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Increasing abundance of *Calanus finmarchicus* in the central and eastern North Atlantic between 1958 and 1996

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The abundance of *Calanus finmarchicus* is known to have fallen between the present and the late 1950s in north-eastern Atlantic shelf waters. Further west in deeper water, however, long-term abundance of the copepod has risen.

Calanus finmarchicus is an important copepod of the large gyral systems of the North Atlantic Ocean and Nordic Seas and its main population densities are concentrated along an approximately south-west to north-east axis across the entire North Atlantic (Glover, 1967; Jaschnov, 1970; Bucklin et al., 1996). Here we show that numbers of *C. finmarchicus* in the Nordic Seas and in the Atlantic Ocean south of Iceland have increased since the late 1950s. This is an unexpected discovery because long-term *C. finmarchicus* abundance has declined in other North Atlantic locations (Beare & McKenzie 1999a,b,c,d). It is well known, for example, that the abundance of *C. finmarchicus* has collapsed in the northern North Sea (e.g. Fromentin & Planque, 1996; Planque & Fromentin, 1996; Beare et al., 1998, Beare & McKenzie, 1999c) with a particularly rapid fall occurring in 1967. Also there is evidence that *C. finmarchicus* is being replaced by the closely related Mediterranean species, *Calanus helgolandicus* (Fromentin & Planque, 1996; Heath et al., 1999). Similar patterns have been reported from the shallower seas of Iceland, particularly over the North Icelandic Shelf Subregion, (Astthorsson & Gislason, 1995) where diminishing numbers of *C. finmarchicus* (May and June) are superimposed on increasing numbers (May and June since the late 1980s) of the Arctic calanoid, *Calanus hyperboreus* (Beare et al., 2000).

Temporally (monthly) and spatially (longitude and latitude) resolved data for stages 5 and 6 of the calanoid copepod *Calanus finmarchicus* for the subregion 30°W to 5°E and 60°N to 63°N were obtained from the Sir Alister Hardy Foundation for Ocean Science (SAHFOS) who run the Continuous Plankton Recorder (CPR) [see Hays et al., 1993; Warner & Hays, 1994]. The data were first divided into four arbitrary subregions (Figure 1) and the time dependence, within each, of zooplankton abundance modelled as a function of long-term trend (absolute time) and seasonality (month) (Beare & McKenzie, 1999b). The application of these models to CPR data, together with information on goodness of fit criteria, overdispersion and residual analyses are discussed in more detail elsewhere (Beare & McKenzie, 1999b,c).

In subregion 1 (Figure 1) surface population abundances ranged between winter minima of ~0.3 and summer maxima of over 70 individuals 3 m^{-3}, and has increased overall between 1958 and 1986 (Figure 2). The shape of the annual seasonal cycle has changed over long-term time, viz the lack of parallelism in the trend lines for April and June (Figure 2). There was also no evidence that the timing of the main seasonal peak had changed

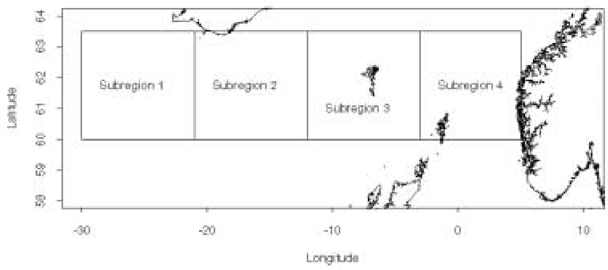

Figure 1. Map showing location of subregions 1, 2, 3 and 4.

systematically. The months of April and June, highlighted (Figure 2) because of their likely importance in the natural history of *C. finmarchicus*, exhibited very different secular trends. Between 1958 and around 1974 they behaved similarly, rising between 1958 and 1964, falling between 1965 and 1970 and increasing again thereafter. In 1974 there was an abrupt divergence and June rose, becoming the peak month between 1979 and 1983. Subregion 2 is south-east of Iceland, due east of the Faroes. In the early part of the series the annual cycle of *Calanus finmarchicus* abundance was bimodal, with peaks in May and August and troughs in June and July (Figure 2). After the late 1960s the annual cycle became progressively more unimodal in shape with a strong May peak shifting to June (Figure 2). Long-term abundance has risen almost four times from ~15 individuals 3 m^{-3} in 1960 to ~60 individuals 3 m^{-3} in 1996. Much of the latter parts of the series demonstrate that the rise in abundance has actually come from sequential June increases, while April abundance has declined (Figure 2). Overall the long-term trend in the abundance of *Calanus finmarchicus* in subregion 3 has also risen slightly (Figure 2). Densities ranged between 0.2 and 50 individuals 3 m^{-3}. The rising trend is associated with seasonal maxima shifting in time from May to June (Figure 2). There is also another strong negative relationship between successive Aprils and Junes (see Figure 2). Regrettably there are no CPR data available for subregion 4 since the end of 1981 and sampling coverage in the middle part of this subregion is also sparse. Surface population abundance of *C. finmarchicus* was much higher than in subregions 1, 2 and 3 ranging between 1.6 and 238.8 3 m^{-3}. The explanation for this observation is unclear to the authors, although it is certainly not due to any bias arising from systematic change in sampling location. Long-term abundances

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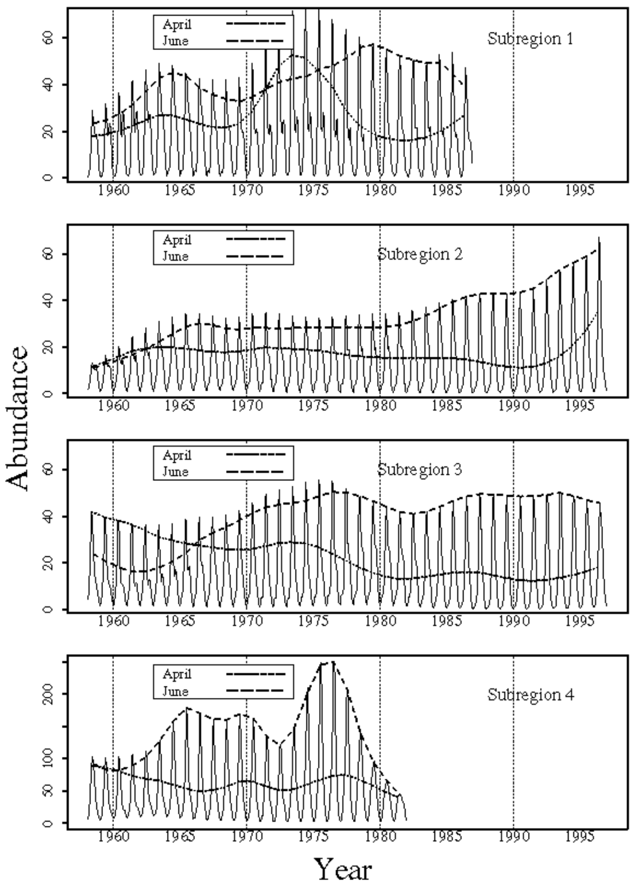

Figure 2. Abundance (numbers $3\,\mathrm{m}^3$) of stages 5 and 6 *Calanus finmarchicus* in subregions 1 to 4 between 1958 and 1996. The months of April and June are highlighted.

rose steadily up until 1975 (Figure 2), while a detailed examination of the time series suggests that the seasonal peak in the year has moved from May in the late 1950s and early 1960s to June more recently. The rising trends we observed in the abundance of *Calanus finmarchicus* (stages 5 & 6) in the North Atlantic could not be explained convincingly using any of the time series data available to the authors (e.g. sea surface temperature, wind stress, sea level pressure, Gulf Stream position, and North Atlantic Oscillation index). The purpose of this short communication, therefore, is to alert the marine scientific community to the fact that *Calanus finmarchicus* abundance has risen in certain parts of the Atlantic Ocean, and that the decline seen in shelf waters (North Sea, North Icelandic Shelf Region) cannot be considered to be a pan-Atlantic phenomenon.

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