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The cross-shore distribution of plankton and particles southwest of Iceland observed with a Video Plankton Recorder

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ABSTRACT

The high resolution distribution of plankton and particles along a transect extending from the coast and across the shelf southwest of Iceland was studied in relation to hydrographic features and chlorophyll *a* fluorescence in late May 2010–2013 with a Video Plankton Recorder. The different groups of plankton and particles showed distinctive distributional pattern. Decaying organic matter (marine snow) was a very significant component of the system. *Calanus finmarchicus* stayed generally shallower than egg carrying *Pseudocalanus* spp. Diel variability in depth distribution of *C. finmarchicus* was not evident. Ctenophores, jellies and fish larvae were most abundant above ~50 m depth. Ctenophores were relatively abundant across the whole transect, while jellies and fish larvae were mainly seen on the landward half of the transect. The data on distribution of copepods (mainly *C. finmarchicus*) were combined with the results of a numerical circulation model (CODE), thus obtaining an estimate of fluxes of copepods in the area. The results show that *C. finmarchicus* may be transported by currents both eastwards and westwards along the south coast, while retention on the bank is also possible. Based on the results of the synthesis of the distributional data and the CODE model, it is hypothesized that the populations off the south coast are at least partly self-sustained in the region.

1. Introduction

The importance of zooplankton as food for fish larvae has stimulated several ecological studies on the planktonic communities in the North Atlantic. Information on large scale and seasonal variation in abundance of zooplankton exist for many areas while more detailed information on vertical variation in response to the regional circulation are often missing. The timing of zooplankton life history events and emergence of nauplii play a vital role for fish larval survival. The main spawning grounds of the commercially important Icelandic fish stocks are on the banks off the south and southwest coasts. In this area the relatively warm and saline Atlantic Water (annual means of T~6–8 °C, S~35.0–35.2), originating from the North Atlantic Drift, is the main water mass (Stefánsson, 1981; Malmberg, 1978). However, close to the shore this water is diluted by freshwater run-off from rivers and thus the Coastal Water (S < 35.0, Malmberg, 1978) is formed. Due to the temporal variability of the fresh water run-off, together with the variable wind forcing, the distribution and magnitude of the Coastal Water may vary considerably from year to year (Ólafsson, 1985; Thórdardóttir, 1986: Gislason et al., 1994). Little information exists on the short-term variation of the involved circulation. Furthermore, its role and influence on the source and retention of zooplankton in the area is poorly understood.

In this study we use two approaches to explore the interaction between zooplankton and the local circulation in this critical area of the southwest coast of Iceland. First the distribution of plankton and physical parameters was maped using a Video Plankton Recorder (VPR) (Davis et al., 1996, 2004) and secondly, the variation of the coastal waters and the horizontal transport of copepods was described using the operational ocean model CODE (Logemann et al., 2013). VPRs have been developed over the past two decades and give exact information regarding the spatial distribution of individuals as well as providing quantitative estimates of plankton abundance, by imaging a given volume of water with a camera (Davis et al., 1992, 2005; Ashjian et al., 2001). The VPR may not differentiate as well between species as plankton nets (Benfield et al., 1996; Ashjian, 2008), but gives comparable information as nets on zooplankton depth distributions (Broughton and Lough, 2006) and concentrations of abundant taxa (Benfield et al., 1996). An important benefit of the VPR is the relative ease of fitting sensors that provide concurrent data on hydrography (temperature, salinity) and phytoplankton biomass (chlorophyll fluorescence) from the same parcel of water as imaged by the VPR, thus providing finely resolved information on zooplankton

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distributions in relation to the environment that would be hard to get by other means.

Using these two approaches this study aims to 1) describe the horizontal and vertical distribution of dominant plankton taxa and marine snow in relation to hydrographical conditions along a transect extending from the coast and beyond the shelf edge southwest of Iceland, and 2) understand how plankton are transported by currents in the region.

2. Material and methods

The investigations were carried out during latter part of May 2010, 2011, and 2013 on the so called Selvogsbanki-transect south of Iceland (Fig. 1). The transect is ~90 km long and extends from around 2 km off-shore (63°41′N, 20°41′W) to a point beyond the shelf edge (63°00′N, 21°28′W). In 2010, the whole transect was taken, whereas in 2011 and especially in 2013, the outermost parts could not be taken due to bad weather.

A Digital Auto Video Plankton Recorder (DAVPR) from Seascan Inc., equipped with a camera that takes colour images at a rate of up to 15 images per second, was used to estimate the abundance and distribution of plankton and particles (Davis et al., 2004). The VPR was fitted with a SBE-49 Seabird CTD and Wetlabs ECO Puck fluorometer/turbidity sensor, by which temperature, salinity, density (depth), fluorescence and turbidity were measured from essentially the same parcel of water where the images were taken. The VPR was towed by the ship in a saw-tooth trajectory ("tow-yos") between the surface and to near the bottom (~20 m above the bottom) or in deeper regions to 400 m (2010), 200 m (2011) or 100 m (2013) depths.

The differences in sample design between the three years deserve some explanation. Originally, the intention was to sample the water column to near the bottom over the shallow banks, and to 400 m depth in the deeper regions. As very few plankton and particles were found below 200 m depth in 2010, it was decided to change strategy and sample only down to 200 m in the deeper regions in 2011 in order to save valuable ship time. The aim was to do the same in 2013. However, due to bad weather forecast for the day of sampling in 2013, it was decided to go only down to 100 m thus saving more time and making it more likely that the whole transect could be taken before the expected bad weather would reach us and make sampling by the VPR impossible. With this strategy we were able to sample almost the whole transect (to ~65 km from the shore). In addition, in 2010 the VPR malfunctioned in the surface layers on the outermost parts of the section resulting in missing data there. As explained in the Results part of this paper, in spite of these changes in sample design, we probably sampled the most plankton rich part of the water column in all three years.

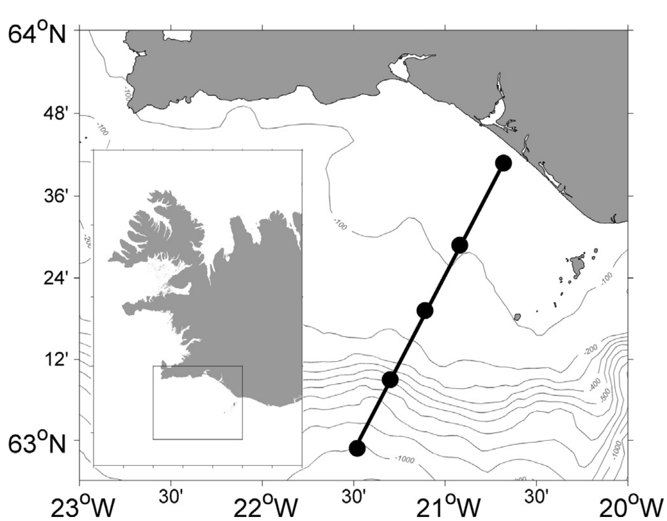

Fig. 1. Map of study area showing the Selvogsbanki transect occupied 26–27 May 2010, 29–30 May 2011, 25–26 May 2013. The circles denote stations where WP2 net was taken.

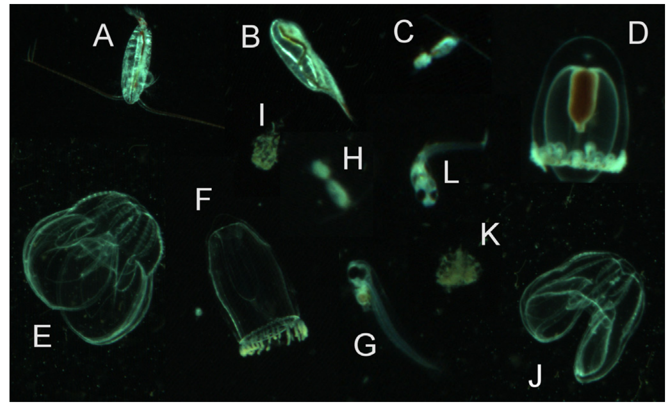

Fig. 2. Example images taken by the VPR in the present study, *Calanus finmarchicus* (A, B), *Pseudocalanus* with eggs (C, H), *Sarsia* sp (D), *Bolinopsis* sp. (E, J), *Aglantha* sp. (F), gadoid fish larvae (G, L), marine snow (I, K). Note that the images are not in the same scale.

Towing speed was close to 2 knots, and the vertical speed of the VPR during lowering and hauling was ~9–18 m/min. During the tow, the depth of the VPR was monitored with a Scanmar depth sensor fitted on the wire just above the VPR. The VPR is a self-contained system powered by a 24 V NiMH battery. The length of each VPR tow was limited by battery life to 2–3 h, so the transect had to be taken by several successive VPR tows. After each tow the VPR was taken aboard the ship that waited on site while the data downloaded from the instrument and the battery was replaced by a freshly charged one; thereafter the VPR was deployed again to continue the transect. This operation (downloading of data and replacing of the battery) took ~10 min. Example images of some zooplankters and particles are shown in Fig. 2.

The VPR tows produce compressed data files of images as well as ancillary CTD and fluorescence data (Hu and Davis, 2006). In-focus images of plankton/particles (Regions Of Interest, ROIs) and environmental data were extracted from these files using the software AutoDeck (Seascan Inc.). The ROIs are time stamped to allow them to be merged with the data from the CTD and the fluorometer that are written to separate data files.

In order to calibrate imaged volume, two approaches were attempted. The first approach was to use VPR calibration equipment and calibration software provided by SeaScan Inc. The principle behind the calibration process is that a transparent plate, with an evenly distributed series of holes in it, is moved from the camera side to the strobe side of the VPR, while the VPR sits in water and is imaging. The focus detection program (VPR_Cal) is then run on the produced calibration file with the same settings as used when extracting ROIs from the field data, thus capturing the holes that meet the criteria set by the extraction settings. Each hole has a certain volume associated with it and by summing up the volumes of all the captured holes over the travel of the target, the software calculates the total observed volume for the setting selected (Anonymous, 2014a). This approach gave an imaged volume of 45.6 ml (SD=0.6, n=3). The other approach to estimate imaged volume was to make use of the fact that the volume is the product of depth of field and field of view (Davis et al., 1992, 2004). The DAVPR has four user selectable settings for field of view. In the present study, a setting with a field of view of 24 × 24 mm was