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The Roles of Advection and in situ Growth in Determining the
Dynamics of Continental Shelf Zooplankton: high frequency
measurements of zooplankton biomass coupled with measurements
to secondary productivity in the Middle Atlantic Bight

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Evaluation of the role of continental margins in planetary carbon cycles can be approached in various ways, with the extremes being knowledge generated either by large-scale studies of a few basic characteristics of the carbon cycle of shelves worldwide (comparative approach) or by temporally intensive studies of a few sites selected to typify contrasting processes. Mechanisms of cross-shelf transfer, for example, are presently of great interest and within the U.S. there are at least four differing continental shelf environments in which cross-shelf processes are driven by storms (southern Bering Sea, northeastern U.S.), by jets and eddies (northern California coast), by freshwater runoff (Bering Sea, Gulf of Mexico), and by frontal meanders and filaments of the Gulf Stream (southeastern U.S.). Because the type and magnitude of the physical forcing, and its variability on an annual scale, are fundamental to the response of the carbon cycle, investigation of each of these shelves would offer insight useful to predictive global understanding of the carbon cycle on continental shelves.

Observational and modeling studies conducted in the Cape Hatteras-Cape Cod region over the past decade have revealed an essential annual balance among processes fixing and oxidizing carbon on the shelf. Such studies have also revealed that seasonal cycles in various processes are key areas requiring investigation. In the present conceptual model of the continental shelf between Cape Hatteras and Cape Cod, a seasonal progression in physical forcing of the shelf, proceeding from storm-driven slope water intrusions and isopycnal conditions in winter to strongly thermally stratified

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conditions in summer, is accompanied by a seasonal progression in species composition and productivity responses of the shelf's biological communities. Prior input-output analyses and models of this continental shelf offered limited predictive understanding of processes controlling the carbon cycle of the region.

Regions of the world ocean exhibiting elevated productivity are often regions driven by mesoscale physical dynamics. The continental shelf between Cape Hatteras and Cape Cod is one of these regions. All studies of the productivity of biological communities eventually have to separate advective effects from *in situ* growth. Right now we have knowledge of some of the processes by which zooplankton contribute to carbon cycling in the sea that is reasonably complete, e.g., respiration, ingestion, excretion, but we have very poor understanding of the variability of biomass of zooplankton and its forcing by the physical environment. Before we can gain comprehensive understanding of the role of zooplankton in the cycling of carbon in the sea, we first have to improve our ability to specify biomass and its variability. Concurrently, we must seek improved knowledge about processes such as growth, reproduction and lipid storage, processes which are fundamental parts of the carbon cycle but are poorly quantified at the present time. Of particular interest are processes by which zooplankton transform the phytoplankton bloom of one season into their body carbon which may be sequestered until the next year, or used for metabolism and reproduction at some intermediate time.

It is now clear that improved understanding of processes involving zooplankton in the sea requires the ability to sample relatively large spatial and temporal domains on scales in which zooplankton are most heavily and directly affected by their physical environment. This is the mesoscale for the most part. In previous studies, we have shown that powerful new insights into the distribution of zooplankton in the sea, especially on the continental shelf, arise from the relatively complete coverage of the water column provided by a moored acoustic Doppler current profiler. In SEEP-II we used the calibrated, commercially available acoustic Doppler current profiler in a moored, upward looking configuration to measure biomass in a single location over a 15-month period. We observed the development of the large-bodied grazers in spring, from which we have calculated rates of secondary productivity and found that growth of zooplankton in spring does not lag growth of phytoplankton. Instead, bloom-like growth of both components of

the food chain occur simultaneously. In terms of grazing rates and the production of sinking fecal material, the average zooplankton biomass observed in spring (April) by the acoustic Doppler current profiler would remove 40% of the standing stock of phytoplankton, converting 30% into zooplankton biomass and 10% into fecal pellets each day (turnover rate = 2.5 d). Traditionally, such a high turnover is usually associated with oligotrophic, open ocean environments, but on the continental shelf off Virginia, high turnover of phytoplankton through zooplankton grazing occurs during the spring diatom bloom. Our observations were in strong contrast to the historical concept of temporal sequencing of phytoplankton and zooplankton blooms in temperate waters in spring. Often the trade-off between experimental and synoptic observations means that either the larger scale "biomass field" or knowledge of rates of carbon transformation are not adequately measured.

In trying to quantify the extent to which physical and biological forcing are responsible for observed distributions of zooplankton, in a way that helps us understand and predict how systems work, we need to be able to extrapolate biological forcing (variables associated with population growth), usually observed on small to mesoscales, to larger scales. And we need to know in general whether physical forcing has a positive or negative feedback to the biological system. Any extrapolation is dependent on larger scale observations, such as an assessment of biomass by the acoustic Doppler current profiler, which have been impossible to make until recently. We will build on our knowledge from our earlier studies and investigate the "biomass field", using the acoustic Doppler current profiler, and the processes that can be deduced from combining the biomass field with measurements of growth (egg production), with measurements of grazing rates, and with formalized, algorithm-like treatments of other processes such as respiration.

Goals: To establish quantitatively the role of larger zooplankton in the cycling of carbon on the continental shelf of the northeastern United States by measuring biomass using an acoustic Doppler current profiler, by measuring biomass using towed MOCNESS nets, and by measuring growth and grazing rates using ship-board incubation experiments. To separate and understand the roles of advection and *in situ* growth in determining the biomass patterns observed and their impact on the carbon cycle.

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Outcome: The Department of Energy decided to abandon its ocean programs, and its ocean carbon cycle research, during the course of this research activity. Therefore, a decade of fruitful research on the role of zooplankton in the carbon cycle of the continental shelf of the northeastern United States ended without achieving its goals. The lack of vision at the DOI with regard to the role of the ocean in planetary problems such as the carbon cycle and climate change continues to this day. With the present management structure at DOI, it is unlikely the huge knowledge gathered in DOE ocean programs over nearly four decades will ever be used in a coherent way to achieve understanding of the continental shelves of the United States.