Biofouling babies could go the distance: barnacle larvae spawned at offshore habitat have greater dispersal potential

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Introduction

The construction of progressively large marine renewable energy arrays around the UK will substantially increase hard habitat availability in many coastal locations. The environmental effects of this habitat alteration may include changes in hydrodynamic conditions and the formation of artificial reefs (Langhamer et al. 2010; Miller et al. 2013) which will be colonised by a variety of biofouling organisms. The makeup of these fouling communities will depend on local environmental conditions (Macleod 2013) and transport processes bringing larvae, juveniles, or adults to/away from the site and other natural or anthropogenic habitats. Consequently, it has been suggested that these structures could act as stepping-stones for the spread of both native and non-native species (Petersen and Malm 2006, Shields et al. 2011), with increasing effort as more structures are installed. Current environmental impact assessment (EIA) regulations state that cumulative effects must be addressed in any EIA. Modelling studies of dispersal are ideally suited to test the relative impacts of physical and biological processes on dispersal, and can help to identity the extent of stepping-stone connectivity between natural habitats and artificial structures during the impact assessment process.

Methods

We aimed to assess the characteristics of dispersing organisms which might enhance their ability to colonise offshore renewable energy structures and spread via stepping-stones: larval behaviour, spawning habitat, and pelagic larval duration.

We coupled a high-resolution, 3-dimensional circulation model of the Firth of lorn and surrounding waters, based on the Finite Volume Community Ocean Model (PVCOM, Chen et al. 2001) to model the transport of barnacle larvae. Barnacles are perhaps the best-studied members of biofouling communities world-wide, and are extremely common around the coasts of Scotland. Biological models of dispersal were developed for three species of barnacles, based on field surveys of horizontal and vertical zooplankton distributions and available literature data on larval duration and seabed habits.

Particles were released from model start nodes at habitat for the selected species (Figure 1) and dispersed for 33 days with either a surface-seeking, bottom-seeking, or realistic re-distributive behaviour (RDB, Figure 2).

Results

Particle transport and dispersal distances (Table 1): Mean transport distances ranged from 189 km to 476.4 km. Dispersal patterns for particles with similar vertical distributions and migrations, and mortality rates suggest that they may be particularly good stepping stones. Detrimental information on spawning locations, pelagic larval duration, larval vertical distributions and migrations, and mortality rates is needed.

Discussion

Transport and dispersal

- Transport and dispersal distances were within the expected range for species with relatively long-lived larvae (10s – 100s km, Shank 2009).
- The minimum dispersal distances suggest that many particles are retained near start habitat, while long-distance dispersal may have important connectivity impacts on distant populations.
- Strong horizontal currents do not always correlate with substantial transport, e.g. S. balanoides particles have greatest transport for surface and RDB runs, but net dispersal is greatest for bottom-seeking particles.

Offshore renewable energy structures

- The transport of particles released in deeper water, far from shore was enhanced when compared to those released in shallower water (R-20 m). These particles spend less time in near-shore friction-slowed currents and turbulence (e.g. ‘sticky water’, Wolanski 1994) before entering stronger, directional offshore currents.
- The offshore locations of renewable energy arrays suggest that larvae released from colonised devices are likely to reflect particles spawned at deeper, offshore locations in this model (R-20 m, e.g. C. harenii).
- Offshore structures may have high connectivity: once colonised they could act as sources of larvae to distant habitats, which could be of particular concern in the case of non-native species.
- Nested hydrodynamic models coupled to well-parameterised particle-tracking routines are useful for exploring transport of a species to and from an array and between networks of arrays along coastlines.

Further applications

Stepping-stone connectivity

- Adams et al. (2014) demonstrated that offshore renewables could act as stepping stones for many species (Figure 5).
- Amplified transport and dispersal of larvae spawned at these structures suggests that they may be particularly good stepping stones.

Further model application

- This model could be adapted to reflect dispersal of species of ecological interest (e.g. polychaetes Sabellaria sp. and horse mussels Modulox modulux) or commercial relevance.
- Detailed information on spawning locations, pelagic larval duration, larval vertical distributions and migrations, and mortality rates is needed.

EIA / cumulative effects

- Modelling studies can clarify the scale of cumulative changes in connectivity processes from planned installations.
- These include emergent benefits (i.e. increase in biodiversity / productivity) or detriments (i.e. spread of non-native species, biofouling causing mechanical failure of devices) of the new habitat they create.