Redistributions of Cetaceans in the Southeast Bering Sea Relative to Anomalous Oceanographic Conditions during the 1997 El Niño

Cynthia T. Tynan
Joint Institute for the Study of the Atmosphere and Ocean
University of Washington
NOAA, Alaskan Fisheries Science Center
7600 Sand Point Way NE, Seattle WA 98115-0070
U.S.A.
e-mail: tynan@afsc.noaa.gov

The distributions of foraging whales typically reflect the productivity of their pelagic and coastal environments (Tynan, 1998; Croll et al., 1998). Whales can therefore serve as important integrators of the regional biomass of their principal prey: euphausiids, copepods and schooling fish. Redistributions of whales can also serve as important indicators of change in the ecosystem. In order to consider how the distribution of whales in the southeast Bering Sea may have changed relative to the anomalous oceanographic conditions of 1997 and 1998, it is first necessary to review the historical distributions of whales relative to the mean circulation.

The general circulation consists of a cyclonic gyre over the deep basin, with the Kamchatka Current forming the western boundary and the Bering Slope Current forming the eastern boundary of the gyre. A 0.5 m sea-level difference between the Bering Sea and the Arctic Ocean drives the mean northward transport through Bering Strait (Coachman, 1993). The circulation and hydrographic structure of the Bering Sea is highly variable on interannual and decadal time scales. Transport in the gyre can vary by as much as 50% due to changes in the Alaskan Stream inflow or alteration in the wind-driven circulation (Schumacher and Stabeno, 1998). The Bering Slope Current is primarily an extension of the Alaskan Stream water which enters through the passes along the Aleutian Chain. This flow turns eastward along the northern side of the Aleutian Chain as the North Aleutian Slope Flow and then continues to the northwest over the slope at mean speeds of 3–15 cm s^{-1} as the Bering Slope Current (Schumacher and Reed, 1992). The nutrient-rich waters of the Bering Slope Current help to create one of the most productive ecosystems in the world.

Approximately half of the Bering Sea consists of the broad continental shelf, which is more than 500 km wide in the eastern portion (Coachman, 1986). The circulation over the eastern shelf is sluggish, with current speeds on the order of 1–5 cm s^{-1} (Schumacher and Kinder, 1983; Coachman, 1986). Three frontal zones divide the shelf into distinct hydrographic domains: an Inner Front at approximately the 50 m isobath separates the Coastal Domain from the Middle Shelf Domain; a Middle Front at approximately the 100 m isobath separates the Middle and Outer Shelf Domains; and a salinity front at the shelf-break separates the Outer Shelf and slope domains (Coachman, 1986).

The region of the Bering Slope Current has been called the ‘green belt’ (Springer et al., 1996) due to its high primary production linked to nutrient availability. Not surprisingly, this region also had high historical catches of fin whales (Nasu, 1974). The historical distribution of right whales (Omura et al., 1969) also suggests that this species tracked the Bering Slope Current and the movement of Alaskan Stream waters in the southeast Bering Sea. It has been decades however since any large-scale synoptic surveys of cetaceans have been conducted in the eastern Bering Sea shelf and slope regions.

In order to quantify the modern distributions of cetaceans in the Southeast Bering Sea, I conducted line-transect surveys of whales from July 17 to August 5, 1997, across the southeastern shelf from outer Bristol Bay to 10 km west of St. Paul Island. Survey effort covered the middle and outer shelf domains as well as the shelf-edge and slope regions.

We completed a total of 2021 km of survey effort. Multiplying this distance by an effective strip width of 6 km produces a survey area of approximately 12,000 km^2.

During the summer of 1997, anomalous oceanographic conditions occurred in the Southeast Bering Sea (Vance et al., 1998). By mid-July, sea surface temperatures were 2–4°C warmer than in 1996 and an extensive coccolithophore bloom of *Emiliania huxleyi* developed over the middle shelf. Our survey found that the coccolithophore bloom was restricted to the middle shelf domain during July and early August. By September, when the first SeaWiFS (Sea-viewing Wide Field-of-view Sensor) satellite images of ocean color were available, the bloom was approximately 700 km wide and extended over most of the southeastern Bering Sea shelf. Both the occurrence of the bloom and the unusually warm temperatures have the potential to alter the trophic dynamics and prey availability in the region.

Results of this cetacean survey suggest that redistributions of some species may have occurred. Five species of large whales occurred in or near the coccolithophore bloom: fin whale *Balaenoptera physalus*, humpback whale *Megaptera novaeangliae*, minke whale *Balaenoptera acutorostrata*, sei whale Balaenoptera borealis, and the northern right whale *Eubalaena glacialis*. The relatively high abundance of large whales south of the Inner Front (50 m isobath) and near the coccolithophore bloom, suggests that conditions on the middle shelf in 1997 provided productive foraging for cetaceans and their principal prey: euphausiids and copepods. This distribution contradicts the historical pattern of higher whale biomass associated with the “green belt” of the shelf edge. This redistribution is consistent with either a shift in foraging ecology linked to anomalous oceanographic conditions during an El Niño year, or is indicative of a longer-term change in the regional productivity and trophic structure of the Bering Sea ecosystem.

It is important to determine how zooplankton production, biomass, and species composition may have shifted in the shelf system. The zooplankton communities of the southeast Bering Sea shelf are separated by distinct hydrographic domains. The Middle Front (100 m isobath) is a hydrographic boundary which also separates two major zooplankton communities: an outer shelf community of large species of calanoid copepods, such as *Calanus plumchrus*, *Calanus cristatus*, and *Eucalanus bungii*; and a zooplankton community inshore of 100 m composed of smaller species such as *Calanus marshallae*, *Pseudocalanus* spp., and *Acartia* spp. (Cooney and Coyle, 1982; Smith and Vidal, 1986). During 1997 and 1998, trophic dynamics may have altered, depending on whether diatom production became limiting and if so, whether zooplankton could efficiently graze the coccolithophores. Some copepods, such as *Calanus*, are able to feed on coccolithophores (Marshall and Orr, 1972). Diet studies and SEM (Scanning Electron Microscopy) analyses of gut contents from zooplankton, collected from the bloom water, may help definechanges in the trophic structure.

During July 1997, I collected two zooplankton samples from the coccolithophore bloom on the middle shelf (58 m depth). Samples were collected with bongo nets (333 μm mesh size) in the vicinity of right whales, a species which forages specifically on calanoid copepods. The species collected were typical of the middle shelf species assemblage: *Calanus marshallae*, *Pseudocalanus newmani*, and *Acartia longiremis*. Historically however right whales fed on *Calanus plumchrus* and *C. cristatus* in deeper water along the shelf break (Nemoto, 1963). Therefore, this population of right whales, which is the world's most depleted population of large whale (National Marine Fisheries Service, 1991), appears to have shifted both its foraging ground and prey species in the Southeast Bering Sea. The higher densities of other species of baleen whales on the middle shelf suggests that this region now supports among the highest zooplankton biomass in the Southeast Bering Sea. It is important to continue to define the effects of interannual and longer-term climatic variability on the productivity, structure, and function of the Bering Sea ecosystem.

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