Shifts in zooplankton abundance and species composition off central Oregon and southwestern British Columbia

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Dr. Dave Mackas is a biological oceanographer and zooplankton ecologist who works mainly on the distribution and dynamics of zooplankton populations in coastal and offshore regions of the Northeast Pacific. He has served on several PICES Committees and Working Groups, presently including BIO, MONITOR, and WG 14 on Micronekton. Despite their semi-youthful appearances and personalities, he and Dr. Peterson have been bumping professional elbows (in a friendly way) for about a quarter of a century.

It has long been known that water masses have characteristic temperature-salinity signatures (Sverdrup et al. 1942), and that these water masses are associated with the major gyre and boundary current systems. Biological oceanographers have also established that many zooplankton species have geographical distributions that correspond well with water masses, and arguably even more closely with the circulation patterns that allow reproductive closure of their life cycles. Because of close associations of many zooplankton species with water masses and water types, certain species can be used as indicators of the presence/absence of a water type, giving rise to the concept of using species as tracers (e.g. Bary 1959, McGowan 1971). Within the California Current, Fleminger (1967) classified the copepod fauna into five biogeographical types: subarctic, transitional zone, Central Pacific species, equatorial oceanic, and coastal neritic species. Coastal neritic species were further classified as boreal-temperate, temperate-subtropical and tropical. As the water goes, so go the plankton.

In the northern half of the California Current system, current speed and direction are strongly seasonal. During spring and summer, surface waters flow toward the south, driven by winds that blow equatorward. The plankton species that dominate the region are transported from the north. Prevailing winds and coastal currents reverse in the fall, usually in late October, and waters flow northward

as the Davidson Current, bringing an assemblage of southern, warmer water species to coastal Oregon and British Columbia waters. Thus seasonal reversals in shelf currents generate changes in zooplankton species composition in shelf and slope waters of the southern British Columbia, Washington and Oregon coasts. The nitty-gritty details of these seasonal changes in copepod abundance and species composition in continental shelf waters off Oregon during the 1970s were described by Peterson and Miller (1977), and for the 1980's for the westcoast of Vancouver Island by Mackas (1992). In both regions, during spring and summer of the 1970s and 1980s, the copepod assemblage was dominated by boreal (subarctic) species -- *Pseudocalanus mimus*, *Calanus marshallae*, *Metridia pacifica*, *Acartia longiremis*, and *Centropages abdominalis*. During winter months they observed a minimum in the abundance of these boreal species and in total copepod abundance, but increased abundance of subtropical neritic (coastal) and/or transitional zone species such as *Calanus tenuicornis*, *Paracalanus parvus*,*Clausocalanus arcuicornis*, *C. pergens*, *Ctenocalanus vanus*, *Acartia tonsa* and *Corycaeus anglicus*. Off Oregon, the more southerly species dominated the winter copepod community (Peterson and Miller 1977), while off BC, their increase was to about 5-10% of the total copepod biomass (Mackas 1992).

We learned from subsequent work in the 1990s, that there is also considerable interannual-to-decadal-scale variability in zooplankton community structure in the northern California Current. The seasonal pattern described above began to break down in the early 1990s, starting a dramatic shift in species composition (Fig 1). The spring-summer abundance of the boreal copepod species declined off both central Oregon and off southwestern British Columbia, while subtropical neritic and transitional zone species (*Paracalanus*, *Ctenocalanus*, and *Clausocalanus* species) became increasingly common in continental shelf waters of both regions. Moreover, the warm water copepods persisted throughout the year to at least 1998, for a total of six years. How can this be? The conventional wisdom is that the presence of warm water species over the extended period of 1992-1998 is explained by persistent El Niño conditions throughout most of this period. This trend to a more southerly copepod community reversed quite suddenly in 1999 -- the ecosystem reverted back to the patterns seen in the 1970s and 1980s, with boreal neritic species dominating the copepod assemblages, and southern subtropical neritics being common only during winter months. The story is not just about copepods! Dramatic changes in euphausiid and pelagic fish species composition also occurred in the 1990s in the northern California Current. The coastal euphausiid *Thysanoessa spinifera* became less abundant in shelf

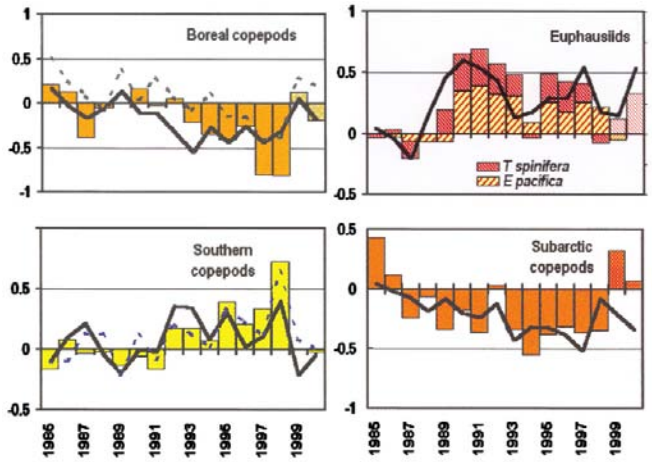

Fig. 1 1985-2000 zooplankton anomaly timeseries for the southern B.C. continental margin (adapted from Mackas et al. 2001 to include 2000 data). Annual anomalies (coloured bar graphs) are averaged within year and within major species groups, and are logarithmic in scale: an anomaly of 1.0 (-1.0) means that species within the group were on average 10 fold more (less) abundant than their seasonal norm. Lines are regression fits against 1985-1998 local (dashed) and large-scale (solid) climate indices.

waters off Oregon and in Barkley Sound (Tanasichuk 1998), and the more oceanic euphausiid species, *Euphausia pacifica*, became common in shelf waters. In addition, warm-water pelagic fishes such as juvenile sardines, jack mackerel and Pacific mackerel became common in continental shelf waters, and the northward-migrating Pacific whiting (hake) population appeared earlier each year since 1992, to the point that in 1998, the migrants reached southeast Alaska. There is evidence that hake were spawning off both the Oregon and British Columbia coasts in the 1990s.

Ecosystem structure began to change again in late 1998 and early 1999, with the near disappearance of most of the subtropical neritic copepods from shelf waters in summer, a return of *Thysanoessa spinifera* to shelf waters, a decline in numbers of warm water pelagic fish, and a hake migration that did not reach as far north as British Columbia in 2000. The PDO changed sign (to negative) in 1999, suggesting that the changes in zooplankton community structure and fish distribution coincided with a shift in climate. By the spring and summer of 2000, the continental margin copepod community was once again composed almost entirely of species that are boreal/subarctic in origin, the euphausiid *Euphausia pacifica* was found only in offshore waters, mackerel had disappeared from shelf waters, no juvenile sardines were found (although adults remained somewhat common), and perhaps most significantly, large numbers of anchovies had returned to the area and were again spawning in the Columbia River plume. The latter point is significant because large numbers of anchovies have not been seen since the 1977 regime shift. These collective observations beg the

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