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The occurrence of *Calanus finmarchicus* (Gunnerus) and *Calanus helgolandicus* (Claus) in the western Irish Sea

R.J.Gowen, M.Dickey-Collas and G.M[c]Cullough[1]

Agricultural and Environmental Science Division, Department of Agriculture for Northern Ireland and [1]Department of Agricultural and Environmental Science, The Queens University of Belfast, Newforge Lane, Belfast BT9 5PX, UK

Abstract. The seasonal abundance of *Calanus finmarchicus* and *Calanus helgolandicus* in the North Channel and stratified region of the western Irish Sea is reviewed using data collected between 1992 and 1996. Both species occur in the western Irish Sea, but were more abundant in the stratified region during spring. Increased abundance during May/June was attributed to an increase in copepodite stages. *Calanus helgolandicus* dominated in both regions, exhibiting spring and autumn peaks in abundance in the stratified region. It is argued that the presence of ripe females and naupliar stages in the stratified region is evidence of an *in situ* breeding population, rather than advection of individuals from population centres outside the Irish Sea. The lack of geographical separation of the two species in the western Irish sea, and reports that both species occur in the Celtic Sea and Malin Shelf, limit the use of either species as indicators of exchange processes between the Irish Sea and neighbouring waters.

Introduction

The conspecific copepods *Calanus finmarchicus* (Gunnerus) and *Calanus helgolandicus* (Claus) are a major component of the zooplankton in oceanic waters and shelf seas of the north-east Atlantic (Rees, 1949; Williams *et al.*, 1994; Planque and Fromentin, 1996). *Calanus finmarchicus* is a cold temperate species with two main populations in the north Atlantic, whilst *C.helgolandicus* is a warmer water species with population centres to the south of the British Isles (Matthews, 1969; Fleminger and Hulsemann, 1977). Their perceived trophic importance has led to many studies on both species over the last 50 years (Marshall and Orr, 1955; Hirche, 1983; Williams, 1985; Diel and Klein Breteler, 1986; Fransz *et al.*, 1991, and references cited therein). However, in the Irish Sea, questions still remain about the abundance, population dynamics and the role of both species in the food web.

According to Planque and Fromentin (1996), the Irish Sea lies between the population centres for each species, which are said to be the Malin Shelf for *C.finmarchicus* and the Celtic Sea for *C.helgolandicus*. In certain years, the western Irish Sea supports a large biomass of *Calanus* spp. (Scrope-Howe and Jones, 1985; Williams *et al.*, 1994). Few studies have distinguished between the two species in the Irish Sea, because either their separation as species was unresolved (Herdman, 1918) or authors have assumed on the basis of earlier reports (Williamson, 1952, 1956) that only *C.finmarchicus* occurred in the area (Scrope-Howe and Jones, 1985).

Williamson (1952, 1956) considered that neither species was endemic, and that the seasonal abundance and geographical distribution of *C.finmarchicus* and *C.helgolandicus* in the Irish Sea were largely dependent on exchange processes

with neighbouring seas. This suggestion has not been tested further, but if substantiated it would suggest that the Irish Sea is similar to the North Sea, where the distribution and seasonal abundance of both species have been related to advection (Rees, 1949; Fransz *et al.*, 1991; Backhaus *et al.*, 1994).

In this paper, we review the seasonal abundance of *C.finmarchicus* and *C.helgolandicus* in the western Irish Sea, based on new data collected over 5 years between 1992 and 1996.

Method

Sampling was undertaken during research cruises on board the RV 'Lough Foyle' at two stations over a period of 5 years (1992–1996). One station was located in the North Channel (54°41′N, 05°20′W) in a water depth of ~135 m and has a

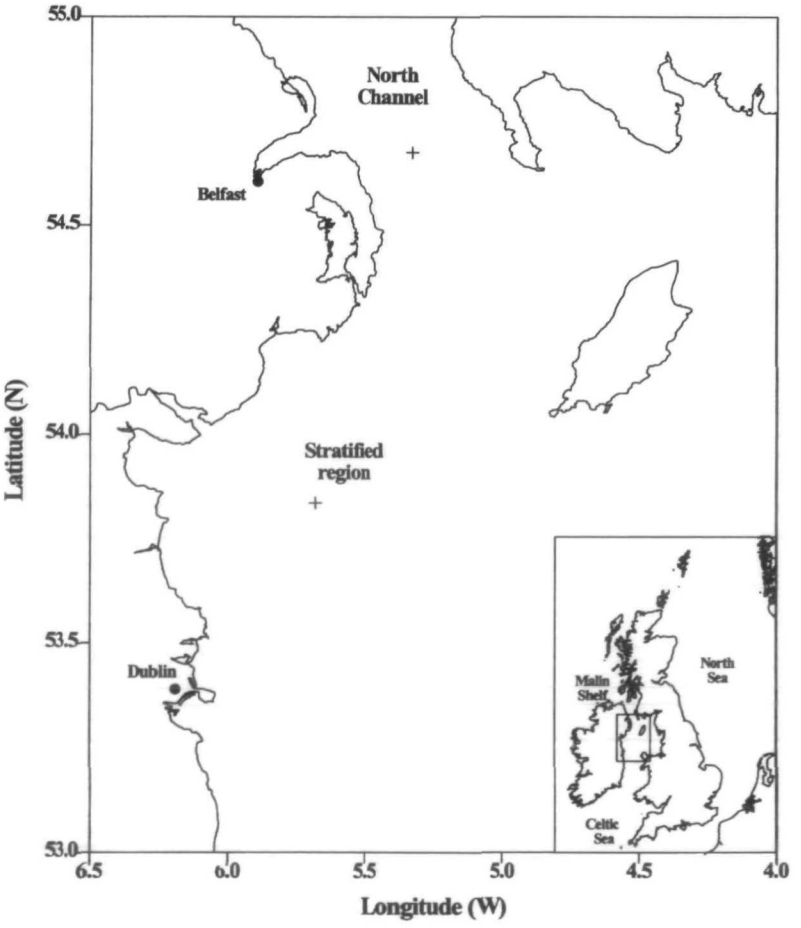

Fig. 1. A map of the Irish Sea showing the location of the sampling stations (+) in the North Channel and stratified region.

mixed water column throughout most of the year [Figure 1; Station 4 in Gowen *et al.* (1995)]. The other station was in the central region of the western Irish Sea (53°51′N, 05°34′W) with a depth of ~105 m, which is thermally stratified during spring and summer [Figure 1; Station 38 in Gowen *et al.* (1995)].

In 1992 and 1993, zooplankton were sampled by vertical haul with a 0.6 m diameter, 300 μm mesh ring net from 2 m above the sea bed to the surface. Flow through this net was not measured and abundance per unit area was calculated assuming that the net has sampled a vertical profile. Between 1994 and 1996, samples were collected with a modified, Gulf III type plankton sampler (Beverton and Tungate, 1967), fitted with a 280 μm mesh net. The sampler was deployed in a double oblique manner from the sea surface to within 2 m of the sea bed. Measurements of water flow by internal and external flowmeters were continuously recorded during each tow. This allowed net clogging to be monitored and the total volume filtered by the net to be estimated. Ring net and Gulf III samples were preserved in 4% buffered formaldehyde. Total *Calanus* spp. abundance was determined by volumetric subsampling (three 5 ml replicates) using a 250 ml Schott Stempel pipette flask. The adults of the two species were distinguished on the basis of the shape and teeth of the basipod of the fifth swimming legs (Rees, 1949; Marshall and Orr, 1953; Matthews, 1967). Copepodite stages were not identified to species.

Results

There was an increase in the abundance of *Calanus* (both species, copepodites and adults) in the North Channel and stratified region during April and May, and a decline in October/November (Figure 2A and B). The data suggest that during the spring there was a greater abundance of *Calanus* spp. in the stratified region compared to the North Channel, although no data were collected from the North Channel in June. In both regions, the May/June increase in abundance appeared to be driven by large numbers of copepodite stages (up to 32.8×10^3 ind. m^{-2}, in the stratified region), whilst the abundance of mature copepods was similar in the two regions (Figure 2C and D).

Calanus helgolandicus was generally more abundant in both regions, and there is evidence of spring and autumn peaks in the abundance of this species in the stratified region (Figure 2C and D). Neither species showed a preference for a particular region. There was considerable variability in the abundance of *Calanus* spp., with data from both regions showing order of magnitude differences in abundance within the same month and between years. For example, during April 1992, abundance in the North Channel varied between 0.5 and 2.9×10^3 ind. m^{-2}, and sampling from the stratified region during May of each year gave a range of abundance from 1.4 to 28.0×10^3 ind. m^{-2}.

Discussion

It is clear from our data, Williamson (1952, 1956) and Planque and Fromentin (1996), that both *C.finmarchicus* and *C.helgolandicus* occur in the Irish Sea.

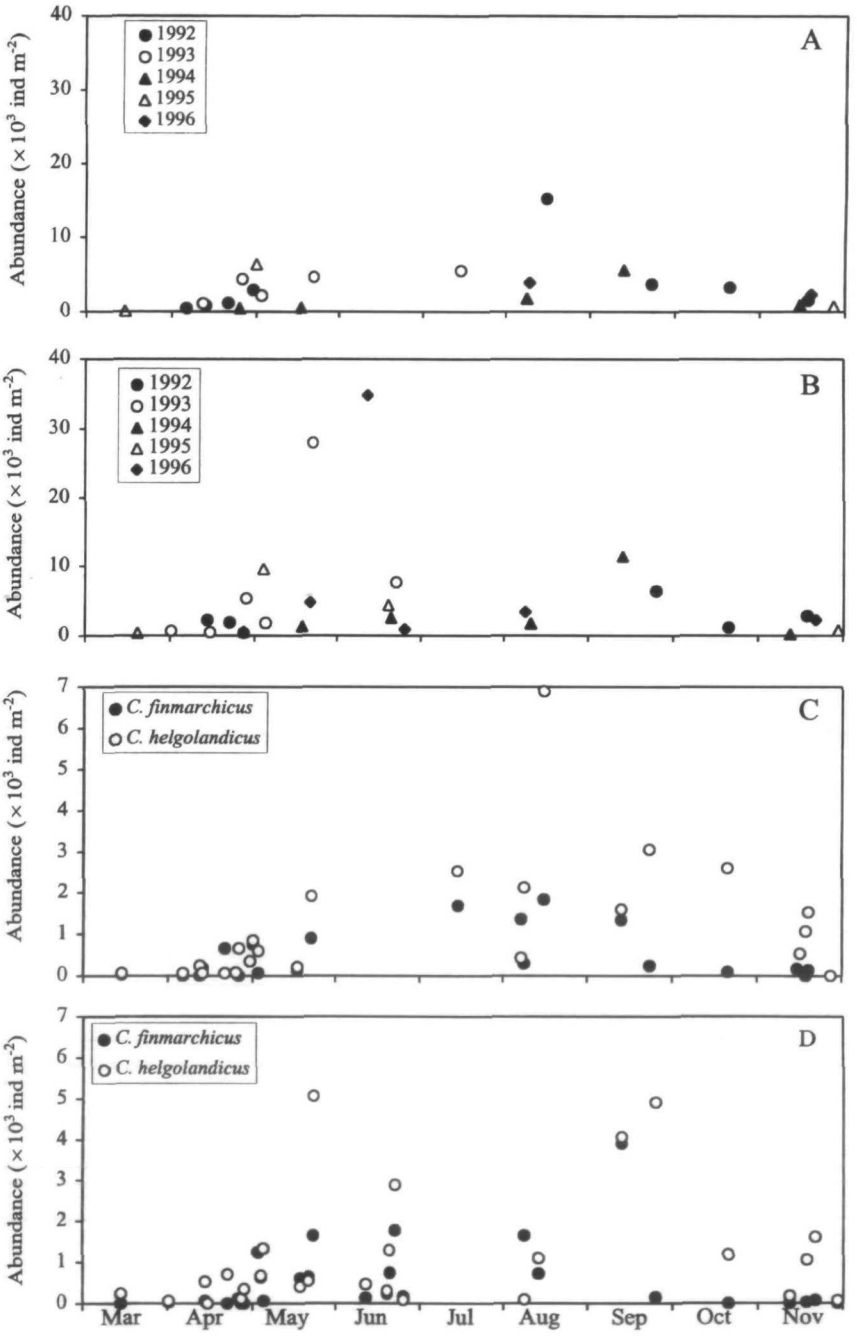

Fig. 2. The seasonal abundance (× 10^3 ind. m^{-2}) of *Calanus* spp. (copepodite stages and adults) and adult *C.finmarchicus* and *C.helgolandicus* in the North Channel and stratified region of the Irish Sea between 1992 and 1996. (**A**) *Calanus* spp. in the North Channel; (**B**) *Calanus* spp. in the stratified region; (**C**) adult *C.finmarchicus* and *C.helgolandicus* in the North Channel; (**D**) adult *C.finmarchicus* and *C.helgolandicus* in the stratified region.

Herdman (1918) did not distinguish between the two species because their separation as species had not been resolved. Any confusion about which species of *Calanus* occur in the Irish Sea, therefore, arises from Scrope-Howe and Jones (1985). They appear to have interpreted the statement 'the population of almost pure *C.finmarchicus* in the north-west in May and June', made by Williamson (1952), to imply that only *C.finmarchicus* occurred in the north-west Irish Sea.

Scrope-Howe and Jones (1985) suggested that the presence of late copepodite and adult *Calanus* in samples from the western Irish Sea was evidence that *Calanus* does not breed in the Irish Sea. In our view, this is unlikely. On the basis of a 10 year study, Herdman (1918) stated that *Calanus 'finmarchicus'* was abundant all year round at a site close to the Isle of Man, suggesting an endemic population. Furthermore, we observed females with developing eggs and *Calanus* nauplii in samples from the western Irish Sea during summer and *Calanus* nauplii have also been reported in samples from the stratified region (Burkart *et al.*, 1995; McCullough, 1996). Recent studies in the western Irish Sea have shown that the establishment of a cyclonic gyre of near-surface water during spring and summer may retain planktonic larvae and zooplankton in the stratified region (White *et al.*, 1988; Hill *et al.*, 1994, 1996; Dickey-Collas *et al.*, 1996a). This implies that the presence of egg-bearing females and nauplii represents an *in situ* breeding population in the summer with little advection, although advection of animals into the region may occur in spring and autumn.

The data collected between 1992 and 1996 are in general agreement with previous observations on the seasonal abundance of *Calanus* spp. The greater abundance of *Calanus* spp. in the stratified region during spring compared to the North Channel is in agreement with observations that *Calanus* spp. are more abundant in stratified waters (Williams *et al.*, 1994). The bimodal peak in the seasonal abundance of *C.helgolandicus* supports the observations of Planque and Fromentin (1996). Finally, there is no indication that either species showed a preference for a particular station, suggesting that there was no distinct spatial separation of the two species, which was also the view expressed by Williamson (1952).

Williamson (1956) attempted to interpret the distribution of the two species on the basis of transport into the north-west of the Irish Sea from a population centre on the Malin Shelf (*C.finmarchicus*), and into waters to the south and east of the Isle of Man from a population centre in the Celtic Sea (*C.helgolandicus*). Such geographical separation within the Irish Sea appears unlikely from our data. Furthermore, a number of studies indicate that *Calanus* populations in the Celtic Sea and Malin Shelf are mixtures of both species (Rees, 1949; Marshall and Orr, 1955; Matthews, 1967; Williams, 1985), although *C.finmarchicus* generally predominates in the Malin Shelf, and *C.helgolandicus* in the Celtic Sea. A recent analysis of continuous plankton recorder data collected over 30 years shows that the Malin Shelf and Irish Sea form part of the region of co-occurrence of the two species (Planque and Fromentin, 1996). It is unlikely, therefore, that exchange between the Irish Sea and neighbouring waters would result in the transport of single-species populations into the Irish Sea.

Zooplankton biomass in the stratified region exhibits small-scale spatial and

temporal variability (Dickey-Collas *et al.*, 1996b), and Figure 2 suggests that the abundance of *Calanus* spp. also shows considerable variability. This variability may be due in part to the irregular nature of our sampling such that abundance peaks were missed. Furthermore, since all of the studies on *Calanus* spp. in the western Irish Sea were limited in terms of sampling frequency, duration or spatial coverage, the question of variability in abundance needs to be addressed with caution.

On balance, the data from a number of studies suggest that in the western Irish Sea, the abundance of *Calanus* spp. exhibits intra-annual (spatial and temporal) and inter-annual variability. For example, the North Channel was sampled weekly in 1992 and abundance ranged from 0.5 to 2.9×10^3 ind. m^{-2}. On the basis of nine samples collected from the stratified region during April/May, Williams *et al.* (1994) give a range from 1.4 to 93.5×10^3 ind. m^{-2}. Scrope-Howe and Jones (1985) report an order of magnitude difference in the mean abundance of *Calanus* spp. between 1980 and 1981 (although the sampling frequency may have influenced the estimates of mean abundance). The 10 year data set of Herdman (1918) provides the best indication for inter-annual variability in *Calanus* spp. Between 1907 and 1916, the average number of *Calanus* spp. in net hauls (between 77 and 107 hauls per year) showed greater inter-annual variability (coefficient of variation 80%) than the other dominant copepod species (coefficient of variation 41–55%). The scale of the inter-annual variability in *Calanus* spp. populations has implications for carbon cycling in the western Irish Sea. Ingestion rates of *C.finmarchicus* and *C.helgolandicus* are an order of magnitude greater than that of smaller copepods (Gamble, 1978; Smith and Lane, 1988), and their size (compared to other copepods) may make them more suitable prey for young fish (Hunter, 1980; Brander and Hurley, 1992; Heath, 1992).

In conclusion, it is apparent that both *C.finmarchicus* and *C.helgolandicus* occur in the Irish Sea, although their spring biomass is higher in the stratified waters of the western Irish Sea than in the North Channel. It is likely that the Irish Sea supports endemic breeding populations which may be supplemented by advection of individuals from neighbouring waters. With our present understanding, the use of either species as an indicator of exchange processes between the Irish and Celtic Seas, and between the Irish Sea and Malin Shelf, is limited.

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