



# Inter-annual variations of zooplankton in the northern coastal Gulf of Alaska

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## Abstract:

The Seward Line in the Northern Gulf of Alaska has been the focus of multidisciplinary sampling for the past 9 years. Over the study period we have observed years favorable and unfavorable to the local zooplankton species (e.g. a 5 fold range in *Neocalanus plumchrus/flemingeri*), and observed the summer import of southern species during warm years (e.g. *Calanus pacificus*, *Mesocalanus tenuicornis*, *Paracalanus parvus*). Surprisingly, even some subarctic species (e.g. *Calanus marshallae*, *Limacina helicina*) appear to do better during many warmer springs. Differences in temperature, along with chlorophyll, drive growth and reproduction of the zooplankton. This has consequences for the annual progression of the *Neocalanus* populations that dominate the spring, and the smaller species, such as *Pseudocalanus*, that dominate the summer zooplankton communities.

## Introduction:

We have long appreciated that the ocean experiences variation from year to year, but only recently appreciate that long-term trends and even pronounced shifts may also be occurring. Short-term events such as El Niño and La Niña can result in changes in ecosystem productivity that result in increased or decreased survival of commercial and non-commercial species. Longer term changes can result in fundamental shifts in ecosystem structure and function, such as the 1976 regime shift in the Gulf of Alaska that resulted in a change from a shrimp dominated fishery to one dominated by pollock, salmon and halibut. One of the greatest challenges to detecting and understanding such changes is the lack of appropriate oceanographic time-series that couple these physical events to their biological manifestations. The multidisciplinary time-series of the northern Gulf of Alaska's Seward Line allows such observation of short and long-term changes in the oceanography of a region that is critical to Alaska's fisheries, subsistence and tourist economies.

## Methods:

Long-term observations began the fall of 1997, with 6 or 7 cruises conducted annually until 2004 under the NSF/NOAA GLOBEC program. During 2005 & 2006, NPRB-funding allowed continuance of cruises in early May and early September. Sampling during cruises consisted of 13 stations along the Seward Line stretching from the coast to well beyond the shelf break, and 3-5 stations in western Prince William Sound (Figure 1). Sampling during all cruises consisted of: A) profiles of temperature, salinity, nutrients and chlorophyll, B) stratified sampling of larger zooplankton (505 µm mesh) and integrated sampling of smaller zooplankton (150 & 53 µm mesh), C) estimation of the community rates of primary production and the rates of secondary production for the dominant zooplankton species (somatic growth & egg production).

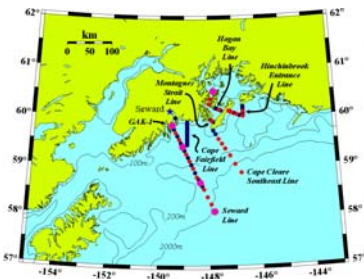


Fig.1. Sampling area. Experimental sites indicated in larger red dots.

## Results (physical):

To date the study period has encompassed the strong 1997/98 El Niño, the strong 1999 La Niña, the moderate 2002/03 El Niño, and the anomalously warm non-El Niño years of 2000 & 2005 (Fig 2a). Each of these events is apparent in the physical time series (Fig 2c). It is not apparent if a 1998/99 regime shift as suggested by a change in PDO sign (Fig. 2b) has occurred within the time-series. With both the 2005 and 2006 profiles consistent with the long-term deep warming trend observed at the inshore station Gak1 for which a 30-year physical time series is available (Fig. 2d,e).

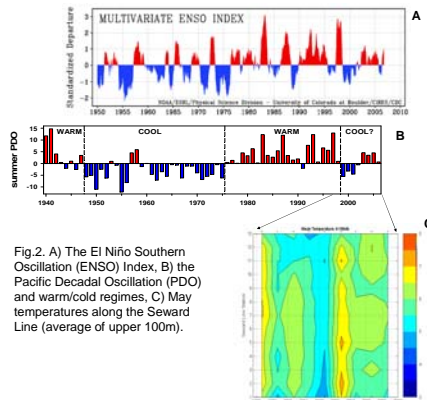


Fig.2. A) The El Niño Southern Oscillation (ENSO) Index, B) the Pacific Decadal Oscillation (PDO) and warm/cold regimes, C) May temperatures along the Seward Line (average of upper 100m).

## Results (biological):

Like all biological communities we can see changes in abundances of species between years. Of the large copepods that dominate the spring, the largest, *Neocalanus cristatus*, shows no significant pattern across years, while the slightly smaller *N. plumchrus/flemingeri* show significantly higher abundances in 3 years and lower abundances in 3 years (Fig 3). Similarly, *Eucalanus bungii*, and *Metridia pacifica*, show significant variation between years, while *Calanus marshallae* shows large increases in abundance during 2005 & 2006. Smaller species (i.e. *Oithona*, *Pseudocalanus*, *Acartia*) are also variable, but there appears to be little consistency in pattern between species. Although warm years may not affect abundance, they do effect growth rates & passage of stages through the ecosystem (Fig 4). Like the copepods, the mucus-net feeding *Oikopleura* and *Limacina* are variable, but for *Limacina*, higher abundances occur only during "warmer" springs (Fig 5).

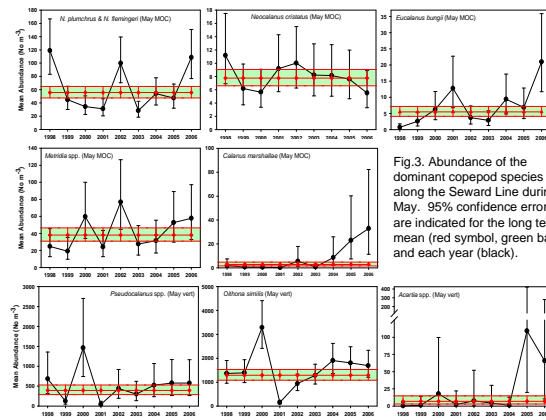


Fig.3. Abundance of the dominant copepod species along the Seward Line during May. 95% confidence errors are indicated for the long term mean (red symbol, green bar) and each year (black).

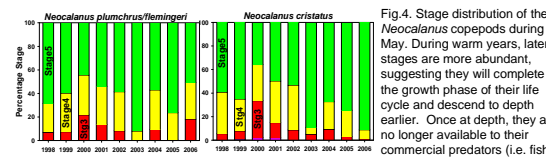


Fig.4. Stage distribution of the *Neocalanus* copepods during May. During warm years, later stages are more abundant, suggesting they will complete the growth phase of their life cycle and descend to depth earlier. Once at depth, they are no longer available to their commercial predators (i.e. fish).

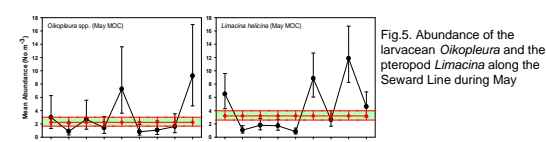


Fig.5. Abundance of the larvacean *Oikopleura* and the pteropod *Limacina* along the Seward Line during May

During the late summer, water temperatures are at their highest and we continue to see significant variability in abundance of the small copepods that dominate the zooplankton (i.e. *Oithona*, *Acartia*, *Pseudocalanus* - Fig 6). More interestingly, during warm years "southern" species often appear within the zooplankton communities. During the 1997/98 El Niño, the copepod *Mesocalanus tenuicornis* became common in nearshore waters, while during 2005 the small copepod *Paracalanus parva* was spread completely across the Seward Line (Fig 7). The copepod *Calanus pacificus* was more consistent, occurring during warm years in offshore waters, but remained notably common even during 2006. When common, these "warm" water species have the potential to change the size-spectra of the zooplankton and may alter the foraging efficiency of visual predators (i.e. fish).

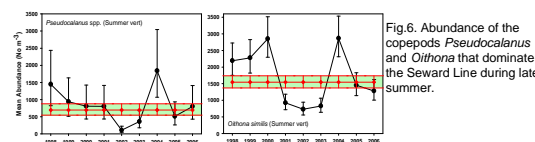


Fig.6. Abundance of the copepods *Pseudocalanus* and *Oithona* that dominate the Seward Line during late summer.

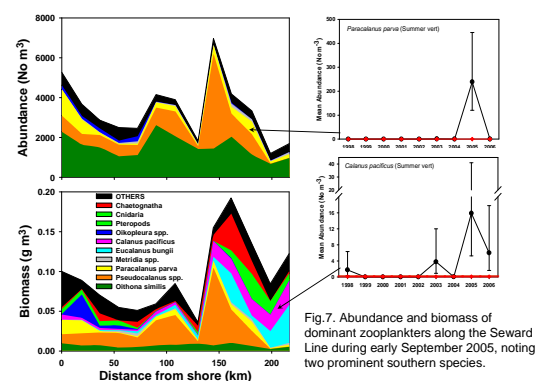


Fig.7. Abundance and biomass of dominant zooplankters along the Seward Line during early September 2005, noting two prominent southern species.

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