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Latitudinal trends and temporal shifts in the catch composition of bottom trawls conducted on the eastern Bering Sea shelf

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ABSTRACT

Latitudinal species diversity gradients are well known in both terrestrial and aquatic ecosystems throughout the world. However, trends in relative abundance and other shifts in community structure with latitude, which can be more sensitive to environmental shifts such as climate change, have received less attention. Here we investigate latitudinal trends in the seafloor community of the eastern Bering Sea using catches of fishes and epibenthic invertebrates in bottom trawl surveys conducted from 1982 to 2010. Our results indicate that the overall biomass of the epibenthic community declines with increasing latitude in the eastern Bering Sea. This latitudinal trend is primarily driven by declining fish catches in the northern Bering Sea, which in turn reflects changes in the structure of the fish community. The fish fauna in northern latitudes is increasingly dominated by gadids, though the species composition of the gadid fauna also changes with latitude, with smaller species becoming more common in the north. The biomass of the invertebrate megafauna remains relatively consistent throughout the eastern Bering Sea, but invertebrates make up a larger proportion of the catch in bottom trawls conducted at higher latitudes. The epibenthic invertebrate megafauna in the eastern Bering Sea is composed primarily of sea stars (Asteriidae) and oregoniid crabs (*Chionoecetes* and *Hyas*), though no clear latitudinal trends in the invertebrate community are evident. Limited trawl data from the eastern Chukchi Sea indicate that the fish community farther north is even more heavily dominated by gadids, and the epibenthic invertebrate community is dominated by asteriid sea stars. Temperature data from bottom trawl surveys in the southeastern Bering Sea over the past decade indicate that there was a distinct temperature shift around 2005, and the relatively warm years of 2001–2005 were followed by five relatively cold years. This shift in the summer temperature regime of the Bering Sea has resulted in lower fish catches, particularly in the “cold pool” region (58–61°N), and a higher proportion of epibenthic invertebrates in the bottom trawl catches of the past 5 years.

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1. Introduction

Latitudinal species diversity gradients are well known in both terrestrial and aquatic ecosystems, and have been extensively examined for decades (e.g. Pianka, 1966; Clarke, 1992; Rohde, 1992; Rosenzweig and Sandlin, 1997). One of the pervasive themes of these studies is the tendency for species diversity to decline with increasing latitude. In the eastern North Pacific Ocean, declining diversity with increasing latitude has been demonstrated on a broad scale in marine gastropods (Roy et al., 1998), bivalves (Roy et al., 2000), and decapod crustaceans (Boschi, 2000). This pattern is not universal, and latitudinal trends can be interrupted by regions of particularly high diversity, such as the rocky intertidal zone of the Gulf of Alaska, which supports an unusually high diversity of benthic invertebrates given its high latitude location (Iken et al., 2010; Pohle et al., 2011). However, it is clear that in a broad variety of biomes throughout the world, species diversity is highest at low latitudes and lowest near the poles (Hillebrand, 2004). A multitude of hypotheses have been suggested to explain the underlying causes of these trends, including many that focus on climatological variables such as incident solar energy and temperature, as well as overall stability in climate (Currie et al., 2004).

Latitudinal trends in species diversity have been well documented, but trends in relative abundance and other shifts in community structure with latitude have received less attention, though some recent studies have begun to address this need (Bluhm et al., 2009; Iken et al., 2010; Konar et al., 2010). Because relative abundance is a more sensitive measure than simple presence/absence, latitudinal trends in the relative abundances of taxa may be more revealing over relatively small geographic

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scales, and changes in climatic forcing variables should affect relative abundance measures over shorter temporal scales. In the northern Bering and Chukchi Seas, much of the primary production settles directly to the benthos, and as a result the pelagic–benthic coupling in these regions is strong (Grebmeier et al., 1988). Given the large spatial area contained within the Bering and Chukchi Seas and the annual variability in ice cover (Wyllie-Echeverria and Wooster, 1998), we expect latitudinal trends in the seafloor community structure to reflect the spatial variability of the pelagic–benthic coupling process, and that long-term temporal shifts in these latitudinal trends may be indicative of fundamental changes in the process due to climate change.

A number of previous studies have examined benthic communities in the Alaskan arctic and subarctic regions. Many of these studies have used bottom grabs to examine the macrobenthic epifauna and infauna (Haflinger, 1981; Stoker, 1981; Grebmeier et al., 1988, 1989; Feder et al., 1994, 2007; Jewett et al., 2009). Others have utilized bottom-trawling gear to examine the larger components of the epifauna in the Chukchi Sea (Feder et al., 2005; Bluhm et al., 2009) or in Norton Sound (Hamazaki et al., 2005). Jewett and Feder (1981) characterized the epifaunal invertebrate community of the eastern Bering Sea and Chukchi Sea using bottom-trawl surveys conducted in 1975 and 1976, and Cui et al. (2009) examined groundfish distribution around St. Lawrence Island in the northern Bering Sea. However, few of these studies have addressed the relative contributions of the ichthyofauna to the epibenthic biomass or the temporal changes in the characteristics of the epibenthic community, and those that have (e.g., Cui et al., 2009) were based on relatively limited spatial and temporal sampling.

Here we analyze bottom-trawl catches of fishes and epibenthic macroinvertebrates from National Marine Fisheries Service (NMFS) standardized bottom-trawl surveys in the eastern Bering Sea. We examine latitudinal trends in the biomass of fishes and invertebrates and in the species composition of the epibenthic megafauna across the entire latitudinal range of the eastern Bering Sea shelf. We also compare latitudinal trends in the composition of the benthic community of the southeastern Bering Sea from the warm years and cold years of the past decade, and comment on limited historical bottom trawl survey data from the Chukchi Sea. This data set is particularly valuable in that it represents a vast quantity of sampling effort (over 18,000 ha of area sampled) distributed over a broad geographic and temporal scale.

2. Methods

2.1. Surveys

This study includes standardized catch data from the annual NMFS eastern Bering Sea shelf bottom trawl surveys conducted during the summer months of 1982–2010 (Fig. 1), as well as smaller-scale NMFS trawl surveys conducted in the southeastern Chukchi Sea in 1976 and the northeastern Chukchi Sea in 1990. Portions of the trawl data presented here for the northern Bering Sea have previously been analyzed by Hamazaki et al. (2005), and data from the southeastern Chukchi Sea were used by Jewett and Feder (1981), Barber et al. (1997), and Feder et al. (2005). NMFS trawl survey data are maintained in a database by the Alaska Fisheries Science Center's RACE (Resource Assessment and Conservation Engineering) Division. Data for standard survey stations back to 1982 can be accessed online at http://www.afsc.noaa.gov/RACE/groundfish/survey_data/default.htm, and data for surveys prior to 1982 can be obtained by contacting the authors.

Survey trawl gear and research trawling operations adhered to the specifications and protocols found in Stauffer (2004). All bottom trawl surveys used an 83–112 Eastern otter trawl constructed with a 102-mm (4-in) stretched mesh body, 89-mm (3.5-in) stretched mesh intermediate, 32-mm (1.25-in) mesh codend liner, 25.3-m (83 ft) headrope, and a 34.1-m (112 ft) footrope. The research trawl was spread by a pair of 1.8×2.7-m (6×9 ft) 816-kg steel V-doors connected to the trawl by a pair of 54.9 m (30-fathom) dandylines. Net opening width for trawls included in this study averaged approximately 16 m, and the distance towed averaged 2.75 km. Catch data were standardized by converting catch weight to catch per unit effort (CPUE), expressed as kg/ha. CPUE was calculated by dividing catch weight by area swept, which was determined by multiplying the mean net width by the distance towed (Alverson and Pereyra, 1969). The survey data examined here were geographically limited to trawls conducted at or north of 55°N, and because the entire sampled area in the northern portion of the Bering Sea (north of 62°N) consists of

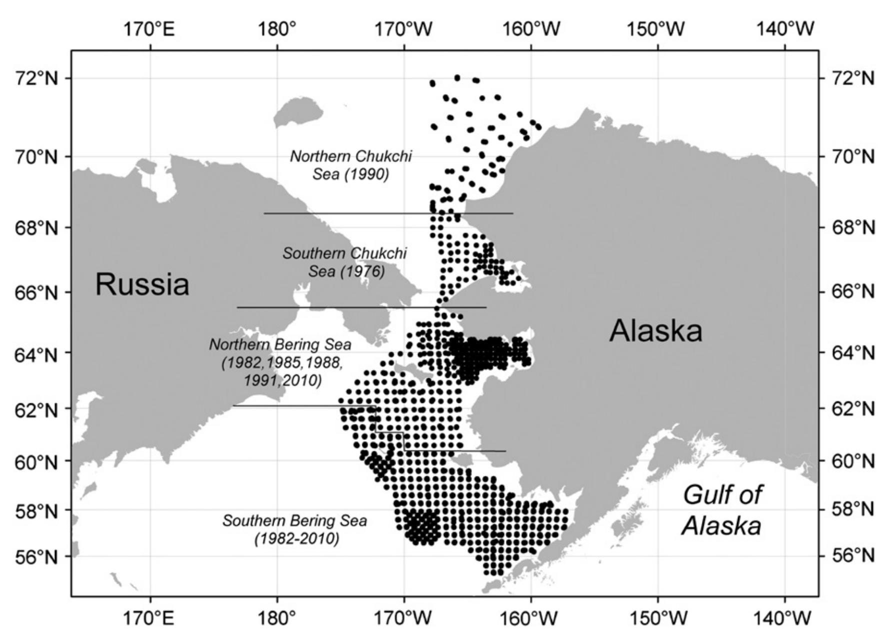

Fig. 1. Map of areas sampled by Alaska Fisheries Science Center bottom trawl surveys included in this study.

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