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Oceanographic and biological influences on recruitment of benthic invertebrates to hard substrata on the Oregon shelf

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ABSTRACT

The number of anthropogenic substrata in the ocean – structures like oil rigs and offshore renewable energy generators – is increasing. These structures provide hard-bottom habitat in areas previously dominated by sand or mud, so they have the potential to alter species distributions or serve as "stepping-stones" between other hard-bottom habitats. It is thus important to understand what factors influence the composition and abundance of benthic fauna recruiting at these sites. We examined recruitment to hard substrata (fouling panels) deployed on sand at various distances from a large rocky reef (~60 m isobath) on the southern Oregon coast in 2014–2015. Recruitment was dominated by the acorn barnacle *Hesperibalanus hesperius*. For the majority of the study period in 2014, an anti-cyclonic eddy was present near the deployment sites. However, anomalously high recruitment of *H. hesperius* during August – early October 2014 coincided with dissipation of the eddy, slower bottom currents, and a positive convergence index, suggesting that *H. hesperius* larvae from the adjacent area may have been accumulated and retained near our study sites. Other sessile species, including hydroids and bryozoans, recruited to the fouling panels in low abundances, and most of these species have long-range dispersal and fast growth. Mobile invertebrates observed on the fouling panels included gastropods and nudibranchs, most of which also have long-range dispersal and fast growth, and are predators as adults. Thus, a community with two trophic levels assembled on the fouling panels in a relatively short time period (< 12 weeks). None of the common hard-bottom species from the adjacent rocky reef recruited to the panels, suggesting that there is a specialized assemblage of species that can exploit hard-bottom habitats surrounded by sandy plains. Our results raise many questions about the influences of dispersal and oceanographic conditions on recruitment to hard substrata.

1. Introduction

Most of the continental shelves are blanketed by soft sediments, so hard-bottom habitats are often isolated and island-like (Wahl, 2009). These habitats include rocky reefs (Steimle and Zetlin, 2000; Tuya et al., 2004), coral reefs (Bellwood and Hughes, 2001; Jones et al., 2009), artificial reefs (Perkol-Finkel et al., 2006; Perkol-Finkel and Benayahu, 2005), anthropogenic structures such as oil platforms (Bram et al., 2005; Page et al., 2008) and litter (Bergmann et al., 2015).

Community assembly on hard substrata has been studied for artificial reefs in the tropics (Perkol-Finkel et al., 2005; Perkol-Finkel and Benayahu, 2009, 2007), but relatively little is known about how new hard-bottom communities develop at temperate latitudes. The increasing numbers of anthropogenic substrata on continental shelves, such as offshore wind platforms and wave-based energy generators (De Mesel et al., 2015; Krone et al., 2013; Miller et al., 2013), could alter species distributions of hard-bottom fauna as they become fouled. Anthropogenic substrata provide hard-bottom habitats where there was previously only sand or mud and could serve as "stepping-stones" between natural reefs. The potential ecological impacts make it important to understand how communities may develop on these substrata.

There are already plans for the installation of wave-based energy generators offshore of Reedsport, Oregon, near our study sites (Elwood et al., 2010). These energy installations include large anchors on the seafloor that could become fouled (Elwood et al., 2010; Scruggs and Jacob, 2009). Numerous subtidal rocky and biogenic reefs on the Oregon coast could serve as sources of larvae, leading to the colonization of seafloor anchors by benthic invertebrates (Gunderson et al.,

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2008; Pearcy et al., 1989; Posey et al., 1984).

Recruitment is influenced by larval supply, larval transport, settlement, and post-settlement processes, and the interactions of these factors (Pineda et al., 2009). Post-settlement mortality can be high in some species, decoupling the processes of settlement and growth to adulthood (Hunt and Scheibling, 1997). Despite these limitations, studies on key species and on meso- or local scales can increase our understanding of recruitment dynamics (Hadfield, 1986; Pineda et al., 2009).

Larval dispersal of benthic invertebrates is often affected by coastal circulation patterns and oceanographic conditions (Chiswell and Roemmich, 1998; Hutchings and Pearce, 1994; Limouzy-Paris et al., 1997), with larvae becoming entrained by temporary or semi-permanent eddies and being retained near shore (Chiswell and Booth, 1999; Lobel and Robinson, 1988). The Oregon coast is well-known for baroclinic mesoscale eddies, which interact with the coastal upwelling system through cross-shelf mass transport (Capet et al., 2008; Strub et al., 1991). Therefore, we investigated how oceanographic conditions might influence recruitment of benthic invertebrates on hard substrata.

We deployed artificial substrata (fouling panels) at five sites on the seafloor, near the 60 m isobath. Sites were located 0–9 km from a rocky reef south of Cape Arago, which is inhabited by a diverse array of sponges, bryozoans, soft corals, and anemones, as well as holothurians, crabs, and fish (Young et al., unpublished data).

We first describe the temporal and spatial patterns in recruitment of benthic invertebrates on the hard substrata. We then describe on a population level how recruitment of the most common species, the barnacle *Hesperibalanus hesperius,* correlated with changes in oceanographic conditions. Finally, on a community level, we compare the identities and functional traits of recruiting species to those present on the adjacent rocky reef, and discuss what our results imply about community assembly in hard-bottom habitats.

2. Methods

Fouling panels (15 × 15 cm) were constructed from clear plexiglass (0.32 cm thick) and scored on one side with sandpaper (100 grit) to provide a rugose texture suitable for settlement. The resulting shallow scratches on the panels were 0.3–1 mm apart, on a comparable spatial scale to the fine roughness elements that have been shown to increase barnacle recruitment in previous studies (Hills and Thomason, 1998; Lemire and Bourget, 1996). Panels were attached to cement blocks (38 × 38 × 20 cm) using stainless steel bolts (0.63 cm × 10 cm) embedded in the cement – one bolt through the middle of the plate – and secured with a wingnut. Two panels were deployed on each vertical side of each block, for a total of eight panels per block (Fig. 1). A galvanized steel eye bolt was embedded in the top of each block and served as an attachment point for a line and surface float.

Blocks were deployed in pairs at five locations along the southern Oregon coast (43° 17′ – 43° 21′ N, 124° 24′ – 124° 27′ W, ~60 m depth) within and at various distances from the rocky reef (0–9 km, Fig. 2). In 2014, blocks were recovered every 3 weeks using R/V *Pluteus*, with some variation in the schedule due to weather. Half of the fouling panels on each block were removed and replaced after 3 weeks, while the other half were left on the blocks for a 6-week deployment. Fouling panels in 2014 were at sea for 21–51 days. In 2015, a combination of weather and logistical difficulties thwarted the planned 3-week schedule, so blocks were deployed and recovered together, spending 79 days on the seafloor (Table 1).

Following recovery, fouling panels were transported in containers of seawater aboard R/V *Pluteus* and maintained in flow-through seawater tanks at the Oregon Institute of Marine Biology (OIMB). All sessile invertebrate recruits present on the front (outward-facing) side of the fouling panels were counted and identified. Specimens were photographed using a digital camera (Canon) on a dissecting microscope (Olympus). For broken panels, the surface area was estimated, and the number of sessile individuals present in that area was extrapolated to 225 cm^2. Mobile invertebrates on the panels were also noted and counted if possible, though mobile organisms often crawled and/or washed off of fouling panels into the surrounding tanks, making accurate counts per plate impossible. We only report the total abundance on all plates for the mobile invertebrates.

Fig. 1. Fouling panel and cement block design. Rope is attached to a surface float (outside picture). Photo by J. Reynolds.

In order to characterize the interaction between oceanographic conditions and recruitment, we calculated the convergence index and average current speed for surface and near-bottom waters at the study sites during each deployment, using the data-assimilative Hybrid-Coordinate Ocean Modeling (HYCOM, https://hycom.org/, Chassignet et al., 2007). Comparisons between HYCOM surface elevation and AVISO (Archiving, Validation and Interpretation of Satellite Oceanographic data) sea surface height suggests that HYCOM represents the evolution of eddies during our observational period well (data not shown), and thus can be used as a good approximation of ocean circulation conditions during the study period. Recruitment was pooled for all sites within a deployment and standardized by the number of days of deployment for a comparison with oceanographic conditions. We explored the relationships between barnacle recruitment, the convergence index, and current speed using Spearman correlations.

3. Results

The most common recruiting species on our fouling panels was the acorn barnacle *Hesperibalanus hesperius*, accounting for 96.7% of all sessile individuals. Patterns in barnacle recruitment are reported below. The second most common species was the hydrozoan *Clytia hemisphaerica*, with 3.0% of recruiting individuals. This species had much higher recruitment at site 4 during deployments A3 and B2, in July–August 2014, than at other sites or during other deployments (Fig. 3).

Other recruits observed on the fouling panels in lesser proportions were the bryozoan *Celleporella hyalina*, the anemone *Metridium senile*, a juvenile mussel and a spirorbid polychaete that could not be further identified (Table 2). These sessile species showed no patterns with regards to recruitment on panels deployed for different durations, with the possible exception of *M. senile*, which was present in much higher abundance on panels deployed for 79 days than on panels deployed for shorter durations (Table 2).

A number of mobile species were observed on the fouling panels, including the nudibranchs *Hermissenda crassicornis*, *Onchidoris*