

I'm a larva, get me out of here! Oceanographic controls on particle retention around coral reef islands.

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Key words:	Physical oceanography, connectivity, dispersal, coastal, model, coral, retention
Research theme(s):	• Oceanography, Climate and Palaeoenvironment
Eligible courses for this project:	• DPhil in Earth Sciences (3-4 years) • Interdisciplinary Life and Environmental Science Landscape Award (ILES LA) • Intelligent Earth (UKRI CDT)

Overview

While coral reef islands are separated by ocean, they may still be ecologically connected through the dispersal of marine organisms. For many species, including corals and other coral reef organisms, dispersal primarily occurs during the larval stage. Predicting connectivity through marine dispersal is very important for marine conservation, fisheries management, and biogeography (Cowen and Sponaugle, 2009).

Larvae are small and can travel significant distances, so measuring larval dispersal directly is usually impractical. Instead, we rely on indirect approaches such as population genetics, or numerical models. Due to their size and weak swimming ability, the larvae of many marine organisms can be reasonably modelled as passive particles once in the water column. Larval dispersal is commonly simulated using a *Lagrangian* (or particle-tracking) approach, based on ocean current velocity fields from ocean models.

This works quite well in the open ocean, where existing ocean models reasonably represent the larger scale (mesoscale) features that dominate oceanography in deeper water and away from boundaries. However, the size of oceanographic processes that drive larval transport is much smaller in shallow water and near the coast, necessitating a higher resolution to reasonably model particle transport in these environments. This requirement vastly exceeds the resolution that is computationally possible in global, and even most regional, ocean models. As a result, state-of-the-art models routinely fail to predict dispersal between islands, in particular retention and exchange between the coastal zone and the open ocean (e.g. Monismith et al., 2018, fig. 1).

Fortunately, there are good reasons to believe that we may be able to *parameterise* (represent without explicitly resolving) transport between the coast and open ocean. For

example, eddies forming in the wake of islands play an important role in particle retention, and their behaviour can be predicted based on large-scale flow regimes (e.g. Heywood et al., 1996). Other processes such as winds and waves may also have predictable impacts on cross-shore exchange (Moulton et al., 2023).

Through a hierarchy of idealised and realistic ocean model simulations, this project will build a mechanistic understanding of the processes that dominate particle exchange between islands in deep water and the open ocean, with the aim of developing a larval retention parameterisation that can be integrated into global or regional ocean models.

Methodology

This project will use the Ryukyu Archipelago of Japan as a case study, featuring a long chain of islands with diverse shapes and sizes in the path of a powerful ocean current. You will first run idealised simulations using simplified island geometry (building on prior work such as Cetina-Heredia and Connolly, 2011) to develop a mechanistic understanding of which processes dominate larval retention around islands in deep water. You will then gradually build up complexity in the model, eventually using a realistic configuration based on various islands in the Ryukyu Archipelago. Finally, you will develop a parameterisation for larval exchange between islands and open ocean, integrating it into a global ocean model and testing it against your high resolution simulations and oceanic drifter data.

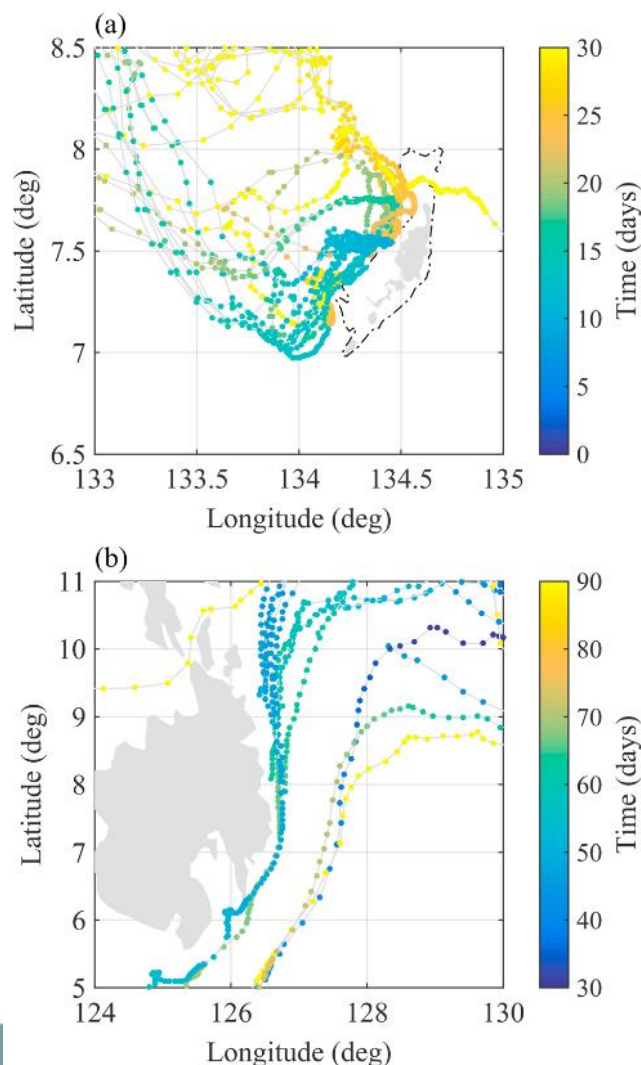


Figure 1: Drifter trajectories from Monismith et al., 2018. Drifters released from Palau (a) often got very close to other islands (b) but not close enough to reach the coral reef itself. Most larval dispersal models have too low resolution to distinguish between near misses (b) and larvae actually reaching the reef.

Timeline

Year 1: Training and rotation projects (ILES/Intelligent Earth).

Years 2 and 3: Idealised and realistic hydrodynamic and larval dispersal experiments.

Year 4: Developing and testing a larval retention parameterisation. Completing papers, presenting at conferences, thesis write-up.

Training & Skills

The student will be provided training as required in physical oceanography and hydrodynamic modelling (e.g. CROCO, NEMO). Depending on student interests, further training and/or collaborators may be introduced into the project (e.g. in marine ecology). A strong quantitative background (ideally physical oceanography, physics, mathematics, engineering, or similar) is strongly desirable for this project but specialist knowledge of oceanography is not essential.

References & Further Reading

Cowen, R. K., & Sponaugle, S. (2009). Larval dispersal and marine population connectivity. *Annual Review of Marine Science*, 1(1), 443–466.

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Monismith, S. G., Barkdull, M. K., Nunome, Y., & Mitarai, S. (2018). Transport between Palau and the eastern coral triangle: Larval connectivity or near misses. *Geophysical Research Letters*, 45(10), 4974–4981. <https://doi.org/10.1029/2018gl077493>

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Further Information

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