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SHORT COMMUNICATIONS

Mesozooplankton biomass in the Celtic Sea: a first approach to comparing and combining CPR and LHPR data

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Zooplankton biomass varies on temporal, horizontal and vertical scales. However, data sets which incorporate all these dimensions at high resolution are very rare. Two devices which measure all these aspects have recently been simultaneously deployed in the Celtic Sea, the continuous plankton recorder (CPR) and the Longhurst–Hardy plankton recorder (LHPR). This demonstrates that integrated biomass derived from the LHPR are not significantly different from those derived using the CPR. Values have, therefore, been combined for the first time to describe the vertical distribution of mesozooplankton biomass at the Celtic Sea shelf edge through an annual cycle. This suggests that the surface biomass peak is broader at the shelf break than in the open ocean and in the autumn the main biomass peak may be below the depth sampled by the CPR.

Zooplankton biomass varies on temporal, horizontal and vertical scales and, to-date, no one sampling device or strategy exists to determine this variability in non-neritic areas. Two devices that between them measure all these aspects have been recently simultaneously deployed (at monthly time-scales) around the Celtic Sea shelf break. The Longhurst–Hardy plankton recorder (LHPR) and the continuous plankton recorder (CPR) have different sampling mechanisms, designed to measure the distribution of plankton in different ways. The LHPR is towed from a research vessel, and samples the vertical structure whilst the CPR is towed by commercial ships and samples the horizontal structure. Data from the CPR, LHPR and UOR (undulating oceanographic recorder) have been contemporaneously collected (Lindley & Williams, 1980; Robinson et al., 1986) but the data were simply combined. This study compares data obtained using the CPR and LHPR and assesses the feasibility of combining the data to develop an adequate description of the distribution of mesozooplankton biomass in this area.

The LHPR was deployed 29 times in the Celtic Sea between 1992 and 1995 to depths of 400 m where water depth allowed, with a depth resolution of 5–10 m. Water flowing in the inlet cone of the LHPR passes via a wider section of net into the cod-end which collects the plankton on an intermittently moving band of gauze (~200-μm mesh), winding on to present a fresh section of gauze at predetermined intervals. The collection and analysis of CPR samples has been fully described by Colebrook (1960). The CPR samples at a constant depth of about 7 m (Hays & Warner, 1993), filtering water onto a continuously moving band of silk (280-μm mesh) which is then cut into samples representing 18 km of tow. The CPR has been towed on three routes in the Celtic Sea area since the early 1960s, on an approximately monthly basis. Abundances were obtained from LHPR samples by splitting the sample in a Folsom splitter, separating the different taxa and converting to numbers m^{-3} using the filtered volume. Total displacement volumes were measured at least three weeks after preservation so that changes in biomass resulting from fixation had occurred (Ahlstrom & Thrailkill, 1963) but with no corrections for shrinkage. Displacement volumes (DV) were converted to carbon biomass assuming that 1 ml DV = 43.2 mg C, a value derived from a compilation of the current literature (A.G.H., unpublished data). The plankton in each CPR sample were identified to species where possible or higher taxonomic categories and the abundance of each taxon recorded according to procedures described in Colebrook (1960). To estimate the mesozooplankton biomass of each sample the abundances of common taxa (occurring on 5% or more of all CPR samples in this area) were multiplied by taxon specific masses, calculated from geographically similar material. Dry weight biomass was converted to carbon using category specific ratios described by Schneider (1989). The aperture of the nose cone of the CPR and the distance towed equates to a filtered volume of 3 m^3 per sample. Flow metres fitted to CPRs on these routes show that 3 m^3 is a representative mean (A.W. Walne, unpublished data).

The region of the Celtic Sea sampled by the CPR was subdivided into three approximately equal areas representing shelf waters, the shelf break (around the 200 m isobath) and offshelf waters which encompassed the monthly variability in the position of the tows. The LHPR samples were designated as onshelf, shelf break and offshelf according to the bathymetric depth at the sampling point, such that samples shallower than about 180 m were representative of shelf waters, 180–1000 m were shelf break, and deeper stations were representative of offshelf waters. The CPR data from this area suggest that zooplankton community composition changes from the shelf to oceanic waters but not in other horizontal directions.

To compare the mesozooplankton biomass estimates of both devices a seasonal cycle was first calculated by averaging the biomass of CPR samples collected during the period of the LHPR deployments for each of the three areas. Biomass was also calculated for the LHPR samples, as integrated mesozooplankton biomass for three bands of water depth (0–50, 0–100 and 0–200 m). The CPR monthly means are compared with individual LHPR haul results in Figure 1. A non-parametric analysis of variance (the data do not have normal distributions so the Mann–Whitney *U*-test was appropriate) was carried out on the months sampled by both devices, for each region, revealing that the estimates from the CPR and the LHPR were not significantly different ($P<0.05$ level). This result is not

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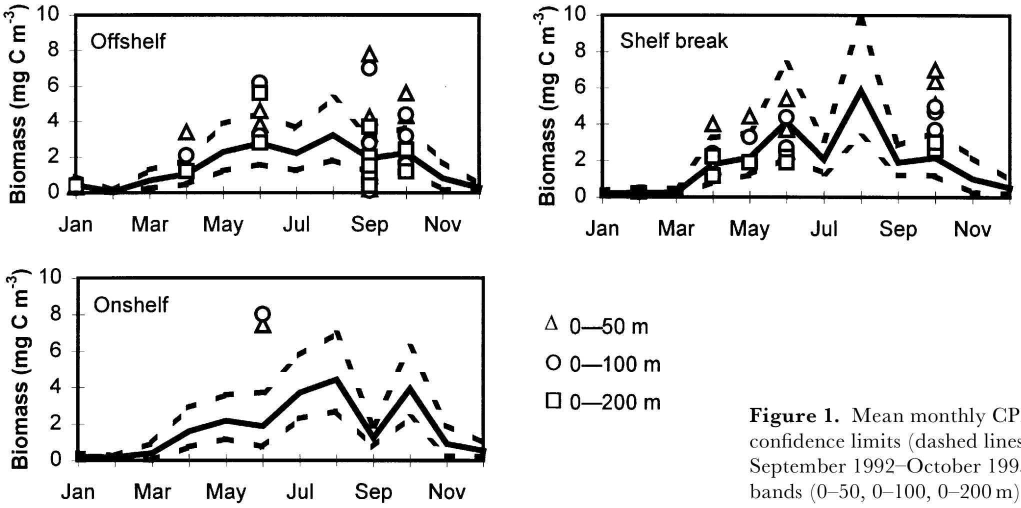

Figure 1. Mean monthly CPR biomass (solid lines) 95% confidence limits (dashed lines) and LHPR biomass for September 1992–October 1995 integrated over water depth bands (0–50, 0–100, 0–200 m) for each haul.

entirely satisfactory as the number of comparable observations was small in some cases (*n*CPR was 16–28, *n*LHPR was 1–6). However, means calculated for both devices for the same month and area of sampling when plotted against each other lay both sides of a line assuming a 1:1 relationship, i.e. one device is not consistently under or over estimating the other. This suggests that the data can be combined so that the LHPR provides profiles of biomass through the depth of the water column and the CPR the seasonal fluctuations. The proportion of biomass in 10 m depth bands was calculated for each month sampled by the LHPR, to 200 m (Figure 2). Since few LHPR hauls were taken at night, and diel vertical migration is known to occur, only daylight samples have been used. As the onshelf area was only sampled once it was not considered further.

The depth profiles for each month in the offshelf area have similarities with a surface peak in the top 20 m and subsequent deeper peaks of similar magnitude at 40–50 and 90–140 m. Winter biomass values were low, summer values the highest and autumn values similar to spring, matching the seasonal cycle described by the CPR data (Figure 1). The profile for autumn 1995 differs from the other periods with the biomass peak appearing as a wide band covering the top 70 m rather than in the surface 20 m with similar, deeper peaks. September was also sampled in 1992 and shows a different profile to 1995 with lower

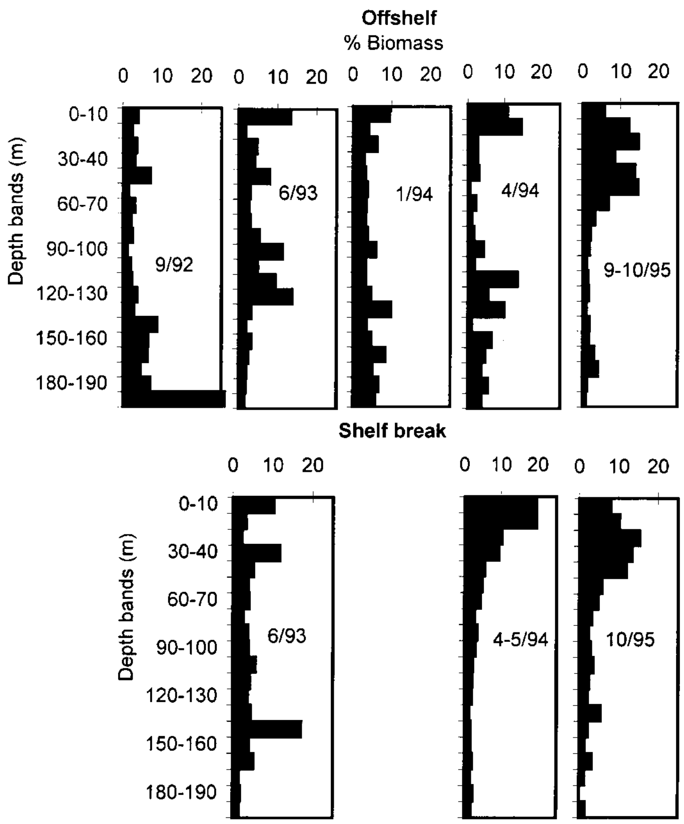

Figure 2. Proportion of mean LHPR daytime biomass, by month, in 10 m depth bands (1992–1995) for the offshelf and shelf break regions.

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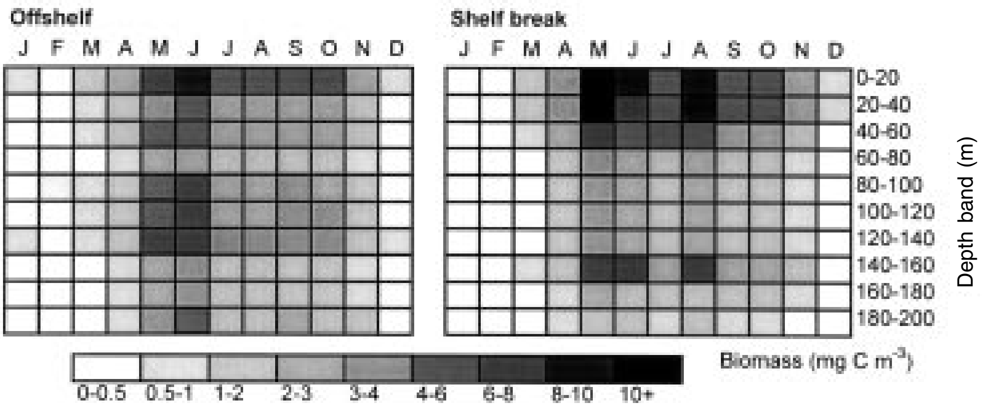

Figure 3. Description of mesozooplankton biomass in the surface 200 m, derived by combining LHPR and CPR data for the offshelf and shelf break boxes, as detailed in text.

biomass and a deeper peak (below 140 m). It is not possible to say which is the 'normal' autumnal pattern and the data for the shelfbreak area are insufficient to suggest a real change in biomass distribution throughout the year. Given that the other three seasons show similar relative profiles (ignoring the actual amounts of biomass) and for the purposes of comparing and combining the two data sources we shall assume no change, whilst recognizing that this is not a fully tested assumption. A mean depth profile of daytime biomass was calculated from the LHPR data for the two boxes, throughout the year. The actual biomass in each 20 m depth band was calculated from the integrated values for each sampled month (the two offshelf September profiles were averaged) and then all sampled months were averaged. Given that sampling occurred in the offshelf region in all four seasons this is equivalent to an annual mean. For the shelf break the overall mean values were reduced to 81% (calculated from the proportion of annual biomass present in the months sampled in the offshelf box) to compensate for the bias towards summer sampling, when biomass was higher. Seasonal cycles were calculated for the two areas as monthly means using CPR data from 1963 to 1995 and the proportion of annual biomass in each month applied to the LHPR depth profiles. The resulting matrix is shown in Figure 3 and describes the levels of mesozooplankton biomass that might be expected in this area throughout the year from the data obtained. No allowance has been made for seasonal or diel changes in vertical distribution, nonetheless, this representation is useful for estimating large-scale processes. Differences can be seen between the two areas. The surface peak at the shelf break is a broader band and shows a bimodal distribution with peaks in early and late summer. The surface peak over the slope is narrower but a second strong peak is evident between 80 and 140 m. Longhurst & Williams (1979) also show subsurface biomass peaks in summer North Atlantic LHPR profiles that had similar magnitude to the surface peak, however, no data for other seasons are described.

This approach has made several assumptions and further sampling would have been preferable. Nevertheless, it provides a valuable description of mesozooplankton biomass at these offshore sites throughout the year against which important aspects of biological processes and material transformations may be predicted or compared. This comparison is the first time that CPR and LHPR data have been co-analysed and combined and integration has utilized the strengths of the two sampling devices. Surface CPR data alone would not pick up the 100 m biomass peak in the offshelf box containing as much biomass in the summer as at the surface. Similarly, unless the LHPR is deployed many times in one place it is not possible to describe the seasonal cycle, and this is typically not viable. That the CPR biomass estimates compare favourably is very encouraging, given the extensive CPR dataset of surface samples. A new generation of CPRs are planned which will have the ability to undulate and this work emphasizes the value of such a device, particularly if deployed on the spatial scales of the current CPR survey (Warner & Hays, 1994).

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