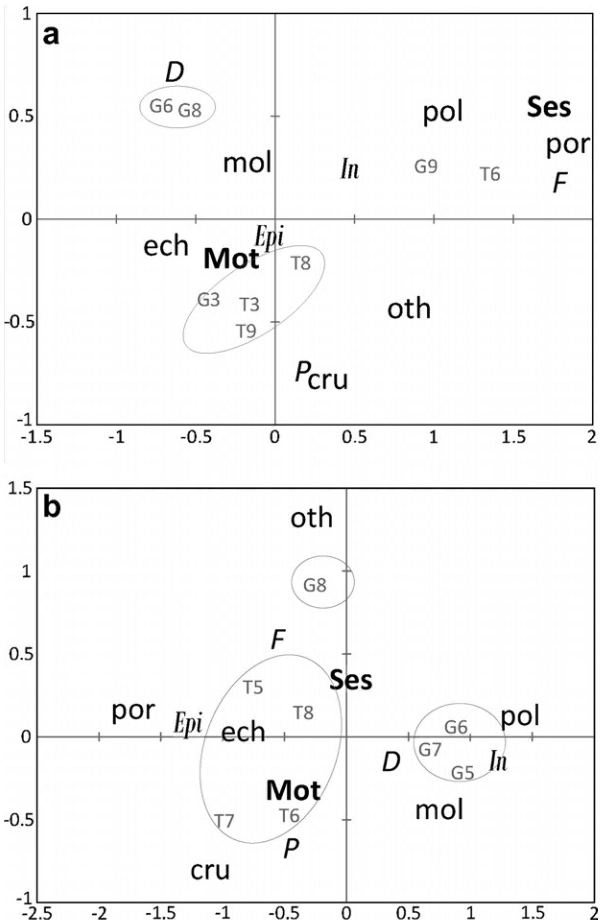

Fig. 4. Biplots from correspondence analyses (CA) of biomass data from the (a) North Sea, and (b) North Cape/Bear Island Channel areas. Circles enclose stations with more than 60% (a) 50% (b) faunal similarity. Notations as in Fig. 3.

species diversity in this region, but the relatively high number of taxa found in our limited sampling in both regions, and at two spatial scales, suggests that the results are robust and can be used for drawing conclusions about gear biases that may exist in terms of estimating impact and sensitivity of communities to human activities.

4.1. Community structure

Both multivariate community composition, trait analysis and the relative taxonomic contribution to total abundance and biomass in the study areas varied considerably between sampling gears (Figs. 3 and 4). Even where the two gears appeared to collect similar communities at broad taxonomic levels it is clear from multivariate community structure and biomass distribution among these broad taxonomic categories, that the taxa responsible for these patterns are different. Few species were common to the two gears across the broader spatial scale (North Sea and Barents Sea). Approximately a third of the taxa from Nucula were collected by both gears within this small region, but despite this, community functions (Figs. 3 and 4 and discussion below) were distinct.

It is certainly no surprise to find that different gears sample different elements of the community. The area sampled, amount of the sediment column sampled, mesh size used to collect each sample, and other biases associated with the gears all interact with the spatial distribution and relative motility of the bottom fauna to contribute to these gear-related differences. The important questions, however, are whether a representative fauna is sampled by each gear, and then how similar in structure and function are the elements sampled by each gear.

In recent studies of the soft-bottom fauna of the Barents Sea, 223 species have been identified from 23 stations (Kendall et al., 1997), 546 taxa from 14 stations (Carroll et al., 2008), and 660 taxa from 47 stations (Cochrane et al., 2009). Our 233 taxa from eight stations in a small part of the southeastern Barents Sea (Nucula), and 187 taxa from four additional, more widely separated, stations (North Cape Bank/Bear Island Channel) represent a relatively large percentage of the species found in these surveys. Additionally, these other surveys sampled within areas of Arctic Water influence in the Barents Sea as well as the Atlantic Water regions where we sampled. There are no published survey data from trawl samples in the Barents Sea. In the North Sea, our 187 taxa from grab samples at four stations is approximately 20% of the 1005 taxa sampled from 235 stations in the 1986 North Sea Biological Survey (Heip and Craeymeersch, 1995). Again, this wider survey sampled across the entire range of habitat variability in the North Sea. Finally, the North Sea Bottom Trawl Survey collected 423 benthic taxa (64% of which were motile) from 241 beam trawl stations (Zühlke et al., 2001). Our four stations sampled a minimum of 84 taxa, 74% of which were motile (Table 2). We feel, then, that our limited sampling collected a substantial percentage of the taxa likely present in our sampling domain. Since the aim of this paper is not to describe the community structure at these locations in detail, and since the data trends are similar at both levels of sampling resolution employed, we feel that the results presented here are qualitatively representative of the benthic community.

There has been considerable discussion in the benthic faunal literature about the issue of surrogacy, i.e., the possibility that patterns in some component of the entire community, or identification at coarser levels of taxonomic resolution (e.g., Warwick, 1988; Olsgard et al., 2003; Włodarska-Kowalczuk and Kędra, 2007), represents the community as a whole. This discussion is based on the desire to balance the effectiveness of using benthic communities as indicators of pollution or other disturbance, and the amount of time, money, and expertise required to identify all taxa to lowest possible levels of resolution. Polychaetes have been shown in some cases to be reasonably effective surrogates (Olsgard et al., 2003; Włodarska-Kowalczuk and Kędra, 2007), but these studies focus on infaunal communities only. It is clear from this study that polychaetes and taxonomic levels as high as Class are insufficient surrogates (e.g., Figs. 3 and 4) to describe the structure of the entire benthic community.

Thus, whereas we likely sampled a large and representative subset of the total biodiversity in the region with the two gears, community structure results indicated little similarity among the community elements sampled. Further investigation is required to determine whether reducing taxonomic resolution, either by analyzing data at taxonomic levels above species (e.g., Olsgard et al., 2003) or by using functional groupings instead of taxonomy (e.g., Bremner et al., 2003), can identify potential surrogates, but the evidence from community analysis suggests that at both spatial scales, grab, and trawl samples collect very different community components and the results of one sampling cannot effectively describe the benthic system, and thus will probably be insufficient to reliably identify possible impacts.

4.2. Functional groups

It is conceivable that, despite sampling different elements of the community, the patterns described by one gear type may be similar to that indicated by the other. The relevance of such a comparison, of course, depends upon the reason for considering the two gears. In this study, we investigate whether more information is needed to effectively assess the potential and actual impacts on community structure *and function* of human activities in the region. Thus, a finding that two gears indicate similar spatial patterns is only relevant if the functional aspects of the two communities (motility, feeding type, etc.) suggest similar sensitivity to expected impacts (e.g., physical disturbance, pollution). In this way, analysis of functional roles of organisms provides the necessary link between individual species and community biodiversity with ecosystem function (e.g., Bolam et al., 2002; Waldbusser and Marinelli, 2006).

In our study, over half the organisms captured by either gear were described as motile. In some cases, especially when biomass was considered, this percentage could be as high as 90% (see Section 3.2). Categorizing an organism as motile or sessile may be quite clear (a sponge or barnacle versus a crab), or more subtle (e.g., near-surface dwellers that build temporary burrows or tubes). The distinction may be more obvious for epifaunal organisms as the scale of motility is often quite large, but for infaunal taxa where there is a well accepted definition of motile versus sessile (the polychaetes *Nephtys* versus *Maldane*), the degree of motility in the motile taxon (*Nephtys*) may extend to only meters or tens of meters in a lifetime. Where effects of human activities are concerned, current definitions may have to be modified to be comparable with the scale of the impact expected. In this case, perhaps few infauna would be described as motile, whereas motile epifauna may be quite relevant for suggesting an organism's ability to avoid or escape a disturbance.

Feeding strategy can offer ecologically relevant information on if and how human activities may affect the ecosystem, from the scale of an organism to the community. Filter/suspension feeders need high quality food arriving from surface waters and/or via bottom currents, which also may make them some of the first organisms impacted by changes in pelagic production, high sedimentation, or from pollution to the water column. Predators and scavengers need a rich community of potential prey in suitable size classes, and may respond positively to enhanced biodiversity, but also to strong disturbances to the seafloor resulting in mortality or exposure of benthic fauna (Kaiser and Spencer, 1996; Ramsay et al., 1998). In one of the few monitoring studies using both trawl and grab sampling, De Juan et al. (2007) found higher abundances of burrowing epifaunal scavengers and motile burrowing infauna in a fished area than in an unfished area, which was characterized by a higher abundance of epifaunal suspension feeders and predatory fish. Deposit feeders may be relatively more resilient to short-term fluctuations in food supply, but may consume and remobilize toxins in the sedimentary system. Furthermore, these feeding traits are often associated with other traits, such as bioturbation potential, that also have ecosystem functions (e.g., Norling et al., 2007).

Functional analysis of benthic assemblages has been shown to delineate communities differently and resolve more detail than traditional taxonomic analysis (Bremner et al., 2003). Even in the broad categories we used in this study, we found very different compositions of feeding traits between the fauna collected with the two gears (Figs. 3 and 4). Detritivores dominated the infauna collected with grabs while predators and filtrators had a much larger share in the trawl material when based on abundances. When based on biomass, filtrator contribution to the communities sampled from North Cape Bank/Bear Island Channel increased considerably, primarily due to the abundance of large sponges. These data indicate that not only do trawls and grabs collect different taxonomic components of the benthic community, but that the gears also sample different functional components, and potentially, faunal elements that could be expected to respond differently to disturbance or pollution. Duineveld et al. (2007) found more large and long-lived species in trawl samples in an unfished area, which had a significant effect on the community recovery, but was unable to demonstrate these community changes from box corer samples. In addition, feeding mode in particular has been shown to be linked with both environmental characteristics of a site and the recent history of bottom fishing activity (Bremner et al., 2006).

Clearly, we used coarse assignments to categories of relative motility and to only one feeding group. This seems to be enough at this stage, however, to show that the gears sample community components with different traits spectra. These traits are known to be important for ecosystem function (and perhaps their value as indicators). More expansive traits studies investigating biotubation potential, life-history strategy, and provision of structural habitat can shed more light on traits that may be best for monitoring effects of different potential stressors.

4.3. Implications for monitoring policy

An effective monitoring program must, at a minimum, match the scale, frequency, and faunal range of sampling with those of expected and potential impacts. In addition, it must be responsive to changes in industry practices and to new scientific information. Industries must work with scientists and policy makers to develop a monitoring regime that fulfills these requirements. The petroleum industry in Norway provides one example of responsiveness to new scientific information derived from monitoring when it switched from oil-based drilling muds to less harmful water-based muds (Gray et al., 1999). In addition to the petroleum industry, mining, dumping, bottom fishing, and dredging for ship traffic or pipeline installation are all industrial activities that can present both chronic and acute impacts that may require monitoring.

Our results indicate that a large taxonomic and functional component of the benthic ecosystem is *not* monitored under current practices in most countries. Both grab and trawl surveys sample elements of the benthos that serve important ecological roles, but elements that are very different from each other. These elements, therefore, may be expected to respond to different types of impacts and/or on different spatial and temporal scales. The presumed tight ecological (e.g., predator–prey) linkages between infauna and epifauna, and between habitat structure and ecosystem function, demand that both elements of the community be monitored for potential effects. Complementary techniques that address this issue are especially important where multiple stressors (e.g., chemical pollution and physical disturbance) may result in different types of impact on the community.

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