Available online at www.sciencedirect.com
ScienceDirect
Progress in Oceanography 71 (2006) 331–361
Progress in Oceanography
www.elsevier.com/locate/pocean

Ecosystem dynamics of the Pacific-influenced Northern Bering and Chukchi Seas in the Amerasian Arctic

Jacqueline M. Grebmeier [a,*], Lee W. Cooper [a], Howard M. Feder [b], Boris I. Sirenko [c]

[a] *Marine Biogeochemistry and Ecology Group, Department of Ecology and Evolutionary Biology, 10515 Research Dr., Building A, Suite 100, The University of Tennessee, Knoxville, TN 37932, USA*
[b] *Institute of Marine Science, University of Alaska Fairbanks, Fairbanks, Alaska 99775, USA*
[c] *Zoological Institute, Russian Academy of Sciences, Universitetskaya emb., 1, St.-Petersburg, 190034, Russia*

Abstract

The shallow continental shelves and slope of the Amerasian Arctic are strongly influenced by nutrient-rich Pacific waters advected over the shelves from the northern Bering Sea into the Arctic Ocean. These high-latitude shelf systems are highly productive both as the ice melts and during the open-water period. The duration and extent of seasonal sea ice, seawater temperature and water mass structure are critical controls on water column production, organic carbon cycling and pelagic–benthic coupling. Short food chains and shallow depths are characteristic of high productivity areas in this region, so changes in lower trophic levels can impact higher trophic organisms rapidly, including pelagic- and benthic-feeding marine mammals and seabirds. Subsistence harvesting of many of these animals is locally important for human consumption. The vulnerability of the ecosystem to environmental change is thought to be high, particularly as sea ice extent declines and seawater warms. In this review, we focus on ecosystem dynamics in the northern Bering and Chukchi Seas, with a more limited discussion of the adjoining Pacific-influenced eastern section of the East Siberian Sea and the western section of the Beaufort Sea. Both primary and secondary production are enhanced in specific regions that we discuss here, with the northern Bering and Chukchi Seas sustaining some of the highest water column production and benthic faunal soft-bottom biomass in the world ocean. In addition, these organic carbon-rich Pacific waters are periodically advected into low productivity regions of the nearshore northern Bering, Chukchi and Beaufort Seas off Alaska and sometimes into the East Siberian Sea, all of which have lower productivity on an annual basis. Thus, these near shore areas are intimately tied to nutrients and advected particulate organic carbon from the Pacific influenced Bering Shelf-Anadyr water. Given the short food chains and dependence of many apex predators on sea ice, recent reductions in sea ice in the Pacific-influenced sector of the Arctic have the potential to cause an ecosystem reorganization that may alter this benthic-oriented system to one more dominated by pelagic processes.

Regional terms: USA; Arctic; Russia; Northern Bering Sea; Chukchi Sea

Keywords: Ecosystem dynamics; Pelagic–benthic coupling; Benthos

* Corresponding author. Tel.: +1 865 974 2592; fax: +1 865 974 7896.
E-mail address: jgrebmei@utk.edu (J.M. Grebmeier).

0079-6611/$ - see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.pocean.2006.10.001

1. Introduction

The seasonally ice-covered Bering and Chukchi Sea shelves are among the largest continental shelves in the world. Pacific water with high nutrient levels upwells onto the shelf of the northern Bering Sea and influences planktonic and benthic foodwebs as well as sediment community dynamics throughout this region. Mean current flow of Pacific-derived water is northward into the Arctic Ocean over most of the year (Woodgate et al., 2005). Sea-ice production, extent, and duration are critical for influencing annual primary production of ice algae and phytoplankton, as well as water mass formation. Current direction and speed influence subsequent organic carbon transport through the system.

Annual primary production estimates (based on a 120 day growing season) for the region range from <50 to 800 g C m^{-2} y^{-1} (Springer and McRoy, 1993; Springer et al., 1996; Sakshaug, 2004; Hill and Cota, 2005), with ice-edge production proportionally more important in regions of limited open water production (Ambrose et al., 2005; Lovvorn et al., 2005). While zooplankton can significantly graze both phytoplankton and microheterotrophs, ultimately limiting export production, zooplankton grazing and the microbial loop in the nutrient-rich, offshore Pacific waters in the northern Bering and Chukchi Seas have less of an impact on overall organic carbon cycling than in nutrient-limited, nearshore Alaska Coastal waters (Walsh et al., 1989; Sakshaug, 2004). The net result of these factors, specifically the extremely high primary production over shallow shelves and relatively low grazing pressure, is that more organic carbon settles to the seafloor where it supports a rich benthic food web. Generally, in shallow arctic regions with high water column production, there are tight coupling and strong spatial linkages of water column organic carbon production and deposition to the underlying sediments. These patterns of abundant benthic carbon supply and high biomass of long-lived benthic fauna in cold Arctic waters are dominant characteristics in these productive Pacific-influenced ecosystems.

Although cold temperatures limit migratory fish populations in these northern regions (Alton, 1974), a limited number of fish species, including Arctic cod (*Boreogadus saida*) and to a lesser extent Bering flounder (*Hippoglossoides robustus*) and saffron cod (*Eliginus gracilis*) have important trophic roles as food for many marine mammals and seabirds (Frost and Lowry, 1980; Bradstreet and Cross, 1982; Springer et al., 1987; Gillispie et al., 1997; Wyllie-Echeverria et al., 1997). Various ice-associated seals, including ribbon, ringed and spotted, migrate seasonally with the sea ice and feed pelagically (Simpkins et al., 2003). In addition, migratory bowhead whales in the western Beaufort Sea are also known to feed opportunistically on zooplankton advected northward from the northern Bering Sea (Moore and Laidre, 2006). The high benthic standing stocks on these northern shelves also support key benthic-feeding apex predators, including Pacific walrus (*Odobenus rosmarus divergens*), gray whales (*Eschrichtius robustus*), and bearded seals (*Erignathus barbatu*; Sheffield et al., 2001; Moore et al., 2003; Simpkins et al., 2003; Feder et al., 2005). These benthic-feeding marine mammals and seabirds (e.g. the spectacled eider, *Somateria fischeri*) provide relatively higher regional predation pressure than fishes (Feder and Jewett, 1978; Grebmeier et al., 1995; Lovvorn et al., 2003; Moore et al., 2003; Simpkins et al., 2003).

Our objective in this review is to summarize published and other available data documenting the marine ecosystem in the northern Bering and Chukchi Seas. In many respects, the northern Bering Sea is more closely connected in hydrographic characteristics to the Arctic Chukchi Sea to its north than to the southern Bering Sea. An Arctic–subarctic temperature front separates the northern and southern sectors of the Bering Sea, and that front appears to be moving northward, with potential for a restructuring of the ecosystem (Overland and Stabeno, 2004; Grebmeier et al., 2006). Sea-ice algal production is important in the more extensively ice-covered continental shelves of the northern Bering and Chukchi Seas, with meso- and macro-zooplankton populations having a relatively smaller overall role in organic carbon cycling relative to other regions of the Arctic (Walsh et al., 1989, 2005; Walsh and Dieterle, 2004). There is an increased importance of benthic populations and processes progressing from south to north on these shallow, Pacific-influenced continental shelves. From an ecosystem perspective, benthic foodwebs play a significant role in influencing trophic dynamics and organic carbon cycling on these productive Amerasian Arctic shelves and, therefore, are a major focus of this review.