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Comparison of near seabed currents at two locations in the Porcupine Sea Bight—implications for benthic fauna

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Recent measurements of benthic currents, within the depth range where the highest abundance of the hexactinellid sponge *Pheronema carpenteri* are found, have been made and compared to historical data for the northern Porcupine Sea Bight region where no *Pheronema* have been recorded. Bottom currents at a location where *Pheronema* have not been recorded are much higher than a location where the sponges have previously been sampled. The measurements provide some evidence to support the hypothesis that the sponges favour a location adjacent to regions where enhanced bottom tidal currents are found, but currents experienced by the sponges themselves are much reduced.

INTRODUCTION

It had been suggested that the depth range at which the hexactinellid sponge, *Pheronema carpenteri* (Thomsen; 1989), occurred in the Porcupine Sea Bight was controlled by the magnitude of the local near seabed currents (Rice et al., 1990). The sponges were present at a depth below, and downstream of, areas where enhanced bottom tidal currents were predicted, caused by the action of reflecting internal waves near resonance conditions (Figure 1). The hypothesis was that whilst the sponges could not tolerate the highest currents caused by the reflecting internal waves, they could take advantage of the organic sediment re-suspended by such currents and advected past the sponge belt by the mean slope current flow.

Zonation of benthic fauna in relation to the hydrodynamic regime is common. For example, Genin et al. (1986) have provided evidence that the distribution of corals on a seamount was controlled by the dynamics of the currents over the seamount. In particular, the highest abundance of the corals was found near the summit and this distribution was due to enhanced currents near the seamount summit. Furthermore, Fredrickson et al. (1992) suggested a correlation between the depth of the highest abundance of the live coral *Lophelia pertusa* (L.), and the depth of internal wave resonance conditions both on the Faeroes shelf and around the submerged banks of the northern Rockall Trough. In addition, Puig et al. (2001) have shown that the highest abundance of juveniles and females of four species of deep-water shrimp occurred at depths across the Mediterranean continental slope where intermediate nepheloid layer generation, presumably caused by strong bottom currents, and detachment was a quasi-permanent feature of the dynamics there.

As part of an EU project (ACES—Atlantic Coral Ecosystem Study), near seabed currents have been measured within the *Pheronema* sponge belt in the north-west Porcupine Sea Bight to test the hypothesis of Rice et al. (1990). This paper describes a simple comparison with other near seabed current records in neighbouring locations. The relation between the current strength and known zonation of benthic fauna in the region is discussed.

MATERIALS AND METHODS

A mooring with two Aanderaa recording current meters, located 10 m and 150 m above the seabed (with sampling interval of 30 mins and a rotor stall speed of 1 cm s^{-1}), was deployed along the north-west flank of the Porcupine Sea Bight in a water depth of 1220 m in September 2000, and recovered in March 2001 (ACES2 in Figure 1). This was at a location in the known *Pheronema carpenteri* sponge belt identified by Rice et al. (1990). Table 1 summarizes the details of this mooring and that of another data set collected in the north-east flank of the Porcupine Sea Bight between 1987–1988 by Dr Robin Pingree of the Plymouth Marine Laboratory where Rice et al. (1990) reported no occurrences of the sponge (Rig 114 in Figure 1). Results from that mooring, referred to as Rig 114, are described in Pingree & LeCann (1989) and Pingree & LeCann (1990). The two current meters were located at comparable heights above the seabed, both within the upper benthic boundary layer, such that no normalization of the data to a reference height was deemed necessary for the comparison of current speeds. Both current meters were deployed at the same time of the year (17 and 19 September in the respective years), so a comparison for seasonal change in current character from September to March can be made, given the problems that interannual variability might cause.

RESULTS

Mean residual flows (Table 1) were both topographically steered along slope, but with a small downslope component, consistent with a location in a bottom Ekman boundary layer. The mean flow was much larger at Rig 114 than at ACES2, and mean current speed at Rig 114 was about double that at ACES2 (Table 1). Figure 2 shows

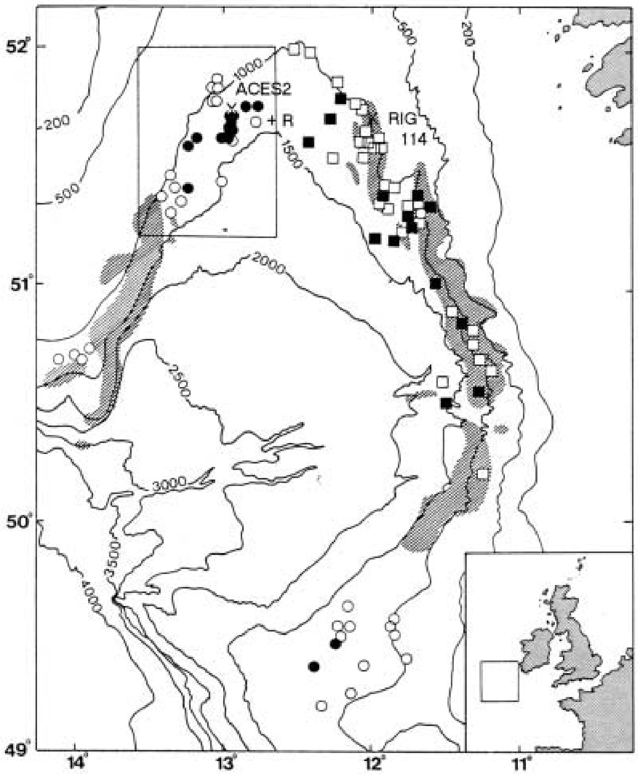

Figure 1. The distribution of the hexactinellid sponge, *Pheronema carpenteri*, in the Porcupine Sea Bight as given in Figure 2 of Rice et al. (1990). Filled symbols show presence, and open symbols, absence of the sponge in samples analysed by Rice et al. (1990). Crosses show the location of moorings analysed and mentioned in the text.

a time-series of daily mean current vectors for the two measurements. Only the time-series for Rig 114 corresponded to the same seasonal time period as for ACES2 is shown. At Rig 114 (Figure 2B), at a depth of 1000 m and where *Pheronema* were not present in the samples of Rice et al. (1990), the flow was strong with daily mean currents often in excess of 10 cm s^{-1}. The flow was persistently poleward along slope with a Neumann stability coefficient, the ratio of the mean vector velocity to the mean arithmetic velocity, of R_{114}=0.98. Pingree & LeCann (1989, 1990) report that this low frequency flow was heavily modulated at a 13.7 d-period, as apparent in Figure 2B, with the strongest daily mean currents measured at the diurnal spring tides. The authors indicated that this variability was associated with baroclinic (internal) diurnal motions. Tidal analysis indicated that the K_1 diurnal component was about twice that of the semi diurnal M_2 component at this location.

By contrast, mean daily currents were less at the ACES2 'sponge belt' mooring at a water depth of 1220 m, between 5–10 cm s^{-1}, less stable (Neumann coefficient R_{ACES2}=0.31), with large mesoscale variability present, and reversals in the direction of flow (Figure 2A). There was a general weakening of the flow during late January and February, as well as at the start of observation in September–October. The measurements at Rig 114 also showed a small reduction in along slope flow during February–March, although measured in a different year. The ACES2 mooring data appeared to show the same SOMA (September–October–March–April) seasonal variability as Rig 114 and other moorings in the Porcupine Bank and Biscay region (Pingree & LeCann, 1989; Pingree et al., 1999; Huthnance et al., 2001).

The difference in the strength of the benthic currents at the two moorings is illustrated in Figure 3, which shows the % exceedance curves for currents at each mooring. The figure shows that measured instantaneous current speeds were generally much larger at Rig 114. About 45% of currents measured at Rig 114 exceeded 15 cm s^{-1}, but only 12% of currents measured exceeded this at ACES2. A value of 15 cm s^{-1} has been considered here as experiments by Thomsen & Gust (1997) have suggested this speed as a threshold for re-suspension of the seabed surface detritus layer. Moreover, a little over 12% of the measured currents at Rig 114 were greater than the maximum current speed recorded at ACES2 during the five month deployment.

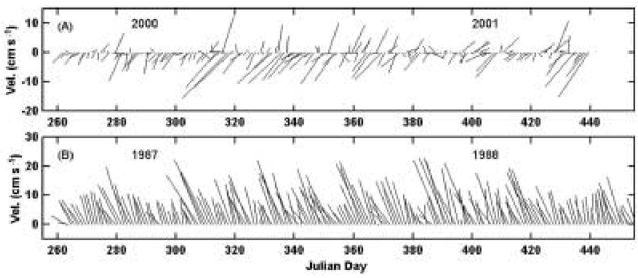

Figure 2. Time-series of mean daily current vectors for (A) ACES2 mooring 10 metres above bed (mab), September 2000–March 2001; and (B) Rig 114 8 mab, September 1987–March 1988. The y axis provides a current speed scale.

Table 1. *Summary of benthic current meter deployments analysed in this paper. ACES2 was deployed during the Atlantic Coral Ecosystem Study, and Rig 114 was deployed by Dr Robin Pingree of Plymouth Marine Laboratory and discussed in Pingree & LeCann (1989, 1990).*

Mooring no.	Latitude/ longitude	Water depth (m)	Height current meter off seabed (m)	Start date	Record length (days)	Residual speed (cm/s)	Residual direction (degT)	Mean speed (cm/s)
ACES2	51 43.75′N 12 54.64′W	1220 m	10 m	17.09.00	187	2.2	223	8.2
Rig 114	51 47.4′N 12 02.6′W	1000 m	8 m	19.09.87	297	11	339	16.3

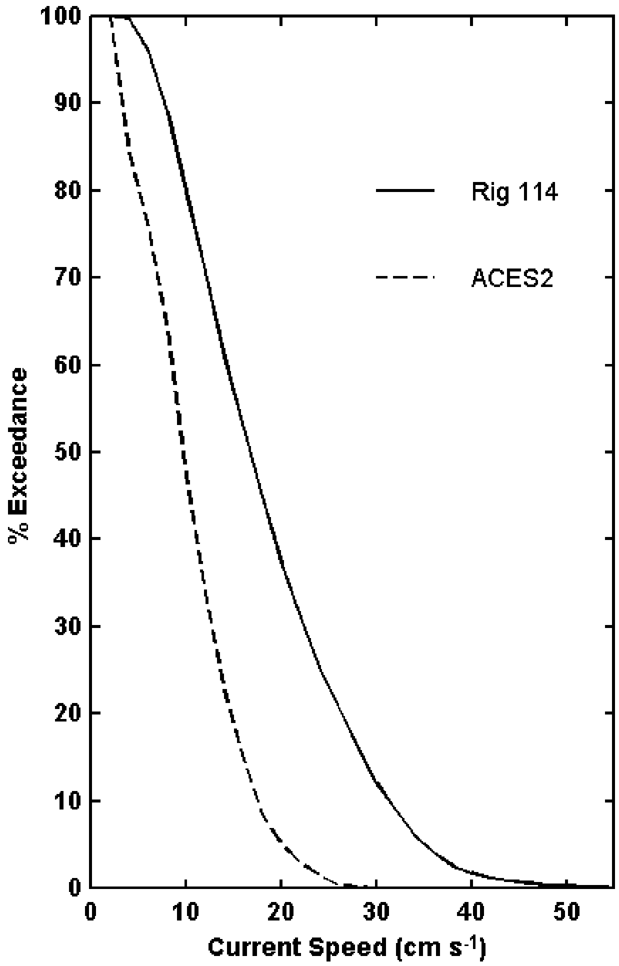

Figure 3. Percentage exceedance curves for the currents measured at Rig 114, 8 mab (solid line) and ACES2 mooring, 10 mab (dashed line).

DISCUSSION

Comparison of measured benthic currents at similar depths in the northern Porcupine Sea Bight have shown that the near seabed currents in a region where *Pheronema carpenteri* have been found were considerably smaller than those measured where they were absent in samples analysed. This would appear to confirm the original hypothesis of Rice et al. (1990) regarding the zonation of the sponge in relation to the strength of the local currents, i.e. that the sponges could not tolerate the highest currents but were found adjacent to these regions where the sponges could take advantage of suspended material advected past their location.

The stronger currents measured in the north-east Porcupine Sea Bight (Pingree & LeCann, 1989, 1990), however, were due to baroclinic motions of diurnal period rather than reflecting M_2 internal waves as proposed by Rice et al. (1990). This is not to say that currents are not also enhanced by the action of reflecting M_2 period internal waves, but whatever the source of the enhanced currents, the resultant increased near seabed currents appear to provide a hostile local habitat for *Pheronema*. The mean near seabed current flow is cyclonic around the Sea Bight, which is favourable for downslope transport of re-suspended material in the bottom boundary layer (Souza et al., 2001). It seems, as postulated by Rice et al. (1990), that the *Pheronema* instead occur downstream and downslope of such areas. This can be noted in Figure 1 where *Pheronema* are found downstream (northwest) of, and at deeper depths than, the position of Rig 114.

The change in the magnitude of currents across the continental slope in the Porcupine Sea Bight has implications for the zonation of other species. As noted by Rice et al. (1990), the strong currents (as measured at the Rig 114 location) provide a suitable habitat for colonization by coral species such as *Lophelia pertusa* and others and which are abundant on the flanks of the Porcupine Bank and Porcupine Sea Bight in regions where strong benthic currents have been measured or inferred (De Mol et al., 2002). Billett (1991) has described the depth zonation of many deep-sea species of holothurians in the Porcupine Sea Bight. In particular two species that are essentially sedentary, *Ypsilothuria talismani* and *Echinocucumis hispida* have been found in a rather limited vertical depth range between 1200–1400 m (see Billett's figure 12). This depth range is just below that of peak abundance for *Pheronema carpenteri* found by Rice et al. (1990). A 62 d duration measurement of currents 1.3 metres above bed (mab) in a water depth of 1327 m (located at position R in Figure 1), during a Bathysnap deployment reported by Rice et al. (1991) has indicated a mean flow was along an isobath to the south-west, with magnitude of about 1.5 cm s^{-1}, and that daily mean currents were about 5 cm s^{-1} or less. This is less than, but similar in character to, the ACES2 mooring some 40 km away and 120 m further upslope, although the Bathysnap data were measured much closer to the seabed. Furthermore, the authors report that currents rarely exceeded 10 cm s^{-1} ($<3\%$ of measurement). Figure 3 indicates that the exceedance of 10 cm s^{-1} at ACES2 was 34% and at Rig 114 the % exceedance increased to 71%. Even given the fact that these currents were measured further from the seabed, currents at 1.3 mab in the same locations would be much less. A variation with depth of benthic currents is apparent, therefore, in the northern Porcupine Sea Bight region. This cross slope variability in benthic currents would appear to contribute to the zonation of fauna, from corals that require a substrate that needs to be keep swept clear, to suspension feeders like *Pheronema* that utilize the suspended material at a depth below the corals, and at greater depths with even lower strength currents, deposit feeders like the two species of holothurians reported by Billett (1991).

The measurements described here, and inferences made from such data, are somewhat simplistic. There is, unfortunately, only a limited data set for benthic currents available at present. In addition, there is no supporting data on the amount or type of material in suspension at the different cross-slope locations and only assumptions between current speed and the suspension of material have been invoked to support the Rice et al. (1990) hypothesis. Near seabed currents measured since the original study of Rice et al. (1990), however, do appear to provide some quantifiable data to support the hypothesis for the zonation of the hexactinellid sponge *Pheronema carpenteri* in the northern Porcupine Sea Bight. The distribution of near seabed currents across the continental slope in this region can also be related to the zonation of other fauna such as corals and sedentary holothurians.

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