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Interannual variability in the Northern California Current food web structure: Changes in energy flow pathways and the role of forage fish, euphausiids, and jellyfish

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ABSTRACT

The Northern California Current (NCC) is a seasonally productive and open ecosystem. It is home to both a diverse endemic community and to seasonally transient species. Productivity and food web structure vary seasonally, interannually, and decadally due to variability in coastal upwelling, climate-scale physical processes, and the migratory species entering the system. The composition of the pelagic community varies between years, including changes to mid-trophic level groups that represent alternate energy-transfer pathways between lower and upper trophic levels (forage fishes, euphausiids, jellyfish). Multiple data sets, including annual spring and summer mesoscale surveys of the zooplankton, pelagic fish, and seabird communities, were used to infer NCC trophic network arrangements and develop end-to-end models for each of the 2003–2007 upwelling seasons. Each model was used to quantify the interannual variability in energy-transfer efficiency from bottom to top trophic levels. When each model was driven under an identical nutrient input rate, substantial differences in the energy available to each functional group were evident. Scenario analyses were used to examine the roles of forage fishes, euphausiids, and jellyfish (small gelatinous zooplankton and large carnivorous jellyfish) as alternate energy transfer pathways. Euphausiids were the more important energy transfer pathway; a large proportion of the lower trophic production consumed was transferred to higher trophic levels. In contrast, jellyfish acted as a production loss pathway; little of the production consumed was passed upwards. Analysis of the range of ecosystem states observed interannually and understanding system sensitivity to variability among key trophic groups improves our ability to predict NCC ecosystem response to short- and long-term environmental change.

1. Introduction

The Northern California Current (NCC) extends from roughly Vancouver Island, British Columbia in the north to Cape Mendocino, California, in the south. Seasonally, it is a highly productive upwelling ecosystem. Upwelling favorable winds predominate following the spring transition in March–April and continue through October–November (Strub et al., 1987). Lower trophic level production in the NCC is closely tied to the strength, timing, and duration of seasonal upwelling and nutrient input along the coastline (Checkley and Barth, 2009).

The NCC also lies within a zoogeographic transition zone; the pelagic community (from zooplankton to fish, birds, and mammals) is a mix of subarctic and subtropical species (Brodeur et al., 2003; Peterson et al., 2002). During the upwelling season, it is home to a diverse pelagic fish community including both year-round resident species (anchovies, smelts, herring) and transient species migrating from the south (sardines, hake, mackerels). The composition of the pelagic community across most trophic levels varies on interannual to interdecadal time scales due to variation in local production and forcing by basin-scale physical processes (e.g., El Niño, Pacific Decadal Oscillation) and associated movement of large water masses (Emmett et al., 2006; Keister and Peterson, 2003). The structure of the NCC food web and the efficiency of energy transfer from producers to top trophic levels also varies interannually (Brodeur and Pearcy, 1992; Litz et al., 2010).

Three mid-trophic level groups are of particular importance to the structure and function of the pelagic NCC food web. (1) Forage fishes: In coastal upwelling systems, small pelagic forage fishes

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