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Transport and retention of dormant copepods in the Gulf of Maine

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Abstract

Variability in the availability of dormant copepods to seed productive shelf areas has been hypothesized to influence the abundance of the dominant copepod species *Calanus finmarchicus* in several regions of the North Atlantic. One source of this variability is advection of dormant copepods in deep water. Using Lagrangian particle simulations, we examined the influence of environmental forcing and copepod behavior on transport and retention of dormant *C. finmarchicus* in the deep Gulf of Maine, in the northwestern Atlantic. Retention in the Gulf of Maine was relatively high, >40% over 6 months, under all conditions simulated. Transport within the Gulf of Maine was high, resulting in shifts of eastern copepods into the western Gulf and of upstream copepods, from slope and Scotian Shelf waters, into the eastern Gulf. Copepod behavior during dormancy was a major source of uncertainty, but it is probably not a major source of interannual variability in retention. Retention increased with the initial depth of dormant copepods, and vertical positioning behavior had a strong influence on retention for simulations started at depths greater than 150 m, because copepods that can stay below basin sill depths are retained. Mean cross-shore winds reduced retention slightly (<2% absolute difference), and mean alongshore winds increased retention by 4–8%. Wind-driven interannual variability in retention was low. Variability in Scotian Shelf inflow had a greater influence on retention than did variability in winds, and inflow-driven changes in retention may contribute to interannual variability in copepod abundance associated with changes in deep-water temperature. However, estimates of advective loss are relatively low compared to measured reductions in dormant copepod abundance, and mortality is probably a major factor in this reduction.

Keywords: *Calanus finmarchicus*; Copepod; Dormancy; Diapause; Gulf of Maine; Interannual variability; Zooplankton

1. Introduction

Quantifying transport of zooplankton is a key element in understanding the zooplankton population dynamics observed in continental shelf regions, and thus understanding the factors that control zooplankton availability as prey for fish and as grazers of phytoplankton. Marine zooplankton have geographical ranges that can span thousands of kilometers, and even the largest zooplankton sampling programs can typically only cover a small fraction of the range of target species. Efforts to understand and model zooplankton population

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dynamics must consider immigration and emigration in addition to reproduction, growth, and mortality. Coupled physical–biological models have made significant progress in comparing the effects of advection and biological processes on near-surface zooplankton population dynamics in many regions, including the Gulf of Maine/Georges Bank region (e.g., Davis, 1984; Lynch et al., 1998; Miller et al., 1998; Werner et al., 2001). However, zooplankton behavior, particularly large-amplitude (100 s of m) seasonal vertical migrations associated with dormancy (i.e. suppressed development) in many dominant copepod species (e.g., *Calanus*, *Neocalanus*, and *Calanoides* species), can move plankton across vertical gradients of horizontal velocity and change the flow velocities to which zooplankton are exposed. Vertical migration associated with dormancy may decrease net advection out of regions favorable for growth and reproduction (Eiane et al., 1998; Johnson and Checkley, 2004; Peterson, 1998). In addition, interactions between behavior, deep flow, and bathymetry influence the horizontal distribution of individuals at emergence from dormancy (Osgood and Checkley, 1997a, b), and can influence the initial conditions for population growth in productive areas (Carlotti and Radach, 1996). In the present study, we use a Lagrangian particle-tracking approach to examine transport, retention, and sources of dormant copepods in deep water of the Gulf of Maine in the northwest Atlantic.

In the Gulf of Maine and Georges Bank region of the northwest Atlantic Ocean (Fig. 1), the copepod *Calanus finmarchicus* is a dominant zooplankton species and an important prey item for larval cod and haddock (Buckley and Lough, 1987; Kane, 1984). *C. finmarchicus* is most abundant in spring on Georges Bank, a productive submarine rise, but it largely disappears from Georges Bank in the fall and winter, when the population is dormant, primarily as fifth copepodid developmental stages, in deep water of the Gulf of Maine, continental slope, and Scotian Shelf basins (Davis, 1987; Meise and O'Reilly, 1996; Miller et al., 1991; Sameoto and Herman, 1990). The Gulf of Maine acts as a source of *C. finmarchicus* repopulating Georges Bank in

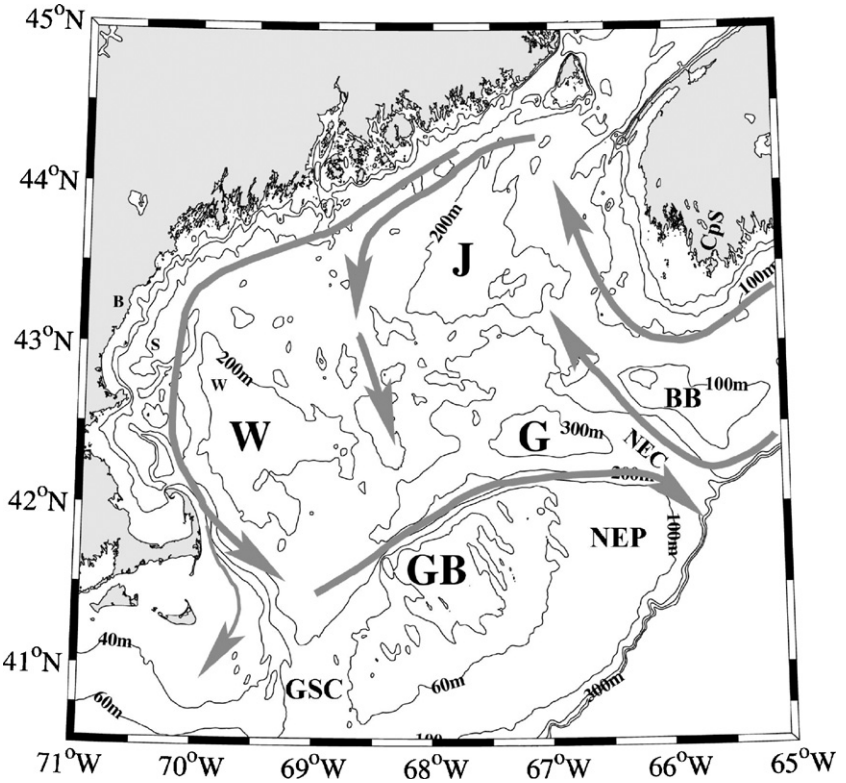

Fig. 1. Circulation in the deep Gulf of Maine. BB—Browns Bank, CpS—Cape Sable G—Georges Basin, GB—Georges Bank, GSC—Great South Channel, J—Jordan Basin, NEC—Northeast Channel, NEP—Northeast Peak, W—Wilkinson Basin.