

Biogeochemical Cycling and Sediment Ecology

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COMMUNITY COMPOSITION OF TIDAL FLATS ON SPITSBERGEN: CONSEQUENCE OF DISTURBANCE?

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Abstract

Physical characteristics of six tidal flats on the island of Spitsbergen in the Svalbard archipelago and their macro-infaunal abundance and biomass, and meiofaunal biomass were compared. All sites are covered by fast ice for 6-8 months and experience low temperatures that kill all macrofauna by December. Only nematodes were observed to survive winter under the fast ice cover. New colonisation occurs in late May. All sites also experience massive freshwater discharge and sedimentation during summer. Flats are of similar size (1 to 4 km²) and characterised by fine-grained surface sediments, salinity below 5 PSU, and 40 to 120 mg/l of particulates in the water. Despite these physical similarities, the fauna inhabiting these tidal flats are very different. Of the 39-macrofauna species sampled, only one (*Lumbricillus* spp.) was found at more than 3 of the sampled areas. Most of the species were collected from only one or two areas. Macrofaunal biomass ranged from 0.9 to 10g dw/m² while density ranged from 100 to 8000 ind/m². Meiofauna abundance ranged from 100 to 8000 ind/10cm², and biomass from 0.1 to 1.7g dw/m². It is proposed that the suite of taxa occupying intertidal flats on Spitsbergen depends on the pool of colonists in the nearby subtidal.

1. Introduction

Physically stressed marine environments like exposed rocky littoral, sandy beaches, and mudflats often host similar, well-defined animal communities [1] [2]. Intertidal mudflats from a wide geographic range are commonly inhabited by a suite of species of which *Macoma balthica*, *Nereis diversicolor*, *Scoloplos armiger*, *Arenicola marina*, and *Hydrobia* spp. are the most common. Communities with this composition have been recorded from the North Sea [3], White Sea [4], Northern Norway [5], New Foundland [6], Greenland [7] and Iceland [8]. Mudflats are also common in the Arctic. On Spitsbergen, a number of intertidal flats have been studied [9] [10] [11], (Weslawski unpub. data), revealing a rich fauna. Surprisingly, species composition, density and biomass vary tremendously among these flats. The aim of the present study is to examine the differences among these flats and determine if differences can be explained by physical factors.

2. Materials and methods

Data for this paper come from published and unpublished studies of six intertidal flats on Spitsbergen (Figure 1). Data from Adventfjord were collected in July 1996 and 1997 on the tidal flat at the mouth of the Advent River. Macrobenthos were collected during low tide, with a 21-cm diameter core, inserted 10cm into the sediment. Three replicate cores were taken at each of 10 stations, combined, sieved through a 0.5 mm mesh sieve, and the material retained on the sieve preserved in 4% buffered formaldehyde. Meiofauna were collected from the same areas as the macrofauna, with a 2-cm diameter core, inserted 5cm into the sediment. Samples were stained with Rose Bengal

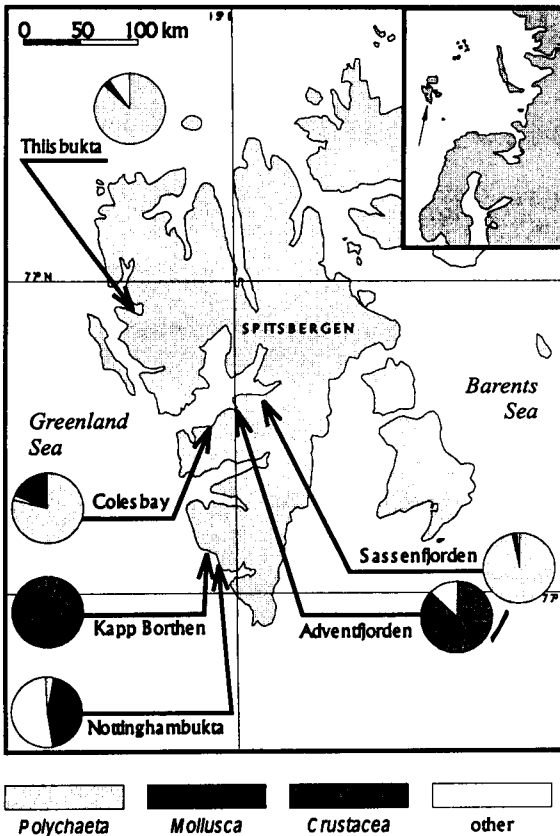


Fig.1 Percent share of major taxonomic groups in macrobenthos biomass in the investigated localities

in 4% formaldehyde, and sieved according to standard procedures [12]. We calculated meiofaunal biomass by converting linear measurements to volume according to Feller and Warwick [13]. Macrofaunal dry-weight was determined by drying animals at 60°C for 24 hours. For each macrofaunal species, the mean specimen size and weight were established and used for biomass calculations based on established relationships [14].

Data from Nottingham Bay and Kapp Borthen were collected by us and have been partly published [12] [15]. Other data were taken from the literature (Nottingham Bay, [9] [11], Sassenfjord, Colesbay, and Thiis Bay, [10]). All studies used a 0.5mm mesh sieve for collection of macrofauna. The first author visited each of the tidal flats considered in this study during the summers 1996 and 1997.

3. Results and discussion

3.1 Physical settings

Despite being located in different regions of Spitsbergen, the 6 flats have similar physical characteristics (Table 1). The flats are typified by riverine discharge resulting in a salinity as low as 5 PSU at low tide, very fine surface sediment, large suspension

loads and consequently large sedimentation rates. Probably the most important physical stress for the infaunal community is the 6-8 months coverage by fast ice. When the ice melts in spring, it removes the upper part (10-cm) of sediment.

4. Faunal characteristics

Thirty-nine species of macrofauna and 6 taxa of meiofauna were collected from Spitsbergen tidal flats during summer (Table 2). No taxon was found in all localities, and only one (*Lubbricillus* spp.) was found at more than 3 locations. Density of macrofauna ranged from 40 to 6000 ind/m², and biomass from 0.9 to 10 g dw/m² (Table 3). The contribution of meiofauna to total benthic infaunal biomass ranged from 10 to 50% (Table 3). Size frequency distribution of benthic species, shows almost equal contribution to biomass from meio and macrofauna (Fig. 2). Such size distributions have been recorded from temperate tidal flats [16] and from Svalbard in the deep sublittoral [17].

Table 1. Physical conditions of 6 intertidal soft-sediment habitats on Spitsbergen Island. The authors collected data for all sites. Fast ice covers all sites from December until June.

	Nottingham Bay	Adventfjord	Sassenfjord	Colesbay	Kapp Borthen	This Bay
Area exposed during low tide (km ²)	2	3	0.5	0.25	2	0.2
Length of supporting river (km)	3	21	15	4	2	1
Initial sediment load in supporting river (mg/dm ³)	200-400	150-500				
Suspended matter during high tide (mg/dm ³)	30 to 100	40 to 130				
Summer maximal temperature at low water	14	8	6		8	
Sedimentation (g/m ² /day)		130-260				26
Percent of silt-clay in surf. sediments	55 to 60	40 to 60	24	46	40	15 to 32
Daily salinity range (HW to LW)	0.5 to 30	2 to 28	5 to 30	15 to 30	10 to 30	
Organic matter content (%)	3	2 to 5				

Table 2. Mean macrofaunal density (individuals/ m²) from 6 intertidal soft-sediment areas and meiofaunal density (individuals/ 10 cm²) from 3 intertidal soft-sediment areas on Spitsbergen. Feeding types: D= deposit feeder, C=carnivore, S=suspension feeder.

Macrofaunal Taxa	Feeding Type	Mean Indiv. Dw (g)	Nottingham Bay ¹	Adventfjord ²	Sassenfjord ¹	Colesbay ¹	Kapp Borthen ⁴	This Bay ¹
<i>Ampharete acutifrons</i>	D	1	0.1					
<i>Ampharete finmarchica</i>	D	1	0.1					
<i>Anonyx sarsi</i>	C	20	0.1					
<i>Aninoella sarsi</i>	C	30	1.5					
<i>Astyris rosacea</i>	D	30	0.1					
<i>Brada granulata</i>	D	20	7					
<i>Callinotus laeviusculus</i>	C	10	0.1					
<i>Capitella sp.</i>	D	1			1130	212		4028
<i>Chaetozoa setosa</i>	D	2						71
<i>Chironomidae n det.</i>	D	1		8				
<i>Chone duneri</i>	S	2	20					
<i>Cylichna alba</i>	C	20	2					
<i>Cylichna scalpta</i>	C	20	0.1					
<i>Dendrodoa grossularia</i>	S	25	41					
<i>Eteone longa</i>	C	2	0.1		565			
<i>Eteone spetsbergenis</i>	C	2	0.1					
<i>Euchone rubrocincta</i>	S	2						71
<i>Fabricia zabella</i>	S	2	0.1					
<i>Gammarillus komari</i>	C	5	0.1					71
<i>Gammarus oceanicus</i>	C	5	0.2				1500	
<i>Gammarus setosus</i>	C	5	0.1	6	71			
<i>Halicryptus spinulosus</i>	D	20	32					
<i>Ischyrocera anguipes</i>	C	5	0.1					
<i>Liocyma flucnosa</i>	S	5	190			70	50	
<i>Lumbricillus spp.</i>	D	1		200	141	35		990
<i>Lumbrineris fragilis</i>	C	5						
<i>Myu truncata</i>	S	50	2					
<i>Nemertea n det.</i>	C	10	0.1					
<i>Onizimus littoralis</i>	C	2	4	600			2750	
<i>Orchomene mimus</i>	C	5	0.1					
<i>Phascolosoma spp.</i>	D	10	0.1					
<i>Polydora caulleryi</i>	D	2						71
<i>Polydora quadrilobata</i>	D	2						353
<i>Prionospio caudatus</i>	D	15	23					
<i>Pygospio elegans</i>	D	1	0.1					
<i>Scalpellum armiger</i>	D	2			1356	600		1060
<i>Spio filicornis</i>	D	1						2120
<i>Spionidae n det.</i>	D	1			5159		50	
<i>Travésia forbesi</i>	D	1	2					
Meiofaunal Taxa								
Nematoda			6459	1640	-	-	466	-
Harpacticoida			112	30	-	-	-	-
Copepoda nauplii			6869	267	-	-	3	-
Turbellaria					-	-	-	-
Oligochaeta			3	0.3	-	-	-	-
Tardigrada				0.9	-	-	-	-
Ostracoda			304	0.4	-	-	-	-

1 [9] [10] 2 [27] 3 [10] 4 [15]

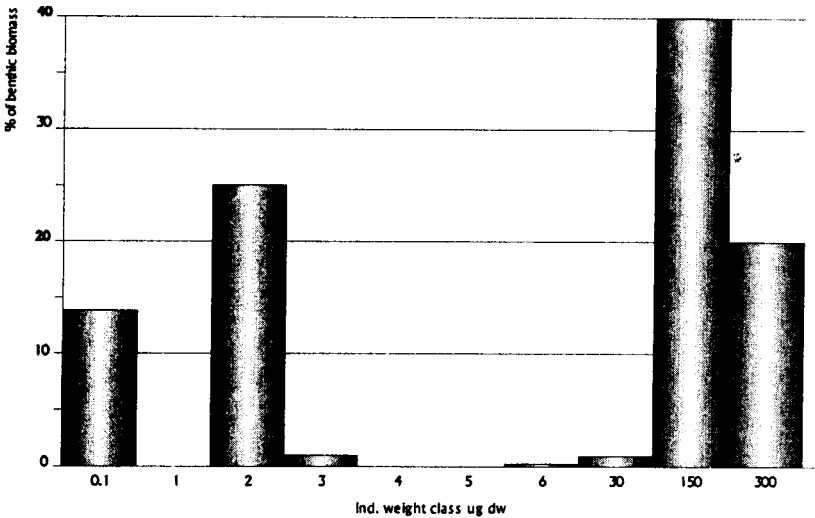


Fig.2 Percent share of organisms in different size (weight) classes in zoobenthos biomass, Adventfjorden tidal flat, July 1996

4.1 IS THERE A TYPICAL ARCTIC MUDFLAT COMMUNITY?

Infaunal abundances and species composition vary tremendously among the intertidal areas examined. Even at taxonomic levels higher than species, very different groups dominate localities: Polychaetes (Sassenfjord, Colesbay), Crustacea (Adventfjord), Priapulida (Nottingham Bay) (Figure 1). Intertidal soft-sediments exhibit very little similarity in faunal composition among locations compared with other marine habitats (*Laminaria* beds, subtidal soft-sediments, and rocky intertidal) on Svalbard that can exhibit a 60-70% similarity in taxonomic composition among sites (Weslawski unpub. data). A Low level of similarity is observed among glacier bays on Spitsbergen, where less than half of the species occurred in all localities [18].

Macrofauna and most of the meiofauna appear to die or leave intertidal areas during the period of fast ice. No animals were recovered from several macrofaunal samples taken from under fast ice cover in winter revealed no animals. Only nematodes, at one tenth of summer density, have been found under fast ice (Weslawski unpub. data). Wisniewska (pers. comm.) found Harpacticoids under the fast ice in Nottingham Bay. Other taxa appear after fast ice melt. Meiofauna recover quickly following disturbance [19] and meiofaunal taxonomic composition and density are similar among Spitsbergen mudflats [12].

Effects of ice on intertidal communities have received little attention. Intertidal mud flats in the Bay of Fundy (Canada) are consistently covered by ice in winter [20]. The top few centimetres of sediment may be frozen in ice [21] and blocks of ice moved by tidal currents leave tracks visible from the air [20]. Some taxa, particularly in the upper intertidal, experience winter mortality, presumably due to the combined effects of ice and low temperature [22]. Many taxa, however, are not influenced by winter conditions [21]. Where severe, ice scour can remove late successional species and allow the colonisation of opportunists [23] [24]. The intertidal of Svalbard certainly experiences sufficiently severe conditions that the seasonal removal of macrofauna can be expected.

Table 3. General characteristics of macro and meiobenthos from 6 intertidal soft-sediment habitats on Spitsbergen. Data were collected during the summer and from literature cited in Table 2.

	Nottingham Bay	Adventfjord	Sassenfjord	Colesbay	Kapp Borthen	This Bay
Average biomass of macrofauna (g dw/m ²)	3.3	1.4	10.6	1.8	≈13.3	10.7
Average biomass of meiofauna (g dw/m ²)	1.7	0.7			1.2	
Average macrofauna density (indiv./m ²)	325	814	8422	952	4350	8834
Average meiofaunal density (indiv./10cm ²)	6000	2500			800	
Taxon dominating macrofaunal biomass	Priapulida	Crustacea	Polychaeta	Polychaeta	Crustacea	Polychaeta
Neighbouring marine benthic assemblage	Phytal zone	Deep sublittoral	Shallow soft sublittoral	Shallow soft sublittoral	Shallow hard bottom	Shallow soft sublittoral

All species listed in Table 1 have been recorded in the sublittoral. No exclusively intertidal species occur on Spitsbergen mudflats. This contrasts with Spitsbergen's rocky intertidal which is inhabited by *Littorina saxatilis*, *Semibalanus balanoides*, and *Gammarus setosus* that have only been recorded from the intertidal [15] [25].

The differences in macrofaunal abundance and composition among flats are likely caused by different patterns in yearly recolonisation. Most benthic species from latitudes as high as Svalbard might be expected to have direct development or lecithotrophic larvae [26]. There has been no study of the reproductive behaviour of Svalbard polychaetes and bivalves. Most of the larvae of benthic animals are present in coastal plankton from April to early June before the flats are ice-free [27]. While some larval colonisation of intertidal areas certainly occurs, many of the colonists may be juveniles transported from the sublittoral. If this is true, then the nearby sublittoral is likely an important source area for intertidal recolonization.

The sublittoral adjacent to each mudflat is different among areas (Table 3). Nottingham Bay, with the richest faunal list, is adjacent to extensive, shallows composed of a mixture of hard- and soft-bottom, overgrown with dense *Laminaria* meadows [9].

The mudflat at Adventfjord is very poor in macrofaunal species diversity. It is flanked by a steep muddy slope, dropping from 0 to 40m in less than 500m distance. The shallow sublittoral zone (2-20m) adjacent to the Adventfjord intertidal is very narrow and lacks any macrophytes [15]. Tidal flats examined by Ambrose and Leinaas [10] (Colesbay, This Bay, Sassenfjord) are probably recolonized from the nearby shallow sublittoral which supports a high diversity of polychaetes [28]. Consequently, the recolonisation of the flats examined, that takes place each year following ice melt, relies on source areas with very different community composition and very different macrofaunal assemblages develop on the adjacent tidal flats. A similar explanation has been offered to explain the composition of intertidal rock pools. Astles [29] found considerable faunistic differences among examined ponds and related each pool's faunal composition to the history of each locality. The importance of history in determining patterns of species distribution and abundance on sublittoral hard [30] and intertidal soft [31] substrates has long

been recognised.

Other factors might contribute to the structure of intertidal communities on Spitsbergen. Shore birds are conspicuous predators on some Spitsbergen mudflats [32] and they can influence the distribution and abundance of intertidal fauna [33] [34] [35] [36]. Despite similarities in grain size among flats, flats may differ in sediment organic content and the abundance of benthic diatoms. The quantity and quality of food has been demonstrated to influence the structure of arctic subtidal soft-sediment communities [37] [38]. The impact of these and other factors in explaining patterns of distribution and abundance of infauna on arctic intertidal flats need to be examined.

In summary, tidal flats on Spitsbergen support seasonal communities inhabited by opportunistic species. Annual colonisation of the flats may be largely dependent on recruits from the adjacent sublittoral community that differ among locations in their physical and biological characteristics. Consequently, tidal flats on Spitsbergen support very different macrofaunal communities. Seasonally ephemeral communities are probably typical of arctic intertidal soft-sediments. Macrofaunal species community structure on these flats, like on Spitsbergen, are dependent on sublittoral communities for recruits. To the extent that arctic sublittoral source communities vary in composition, intertidal flats will harbour different suites of species.

5. Acknowledgements

We wish to express our thanks to Drs. Alexander Keck and Ole Jorgen Lønne for their help with the University Studies on Svalbard (UNIS) and IOPAS Co-operative Project "Arctic Tidal Flats" and to Dr. William G. Ambrose, Jr. and two referees for their comments on earlier drafts of this manuscript.

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