Calanus finmarchicus

Background

This rice-sized planktonic crustacean is primarily an oceanic and subsurface species carried into coastal regions and open bays. Although *C. finmarchicus* has been reported as widely distributed (Wilson 1932), it is likely most abundant in the North Atlantic (Marshall and Orr 1955), where it represents more than half of the copepod biomass (Planque and Batten 2000). In the northwest Atlantic it occurs from the Arctic (79°N) to Chesapeake Bay. North of Cape Cod and offshore it is the most abundant copepod throughout the year, including the Gulf of Maine and Georges Bank region. Occurrences south of Cape Cod are sporadic (Gerber 2000). Bathymetrically, the species has been reported from near-surface waters down to 4000m. However, other then when hibernating (see below) this species is most dominant within 200 m from the ocean surface.

Life cycle

From eggs, shed into near-surface waters in early spring (March-April), emerge nauplii larvae within about 24-72 hours from spawning. Naupliar development consists of six consecutive moulting stages (N1-N6), resulting in progressively larger and morphologically more complex larvae. This is followed by a metamorphosis of N6 to a first copepodite stage (C1), with five subsequent moults culminating in a (C6) mature animal. Development is synchronized with the diatom spring bloom, representing the major food source for *C. finmarchicus*.

At typical temperatures development from egg to adult takes about one month, with eggs maturing for about another month. This allows for the production of three or more generations during a season (Marshall and Orr 1955). With the onset of colder temperatures during late summer and fall mostly pre-adult C5 copepodites migrate into deeper water, entering a period of dormancy (diapause), forming dense layers near the bottom of basins and continental slope waters at depths of 500-2500 m. This permits survival during periods of food shortage (Hirche, 1996). In late to mid-winter survivors migrate to surface waters, favouring nearshore transport, where they undergo the terminal molt to maturity and reproduce to produce the first generation in spring.

Fishery

There is no fishery for *Calanus finmarchicus* but it is a key component of the North Atlantic ecosystem and an indicator of the state of the marine food web since it is vital link in channelling energy between primary production and higher trophic levels that include fisheries species. Rich in lipids and fatty acids, this copepod is crucial component of the cold water food chain, being the primary food source for juvenile and adult fishes such as cod, haddock, herring and mackerel (Gerber 2000, Wilson 1932). Other similarly dependent species are sea birds, such as leaches storm petrels, and whales, including sei, bowhead, and the severely endangered right whale (Greene and Pershing 2004). Invertebrates such as siphonophores and euphausiids are also major *C. finmarchicus* predators (Benfield et al., 1999).

Temperature limits
Sea surface temperatures in the current distribution of *C. finmarchicus* range from a February minimum of -2.1ºC to an August maximum of 24.1ºC. Carlotti et al. (1993) summarized data for specimens occurring at temperatures ranging from 0-17ºC, finding that for different copepodite stages lower temperatures were more beneficial in that specimens were generally characterized by higher body weights and vice versa, with an increased effect noted in early copepodites. This agrees with the general perception of *C. finmarchicus* as an indicator species of cold subarctic waters (Beaugrand et al 2002).

Impacts
Temperature plays a significant role in the timing and development of plankton communities and therefore the development of other marine communities. A 4ºC rise in global temperature will impact the future distribution of *Calanus finmarchicus* in the western Atlantic. Results from the four models under two scenarios agree in a predicted loss of range in waters south of Cape Cod. This loss extends as an easterly band into the Atlantic, with the CSSR model showing a widest affected area. With *C. finmarchicus* occurring further into the Atlantic, these losses are likely to extend further offshore beyond areas not covered in this study. In addition to these affected regions the CSSR and GFDL models show potential habitat loss in parts of the Gulf of St. Lawrence, with the former model also indicating loss of habitat in Labrador waters. No northward gain of habitat is predicted in our study, but this is not necessarily so as the study did not extend to the northern limit of *C. finmarchicus* (79ºN).

With the present-day sporadic occurrence of *C. finmarchicus* south of Cape Cod, that is likely associated with temperature limitations, any impact related to this copepod should be less in that region than elsewhere. However, adjacent northeast areas that include the Gulf of Maine, will likely become suboptimal for growth and survival under the predicted temperature scenario. The likely resultant shift of decreased abundance and biomass of *C. finmarchicus* into the Gulf would have considerable effects, as this copepod is a primary food source for several commercial fish, sea birds and whales in that area.

Calanus finmarchicus may adapt to increasing water temperatures resulting from global warming by slowly shifting its distribution northward to remain in suitable temperatures. This appears possible because of their life history, mobility, and the presence of appropriate habitat where water temperatures will remain suitable. Northern expansion beyond the present range appears limited, however, and *Calanus*-dependent species would likely be negatively impacted in the southern range of *C. finmarchicus*. Thus local southern fishing activities would also be affected, as could the whale watching industry.

There are indications that *C. finmarchicus* is sensitive to subtle changes in climate, as it appears to already have been affected by climate change. It is established that there has been a reduction in biomass and abundance of *C. finmarchicus* over the last 30-40 years (Anon, 2004). Climate warming in areas surrounding Greenland, that increased

freshwater input to the Atlantic, decreased the process of water cooling and sinking at sea that is part of the North Atlantic Oscillation (NAO). This affected the formation of cold bottom water volume and also changed wind patterns. Both allow copepods to ascend and then be carried to appropriate areas. The reduction of the NAO has effectively reduced the supply of copepods. As warming continues, this trend is likely further change the predominance of *Calanus*.

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