

## **Sinking particles and Pelagic Food Webs in the SE Bering Sea: 2001**

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### **ABSTRACT**

The southeastern Bering Sea shelf is an economically and ecologically important system that is subject to substantial natural and human-induced change (National Research Council, 1996). Despite this, long term observations are limited and fragmentary in time and space, which severely restricts our ability to identify the effects of climatic variability on the ecosystem. The only long-term, comprehensive record of the changes in the ocean environment are observations collected from biophysical moorings (Stabeno et al., 1998; 1999; 2001). Since 1995 Stabeno and collaborators have been monitoring site M2, over the Bering Sea middle shelf near 56° N, measuring temperature, salinity, chlorophyll, current speed, and meteorological conditions. A time-series sediment trap, which collects particles sinking out of the surface waters, has been deployed near that mooring since 1997, with support from NOAA during 1997-2000 and with support from the Pollock Conservation Cooperative Research Center for 2001. A parallel time series of zooplankton samples has also been collected. The carbon and nitrogen stable isotope composition and selected lipids, including wax esters and sterols, have been measured in the sediment trap and zooplankton samples. The composition of sinking organic material collected by the trap has reflected changes in oceanographic conditions during the 1997-2001 period.

### **INTRODUCTION**

Significant climatic variations have occurred in the northern North Pacific Ocean and Bering Sea over the past 50 years, and these have been associated with major changes in the productivity of higher trophic levels (National Research Council, 1996). In the mid-1990s, several groups of scientists attempted to predict the impact of future global warming on the Bering Sea (e.g., US GLOBEC, 1996). Among the changes forecast for the eastern Bering Sea were decreases in wind mixing energy, the supply of nutrients, and sea ice extent and thickness, and an increase sea surface temperature. The effects of climatic change on Bering Sea organisms are difficult to predict.

In 1997, conditions similar to those predicted for global warming occurred (Stockwell et al., 2001). These physical conditions were accompanied by marked changes in phytoplankton populations, a die-off of seabirds, and a failure of the red salmon fishery. Although 1998 was markedly stormier than 1997 and surface water temperatures were not unusually warm, sea ice covered the mooring site only briefly in February and the depth-averaged water temperature remained well above normal. In contrast, 1999 was the coldest year since the 1970s, with extensive sea ice cover during spring. Sea ice retreated in March of 2000 and spring and summer temperatures were close to the long-term climatic mean. Mooring data for summer 2001 are not yet available, but sea ice coverage over the winter of 2000-01 was less than average. Coccolithophorid blooms have persisted over the southeastern shelf throughout the 1997-2001 period, although they had never been observed before 1997.

The seasonal advance and retreat of sea ice over the Bering and Chukchi Sea shelves clearly has a strong influence on biological processes in the Bering Sea. For example, the timing and grazing of spring blooms (Alexander et al., 1996), bottom water temperatures and the distribution of certain demersal fishes (Wyllie-Echeverria, 1995), a massive increase of jelly-fish over the southeastern shelf since 1990 (Brodeur, et al., 1999), recruitment of pollock (Ohtani and Azumaya, 1995; Quinn and Niebauer, 1995) and the geographic distribution of marine mammals have been linked to interannual variability seasonal sea ice in

the Bering Sea. During summer and fall the entire shelf is usually ice free, but during winter strong northeast winds cause extensive ice formation along leeward coasts and advect the ice southwestward. The maximum ice extent typically occurs in late March. From year to year the position of the southern limit of ice extent can vary by hundreds of kilometers. Associated with the presence of ice is a phytoplankton bloom which can begin as early as March (Stabeno et al., 1998; 2001) but more typically occurs in late April or early May (Alexander et al., 1996; Niebauer et al., 1995). The bloom associated with sea ice can account for a large fraction of the total annual phytoplankton production (Niebauer et al., 1990).

The specific hypothesis being addressed by the research described here is that the composition of sinking particles reflects changes in the pelagic food web, which in turn is affected by weather and climate over the southeastern Bering Sea shelf. The composition of material collected by sediment traps mainly reflects the extent of grazing of primary production by zooplankton and productivity variations over time. The material collected by the sediment traps also indicates the materials being supplied to the benthos (Henrichs and Smith, 1999; Smith and Henrichs, 1998; Smith et al., submitted).

## PROJECT DESCRIPTION AND METHODS

Sediment traps have been deployed continuously since late April, 1997, at Site 2 within the middle shelf domain (56°53'N, 164°02'W, 35 m depth of deployment in a 70 m water column). The traps were deployed and recovered in February and September. Mercuric chloride was used as a poison in the trap sample cups (Wakeham et al., 1993). On recovery, trap samples were split. One split was preserved in formalin for later microscopic examination. The remainder was screened (to remove the few large, intact zooplankton), filtered and rinsed free of preservative, and then the filters were stored frozen until analysis. Phytoplankton and zooplankton samples were collected using 150 and 333  $\mu\text{m}$  mesh bongo nets. Single zooplankton species were sorted from these samples. Zooplankton and sediment trap samples were analyzed for TOC, TN,  $\delta^{13}\text{C}$ , and  $\delta^{15}\text{N}$  using the Europa mass spectrometer facility (with Roboprep) located at UAF. Certain lipid markers specific for phytoplankton and zooplankton (wax esters, sterols) are being measured to identify the sources of particles collected by the sediment traps. Lipid methods are described in Wakeham (1982) and references therein.

## 1997-2001 RESULTS

Due to space limitations, this discussion will mainly address the nitrogen isotopic data, since they clearly show seasonal and interannual trends. However, there are related patterns in the other data sets as well, some of which are described elsewhere (Henrichs and Smith, 1999; Smith and Henrichs, 1998; Smith et al., submitted).

The  $\delta^{15}\text{N}$  was significantly greater for copepods, euphausiids, and scyphozoan jellyfish in 1997 than in other years at M2 (Table 1). Stratification was unusually strong in 1997 due to unusually warm and calm weather conditions, and this resulted in unusually great nutrient depletion at M2. The elevated  $\delta^{15}\text{N}$  arose from  $^{15}\text{N}$  enrichment of the residual dissolved inorganic nitrogen as it was consumed by phytoplankton (e.g., Altabet and Francois, 1994). The carnivorous chaetognaths did not have elevated  $\delta^{15}\text{N}$  in 1997, but their  $\delta^{15}\text{N}$  decreased sharply in 2001. As the other zooplankton had similar  $\delta^{15}\text{N}$  from 1998-2001, this suggests a change in trophic level of the chaetognaths.

During 1997 and 1998, the  $\delta^{15}\text{N}$  of Site 2 sediment trap samples decreased from early spring through summer, fall, and winter (Fig. 1). The value appeared to "reset" abruptly to the annual maximum in

February or March; the timing of this event corresponded to the reappearance of intact diatoms and flagellated protozoans in the samples. These appeared before stratification of the water column or the spring phytoplankton bloom, consistent with the early appearance of some water column fluorescence due to chlorophyll (Stabeno et al., 1999). During 1999 and 2000, there was a  $\delta^{15}\text{N}$  decrease from spring to summer, but the values increased again in fall to levels similar to those in 1997-98. This temporal trend reflected annual changes in zooplankton isotopic composition, since those collected in February tended to have high  $\delta^{15}\text{N}$  compared to those collected in spring and early summer. In 2001, however, winter  $\delta^{15}\text{N}$  was relatively low. Lipid data interpreted so far suggest that 1997-99 winter samples from M2 contained more material derived from bacteria, and less from zooplankton, than spring or summer samples. Most years there was an increase in the sediment trap collection of material and in the numbers of diatoms in the samples during April or May, coincident with water column stratification and a spring bloom. This was associated with decreased  $\delta^{15}\text{N}$ .

During 1997-98, the sediment trap  $\delta^{15}\text{N}$  ranged from about 12 to 16 ‰ at Site 2. The lower part of this range is consistent with an origin in a combination of sinking diatom aggregates and crustacean fecal material. The higher  $\delta^{15}\text{N}$  values may also reflect microbial decomposition of the particles before they entered the traps, or origins from higher trophic level organisms. The  $\delta^{15}\text{N}$  of spring and summer, 1999-2001 Site 2 sediment trap samples was about 2 ‰ less than in 1997 and 1998, ranging between 7 and 11 ‰ (Fig. 1). We are as yet not certain what was responsible for this change, but it appears to be linked to changes in nutrient availability. During 1997, stratification was strong and nutrients were depleted throughout the photic zone, which extended into the pycnocline (Stockwell et al., 2001). Such depletion would result in enrichment of the residual nutrients in  $^{15}\text{N}$  (e.g., Altabet and Francois, 1994), leading to the heavy  $\delta^{15}\text{N}$  values seen in zooplankton and sediment trap samples in 1997. The spring and summer of 1998 were much stormier, resulting in repeated deep mixing, and high surface water nutrient concentrations through June. Nutrient data are presently available only through 1999, but they suggest that one reason for the interannual differences in  $\delta^{15}\text{N}$  was the markedly lower ammonium concentrations in spring of 1999. The source of this elevated ammonium in 1997-98 could be organic matter that sank to the sediment-water interface the previous year and decomposed, releasing ammonium (Whitledge, personal communication). Spring resuspension of that material during storms could lead to distribution of ammonium throughout the water column.

During fall, the amount of organic matter accumulated by the Site 2 traps showed substantial maxima, comparable to those in spring that were closely linked in time to increasing wind velocities, which result in a breakdown of the summer stratification and new nutrient supplies to the photic zone. This observation is consistent with fall fluorescence maxima recorded by the biophysical mooring (Stabeno et al., 1999). Hence, the data so far indicate that the spring bloom may not be the predominant source of organic matter to the benthos of the middle shelf.

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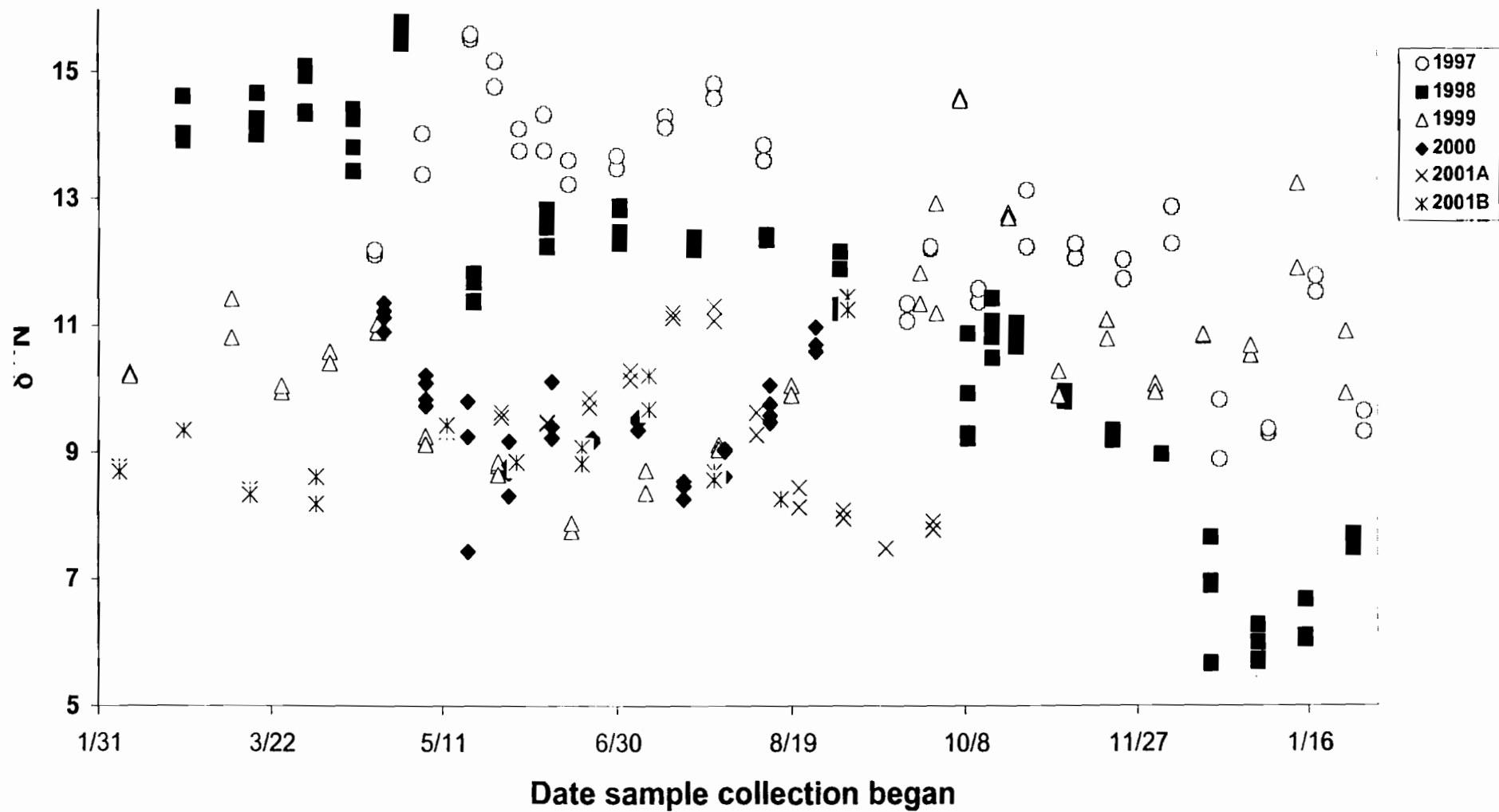
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Table 1. Stable isotopic composition of zooplankton collected over the Bering Sea middle shelf, 1997-2001.

Year	Zooplankton type	$\delta^{15}\text{N}$	Standard deviation	$\delta^{13}\text{C}$	Standard deviation
1997	Copepod	13.2	1.5	-22.8	1.8
1998	Copepod	9.8	1.0	-23.2	0.7
1999	Copepod	10.7	1.0	-20.4	0.9
2000	Copepod	10.1	1.1	-22.7	1.1
2001	Copepod	10.2	0.9	-21.4	1.0
1997	Euphausiid	12.3	1.7	-20.0	1.9
1998	Euphausiid	10.4	1.4	-20.7	0.8
1999	Euphausiid	10.0	2.5	-19.0	1.1
2000	Euphausiid	10.6	1.7	-20.6	0.9
2001	Euphausiid	10.3	1.6	-21.4	1.2
1997	Chaetognath	15.2	1.1	-20.7	0.8
1998	Chaetognath	15.0	1.4	-21.8	0.6
1999	Chaetognath	14.6	1.2	-21.1	0.7
2000	Chaetognath	15.0	1.0	-21.7	0.6
2001	Chaetognath	11.2	0.7	-21.0	0.7
1997	Scyphozoan	14.8	2.1	-20.5	0.3
1998	Scyphozoan	12.6	0.8	-20.1	0.9
1999	Scyphozoan	13.0	1.1	-19.7	0.7
2000	Scyphozoan	12.5	0.5	-20.8	1.4
2001	Scyphozoan	10.8	0.7	-19.6	1.6



**Figure 1.  $\delta^{15}\text{N}$  of sediment trap samples collected on the Bering Sea middle shelf during 1997-2001.**

