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Poleward and equatorward currents in the Pacific Eastern Boundary Current in summer 1995 and 1998 and their relationship to the distribution of euphausiids

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Abstract

This paper examines the relationship between poleward and equatorward current patterns and the spatial distribution of euphausiids based on acoustic survey data collected in summer 1995 and 1998 in the California Current Ecosystem. Contiguous poleward (usually an undercurrent) and equatorward near-surface current core areas were identified by applying current velocity and distance thresholds along each survey transect. Both currents were pervasive along the coast, but poleward volume transport in both years was about an order of magnitude greater than the equatorward near-surface current volume transports. The poleward volume transport was higher in 1998 than in 1995, especially north of Cape Blanco. The poleward transport centroid was generally further offshore than the surface transport centroid, and was closer to the slope in 1998 than in 1995. The depth centroid of euphausiid patches was generally shallower than the depth centroid of the poleward volume transport centroids. The onshore–offshore location of euphausiid patches was significantly related to the location of the poleward transport centroids, although not in all regions. The patches were not related to the location of equatorward near-surface transport centroids.

Differences in the north–south euphausiid distribution were observed between 1995 and 1998. In 1995, there was a much higher abundance of euphausiids in the region immediately north of Cape Blanco, while in 1998, euphausiid abundance was high throughout the survey area. We hypothesize this difference to be in part a result of differences in current patterns between the 2 years and the manner in which currents interact with euphausiid diel migration.

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1. Introduction

The California Current Ecosystem (CCE) supports a great abundance of euphausiids dominated by *Euphausia pacifica* and *Thysanoessa spinifera*. These two species also serve as the major food item for pelagic fish species, especially the gadoid, Pacific hake (*Merluccius productus*, Livingston and Bailey, 1985; Tanasichuk et al., 1991), which is the most abundant mesopelagic fish throughout the CCE during the summer (Dorn et al., 1999). These euphausiid populations are pervasive along the coast and exist in large patches or swarms, which begin near the coast and can extend up to 150 km offshore, well past the continental shelf-break zone (defined as the zone having a bottom depth between 200 and 800 m, Swartzman and Hickey, 2003). Euphausiids migrate on a diel basis likely because of heavy predation (De Robertis, 2002), moving up in the water column at dusk, presumably to have access to their plankton food sources (both phytoplankton and smaller zooplankton, Nakagawa, 2002) and down again near dawn.

The diel migration occurs in the presence of strong coastal currents. In general, over the shelf in summer, currents are equatorward (Strub et al., 1990). Over the slope, surface currents are equatorward, but the seasonal poleward California undercurrent dominates subsurface currents (Hickey, 1998). This undercurrent, a ubiquitous feature of Eastern Boundary systems, generally has a higher velocity core at depths of 200–300 m, just below the shelf break. The high-speed core is relatively narrow (10–20 km), with typical speeds of 10–20 cm s^{-1} (Pierce et al., 2000).

The strength and persistence of these currents provide a challenge to diel migrating euphausiids, which maintain average swim speeds between 1 and 2 body lengths per second (1.8–3.5 cm s^{-1}; De Robertis et al., 2003) and therefore cannot maintain their position by swimming against the currents. Thus, they may be at risk of being swept out of the shelf-break zone or away from aggregations of their prey. However, it has been suggested (Mackas et al., 1997) that adult euphausiids can maintain their position along the continental shelf break through diel migration. Both the poleward undercurrent and the near-surface equatorward current, meander and change in velocity and size over space (Pierce et al., 2000). Thus, the effect of diel migration by euphausiids in the CCE on their spatial distribution may depend on both the longer-term pattern of the undercurrent and surface current and the onshore–offshore currents associated with upwelling and with tides. This paper examines the meso-scale pattern of these currents during summer 1995 and 1998 in the CCE and their relationship to euphausiid abundance to determine how the strength and location of the undercurrent and surface current influence the euphausiids' distribution.

2. Data and methods

The data used in this paper were collected by the National Marine Fisheries Service Alaska Fisheries Science Center aboard the M/S Miller Freeman during July and August 1995 and 1998. The ship was equipped with a hull-mounted (9-m depth) SIMRAD EK-500 split-beam echosounder operating at 38 and 120 kHz. An RD Instruments 153.6 kHz narrow-band, hull-mounted Acoustic Doppler Current Profiler (ADCP) measured currents throughout the survey. These data were processed, using University of Hawaii CODAS software, to produce north–south and east–west current velocities in 2.5-min horizontal (about 0.75 km at 10 knots) × 8-m vertical bins (Pierce et al., 2000; Kosro et al., 2001). The ship followed transects in an east–west direction, crossing the shelf-break zone at 10 nm intervals in both years from mid-California to Vancouver Island, British Columbia (Fig. 1, Swartzman and Hickey, 2003). Since the primary purpose of the survey, i.e. assessment of abundance of Pacific hake (*Merluccius productus*) was conducted during the daytime only, the majority of the data were collected during the day. For the present paper, only daytime data were selected.

Zooplankton patches were identified using both the 38 and 120 kHz data from SIMRAD, by image thresholds and by image differencing and morphological filters, based on geometric models and net corroboration (Stanton and Chu, 2000;