

A temporal comparison of a benthic infaunal community southwest of St. Lawrence Island, Bering Sea between 2006 and 1970–1974

Tracie Erin Merrill · Brenda Konar ·
Bodil Bluhm

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Abstract Benthic infaunal biomass and abundance may be changing in Bering Sea communities. This study compared benthic infaunal biomass, abundance, and community composition southwest of St. Lawrence Island in an important forage area for benthic-feeding birds and mammals between 1970–1974 and 2006. Invertebrate biomass and abundance were significantly greater in 2006 than in 1970–1974 primarily due to high nuculid (*Bivalvia*) biomass and abundance that contributed 13.2% (biomass) and 8.5% (abundance) to differences in community structure between the sampling periods. This is in contrast to St. Lawrence Island Polynya studies conducted in the 1980s and 1990s that documented decreases in benthic biomass and abundance. Spatial scale of sampling, selective predation, a strong recruitment event, and/or sampling design may account for the difference in trends among the studies.

Keywords St. Lawrence Island Polynya · Bering Sea · Benthic · Biomass · Abundance · Infauna · Change · Nuculidae

Introduction

Polynyas are recurring ice-free areas in arctic seas (Smith et al. 1990). The St. Lawrence Island Polynya (SLIP) forms each winter south of St. Lawrence Island (SLI) in the northern Bering Sea (Pease 1987). The annual formation of the SLIP maintains an area of cold water, a “cold pool,” (Coachman et al. 1975), associated with high productivity and nutrients (Grebmeier and Cooper 1995). Over the last 20+ years, extent and thickness of both annual and multi-year sea ice in the Arctic have declined as a result of climate change (Serreze et al. 2007). Lower winter ice cover and higher air temperatures have caused a contraction of the summertime extent of the SLIP cold pool (Wyllie-Echeverria and Wooster 1998). Uncertainty exists as to the effect this, along with other climate-related processes, will have on food availability for the abundant benthic avian and mammal predators in this part of the Bering Sea (Grebmeier et al. 2006).

Since the 1990s, there have been reported declines and/or northerly shifts in foraging grounds of bottom-feeding birds and mammals in the Bering Sea such as spectacled eiders and gray whales (Stehn et al. 1993; Lovvorn et al. 2003; Moore et al. 2003, 2006). Within the SLIP and north of SLI, benthic infaunal invertebrate biomass has declined and bivalve communities have changed in composition since the mid-1980s assessed through large scale studies (Grebmeier and Cooper 1995; Grebmeier and Dunton 2000; Grebmeier and Cooper 2004; Grebmeier et al. 2006; Coyle et al. 2007; Lovvorn et al. 2009). While large scale studies are valuable,

T. E. Merrill
University of Alaska Fairbanks, Fairbanks, AK, USA

Present Address:
T. E. Merrill (✉)
P.O. Box 18, Seldovia, AK 99663, USA
e-mail: tmerrill@svt.org

B. Konar
Global Undersea Research Unit, University of Alaska Fairbanks,
P.O. Box 757220, Fairbanks, AK 99775-7220, USA
e-mail: bkonar@guru.uaf.edu

B. Bluhm
School of Fisheries and Ocean Sciences,
University of Alaska Fairbanks, P.O. Box 757220,
Fairbanks, AK 99775-7220, USA
e-mail: bluhm@ims.uaf.edu

smaller, local/regional trends may be different and can be relevant to benthic predator populations that have limited foraging ranges (Menge et al. 1997). Therefore, the status of a specific benthic infaunal community southwest of St. Lawrence Island was evaluated in 2006 (named Benthic Cluster Group VIII, Subgroup A-1 by Stoker 1978), which was first sampled in 1970–1974 (Stoker 1978). This community type was identified as being dominated by selective detritus-feeding bivalves, such as *Macoma calcaria* (Tellinidae) and *Eunucula bellotii* (Nuculidae), and the filter feeding ascidian, *Pelonaia corrugata*, and was originally classified as a “sub-group” of a larger cluster group (Stoker 1978). This area is a particularly important forage area for walruses and other benthic feeding mammals and birds where they feed on invertebrates such as bivalves, gastropods, amphipods and polychaetes (Fay et al. 1989; Lovvorn et al. 2003; Moore et al. 2003).

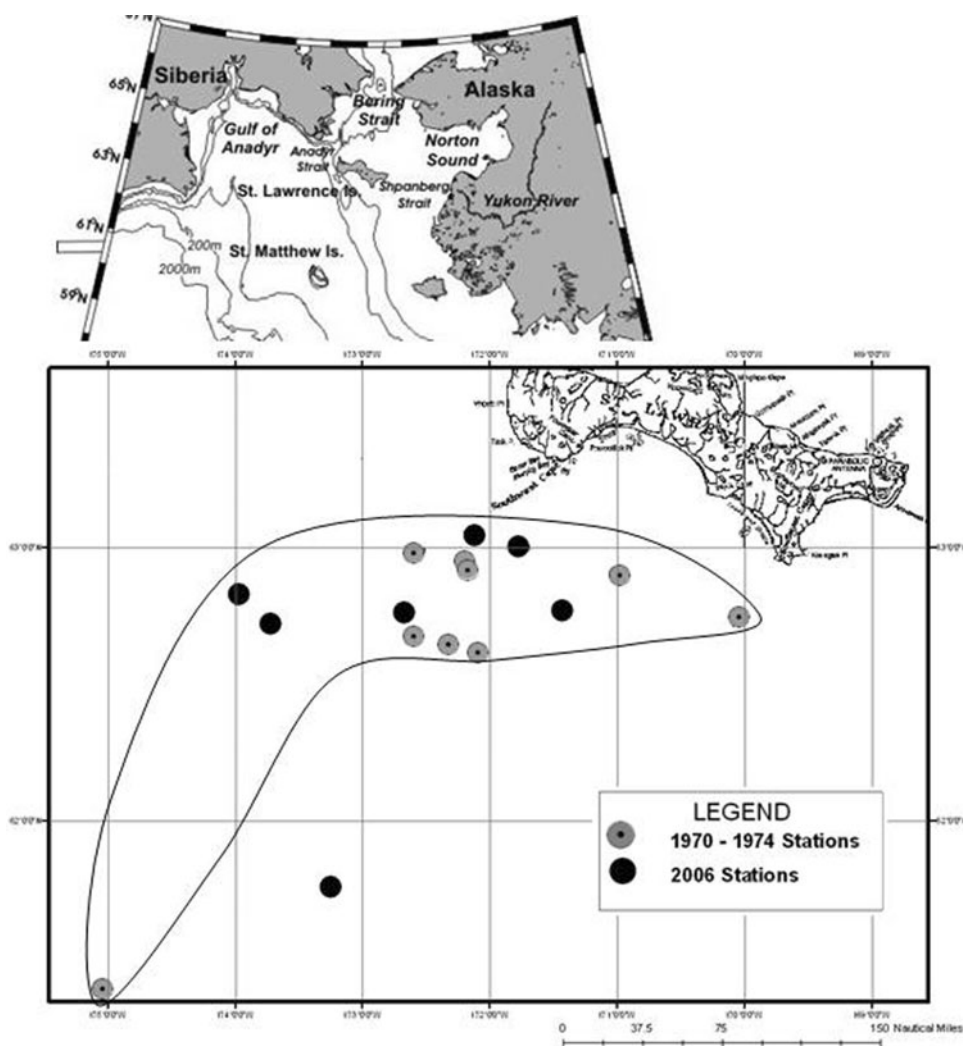
Based on the previous studies cited above, we hypothesized that between stations sampled in 1970–1974 and stations sampled in 2006 (1) invertebrate biomass and

abundance would have significantly declined and (2) invertebrate community structure would be significantly different.

Materials and methods

In March 2006, seven stations located south of St. Lawrence Island and in Stoker’s Cluster Group VIII, Subgroup A-1 were sampled opportunistically during a 3 week cruise aboard the Russian ice-breaker, *Magadan* (Fig. 1). At each station, water depth and GPS coordinates were recorded and five replicate benthic faunal samples were taken using a 0.1 m² van Veen grab. Benthic faunal samples were sieved through a 1 mm screen and all animals retained on the screen were preserved in 10% buffered formalin for later sorting and analysis. After 4 weeks, faunal samples were transferred into 50% isopropanol and re-sieved using a 2.8 mm sieve at the lab to match the sieve size used by Stoker (1978). Invertebrates were sorted to family, blotted

Fig. 1 Stations in the St. Lawrence Island Polynya in the northern Bering Sea (by year) from which benthic infaunal data were compared. Outlined area = Benthic Cluster Group VIII, Subgroup A-1 as defined by Stoker (1978)



dry, weighed to the nearest gram, and counted. After square-root transformation, mean invertebrate biomass and abundance were compared between 1970–1974 and 2006 with ANOVAs (Analysis of Variance, R, version 2.5.1). ANOSIM (Analysis of similarity, PRIMER, version 6) was used to test for between station group similarity with global $R = 1$ indicating completely distinct communities and global $R = 0$ indicating complete overlap between groups (Clarke and Warwick 2001). Taxa contributing most to the differences between station groups were identified using SIMPER (Similarity Percentages Routine) analysis. Mean abundance and biomass data from five replicates each taken at nine stations in the same area sampled by Stoker in 1970–1974 were used for comparison (Fig. 1). Stations within Stoker's Cluster Group VIII, Subgroup A-1, were located between 61.37 and 63.04°N and between -175.05 and -170.05°W. Although within the same identified community type, 2006 stations were not at the exact same locations as 1970–1974 stations. Stations varied in water depth from 42 to 86 m and in sediment composition from fine sand to fine silt. Data were included from one 2006 station that fell spatially outside Stoker's Cluster Group VIII, Subgroup A-1 because Multi-Dimensional Scaling (MDS) plots revealed no significant differences in infaunal community composition, for both average biomass and abundance, from other 2006 stations.

Results

Mean infaunal biomass across all stations (grams wet weight per m^2) was significantly lower (ANOVA, $F = 201.54$, $df = 1$, $P \leq 0.0001$) for stations sampled in 1970–

1974 (170.1 ± 37.0 s.e. g/m^2 , $n = 9$) relative to stations sampled in 2006 (520.8 ± 97.6 s.e. g/m^2 , $n = 7$, Table 1). Average abundance across all stations \pm SE was also significantly lower (ANOVA, $F = 359.01$, $df = 1$, $P \leq 0.0001$) for stations sampled in 1970–1974 (625 ± 148 individuals per m^2) compared to stations sampled in 2006 ($1,699 \pm 272$ individuals per m^2 , Table 1). Benthic community (taxonomic) composition between 1970–1974 and 2006 was moderately, but significantly different based on biomass (ANOSIM, Global $R = 0.368$, $P = 0.002$, Fig. 2) and greatly differed based on abundance (ANOSIM, Global $R = 0.657$, $P = 0.001$, Fig. 3). Differences in Nuculidae biomass and abundance contributed the most to differences in community structure between 1970–1974 and 2006 stations (Tables 2, 3). For biomass, among the top ten families contributing to temporal differences were five families of bivalves: Nuculidae, Tellinidae, Nuculanidae, Mytilidae and Cardiidae. With the exception of Styelidae, biomass in 2006 was higher in all the top ten families compared to 1970–1974. For abundance, Nuculidae and five polychaete families (Orbiniidae, Maldanidae, Cirratulidae, Capitellidae and Glyceridae) were among the top ten families contributing to the differences between sampling periods. With the exception of Pontoporeiidae, abundance in 2006 was higher in all the top ten families compared to 1970–1974.

Discussion

Contrary to other Bering Sea studies conducted in the 1990s and in 2001 (Grebmeier and Cooper 1995; Grebmeier and Dunton 2000; Grebmeier and Cooper 2004),

Table 1 Mean weight (g/m^2) and mean abundance (indiv./ m^2) \pm 1 standard errors of stations sampled in 1970–1974 and 2006

Station No.	Year	Mean weight Wt (g/m^2)	Mean abundance (indiv./ m^2)
57	1970–1974	77.06 ± 17.27	116 ± 15
67	1970–1974	107.44 ± 21.08	764 ± 79
68	1970–1974	165.11 ± 36.20	468 ± 42
69	1970–1974	6.79 ± 2.41	156 ± 48
88	1970–1974	362.03 ± 65.74	$1,558 \pm 251$
89	1970–1974	245.14 ± 25.69	642 ± 55
92	1970–1974	290.77 ± 45.47	968 ± 75
93	1970–1974	139.78 ± 12.37	370 ± 38
94	1970–1974	137.06 ± 24.75	580 ± 68
1	2006	193.0 ± 49.21	874 ± 94
2	2006	960.46 ± 24.62	$2,583 \pm 130$
3	2006	570.34 ± 59.94	$2,050 \pm 47$
4	2006	376.72 ± 31.71	972 ± 72
5	2006	300.74 ± 59.16	$1,090 \pm 98$
6	2006	682.93 ± 89.55	$2,480 \pm 110$
7	2006	560.91 ± 86.27	$1,842 \pm 227$

the results of this study suggest an increase in benthic infaunal biomass and abundance between 1970–1974 and 2006, primarily due to high biomass and abundance of the

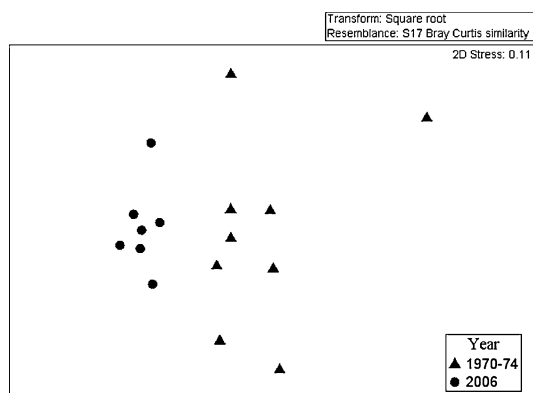


Fig. 2 MDS plot showing the similarity of infaunal communities at stations in the St. Lawrence Island Polynya sampled in 1970–1974 ($n = 9$) and 2006 ($n = 7$) based on square-root transformed biomass data (2.8 mm mesh)

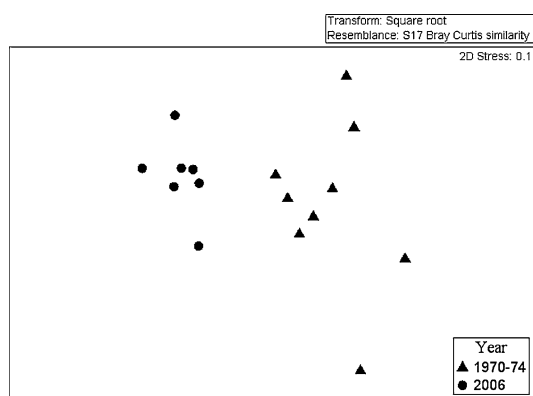


Fig. 3 MDS plot showing the similarity of infaunal communities at stations in the St. Lawrence Island Polynya sampled in 1970–1974 ($n = 9$) and 2006 ($n = 7$) based on square-root transformed abundance data (2.8 mm mesh)

bivalve family Nuculidae. *Eunucula bellotii* was the major bivalve present in this family (personal observation). Several explanations are possible for the observed high abundance and biomass values in 2006. The area sampled could have experienced a strong recruitment event of *E. bellotii* in recent years. Recruitment, and increases of *E. bellotii*, have been observed over the last 15 years, with small scale variability, within the dominant western cluster group in the Bering Sea identified in Simpkins et al. 2003. Species in the bivalve family Nuculidae, such as *Nucula turgida*, are long lived and have been reported to have life spans of at least 7 years (Davis and Wilson 1985; Wilson 1988). Similar to the increase in *E. bellotii*, recruitment peaks may have occurred for various polychaete families and for the ophiuroids. In the Northeast Water Polynya, seasonal recruitment peaks have been observed in various polychaete families (Ambrose and Renaud 1997) while ophiuroids are also known to have mass recruitment events in the Mediterranean (Turon et al. 2000).

Alternatively, biomass and abundance of infaunal invertebrates within the sampled area may have steadily increased over time while they decreased on the larger spatial scale sampled in the post-1980 studies used for comparison here. Benthic communities are extremely variable in space and time and are patchily distributed because of many physical and biological interactions. Substrate type greatly influences the distribution of benthic marine invertebrates because many have specific requirements and/or preferences for sediment grain size and/or chemical composition due to variations in feeding styles and habitat (e.g., epifaunal vs. infaunal) (Stoker 1978; Sirenko and Koltun 1992). Currents can influence variation in the amount and composition of sediments, food (carbon), and nutrients deposited to the benthos (Grebmeier and Cooper 1995; Grebmeier and Dunton 2000; Grebmeier and Barry 2007). Fluxes in larval settlement and mortality (produced by natural causes, predation, disturbances, and/or competition) can dictate colonization of available habitat (Gaines

Table 2 Top ten families contributing to the differences observed in benthic infaunal community composition in the St. Lawrence Island Polynya between 1970–1974 ($n = 9$) and 2006 ($n = 7$) based on SIMPER analysis of square-root transformed biomass

Family	Class/order	Group 1970–1974 average biomass (g/m^2)	Group 2006 average biomass (g/m^2)	Contribution (%)
Nuculidae	Bivalvia	8.88	183.07	13.15
Tellinidae	Bivalvia	15.07	97.57	8.20
Ophiuridae	Ophiuroidea	17.50	61.14	6.19
Nuculanidae	Bivalvia	13.28	56.37	5.54
Amphictenidae	Polychaeta	14.65	34.84	5.49
Styelidae	Ascidiacea	26.04	0.00	4.71
Maldanidae	Polychaeta	0.05	9.52	3.79
Naticidae	Gastropoda	3.44	11.20	3.26
Mytilidae	Bivalvia	2.42	12.59	3.02
Cardiidae	Bivalvia	7.17	8.65	2.69

Table 3 Top ten families contributing to the differences observed in benthic infaunal community composition in the St. Lawrence Island Polynya between 1970–1974 ($n = 9$) and 2006 ($n = 7$) based on SIMPER analysis of square-root transformed abundance

Family	Class/order	Group 1970–1974 average abundance (numbers/m ²)	Group 2006 average abundance (numbers/m ²)	Contribution (%)
Nuculidae	Bivalvia	32	419	8.54
Orbiniidae	Polychaeta	32	215	4.92
Maldanidae	Polychaeta	1	71	4.77
Pontoporeiidae	Amphipoda	176	59	4.36
Amphictenidae	Polychaeta	37	100	4.36
Cirratulidae	Polychaeta	1	92	4.25
Capitellidae	Polychaeta	0	45	3.51
Tellinidae	Bivalvia	60	151	3.37
Glyceridae	Polychaeta	0	44	3.14
Ophiuridae	Ophiuroidea	26	60	2.96

and Bertness 1993; Gosselin and Qian 1997; Wahl 2001). Additionally, alterations in sea water temperature can modify fecundity and predation rates among marine organisms (Nomaguchi et al. 1997; Napp et al. 2000; Hunt et al. 2002).

In the post-1980 studies, sampling encompassed a geographic area approximately two times larger than ours and included at least 24 stations within the SLIP (Grebmeier 1987; Grebmeier and Cooper 1995). The effects of local biotic processes, such as competition and predation, can be obscured at larger, regional scales (Huston 1999). As example, the increase of *Eunucula bellotii* in the study area may be caused by selective predation on other species. The 2006 sampling occurred at stations where bivalve biomass and predation pressure from walruses, spectacled eiders, gastropods and other predators were high (Fay et al. 1989; Lovvorn et al. 2003). Spectacled eiders (*Somateria fischeri*) selectively consume *Nuculana radiata* in the Bering Sea (Lovvorn et al. 2003). Despite higher energy content per gram in *Eunucula bellotii*, spectacled eiders appear to prefer *N. radiata* over *E. bellotii* (at least within the size range of 10–14 mm) possibly because of the increased expenditure of energy needed to crush the thick shell of *E. bellotii* (Lovvorn et al. 2003). Additionally, spectacled eiders prefer bivalves within the size range of 18–30 mm and *E. bellotii* tends to be smaller than these lengths (Lovvorn et al. 2003). If *N. radiata* is being selectively consumed by predators within the study area, then *E. bellotii* may be impacted less by predation pressure and so establish dominance. However, the nuculid bivalve abundance and biomass numbers observed in this study parallel what has been found in a larger scale, 40 station time-series analysis in the SLIP (Dr. Jacqueline M. Grebmeier, University of Maryland, Center for Environmental Science, personal communication) making this explanation unlikely.

It should be noted that the 2006 stations were not at the exact same locations as the 1970–1974 stations within Stoker's Cluster Group VIII, Subgroup A-1, nor were they

directly within the core sampling areas referenced in Grebmeier et al. (2006) and so some degree of spatial variability could limit comparability. The cluster analysis methods used by Stoker (1978) to identify and define benthic community types within the Bering and Chukchi Seas were also based on large spatial scales which may further confound the effects of spatial variability in this study.

While this study has shown an increase in benthic infaunal biomass and abundance between 1970–1974 and 2006, it also suggest that small-scale local sampling of specific communities might yield different results than large-scale regional sampling regarding temporal changes in Bering Sea benthic communities. Detecting localized changes in the prey base of bottom-feeding predators in the Bering Sea may be critical to understanding how predators, such as walruses, spectacled eiders and gray whales, are being impacted by changing amphipod and bivalve populations. Therefore, small-scale sampling designs based on specific communities should be utilized in addition to larger, regional sampling designs in future studies examining Bering Sea benthic communities.

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