

A Gene's View of Oceanography: Genetic Mapping of Hidden Population Boundaries in Barnacles

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(The following text is excerpted and expanded from Palumbi and Warner, *Science*, Jan. 3, 2003)

As Bilbo Baggins famously warned, travel is an uncertain business, "You step into the Road, and...there is no knowing where you might be swept off to." For the better part of a century, marine biologists have assumed the roads of ocean currents are just as uncertain, and that the drifting eggs and larvae and rafting propagules of many marine species end up far from their homes, on distant shores. But the last two years have seen increasing evidence that at least some marine species with the potential to disperse widely instead show a remarkable fondness for home. Instead of being citizens of a global ocean, many marine species seem to live in ocean neighborhoods whose borders are surprisingly small.

Along the west coast of the United States, intertidal barnacles are immobile and thickly coat the rocks. But their larvae are scattered into the sea, to drift for weeks before seeking the shelter of a different rock on a different shore. Where these larvae go has long been sought, an ecological grail that has been at the center of marine ecology. Why worry about barnacles? As one of the most abundant organisms on the west coast (there are more barnacles in California, Oregon and Washington than there are humans on Earth), they provide abundant material for experimentation and genetic scrutiny. This scrutiny has paid off by showing that barnacle larvae can sometimes remain quite close to home, especially when, offshore, the ocean cooperates.

Genetics can help underscore the way marine populations move by comparing the genetics of individuals collected at different places. Because every adult, larva or egg that moves carry with it the genes it inherited from its parents, genetic variation can serve as a kind of natural tag. From DNA sequences of genes extracted and amplified from hundreds of adult and larval barnacles we can easily look for neighborhood patterns. Is the DNA from barnacles collected close together more similar to the DNA of barnacles collected 100s or 1000s of km apart? The answer has been a resounding "Yes," for U.S. West Coast barnacles, showing that ocean neighborhoods are defined by distances as small as 10s of km.

This is true especially along the coast of Oregon where well known ocean conditions favor persistence of a special kind of ocean neighborhood. Ocean currents sometimes form gyres – circles of moving water spinning through the ocean like a marine snake eating its own tail. These gyres trap water inside and pull nutrient rich water from the sea floor like a tornado picked up Dorothy's house. The water inside these gyres is thus very nutrient rich and exploding with single celled algae. Algae are the food of barnacle larvae, and may accelerate their growth rate. Clearly, ocean gyres and larval fates are linked.

A persistent ocean gyre churns off the Oregon coast near the outpost lighthouse on Heceta Head. Generated by the broad shallows of the Heceta Bank just offshore, this gyre is a primary player in ecological variation studied by Bruce Menge, Jane Lubchenco and colleagues. Our new studies – conducted by Erik Sotka and Stephen Palumbi – firmly link this ocean

feature to genetic changes in the barnacles along the shore. Barnacles on rocks of Heceta Bank show genetic differences from those outside the influence of the Heceta Gyre – they live in a different ocean neighborhood, one affected largely by the gyre and its soup of rich nutrients.

So far, only genetics has been able to show the influence of the gyre on the dispersal of shore-based populations. The implications are clear for not only barnacles, but for other marine species – to manage and protect marine ecosystems requires we understand the borders and extents of ocean neighborhoods and incorporate them into our planning. Some areas represent substantially different neighborhoods – Heceta Head is a relatively rich neighborhood replete with food and bursting with population growth. Neighborhoods that can export surplus population growth are the heart of our fishing industries and should be protected. So far, barnacle data cannot be used to suggest complete management plans because barnacles are not on anyone's list of critical species. But the barnacle data can pinpoint where neighborhood boundaries might be, allowing us to focus our attention on the way commercially and ecologically important live, and the neighborhoods they live in.

This example is confirmed by an increasing number of island species that have been shown to have fine-scale genetic structure and therefore low dispersal. Just such a conclusion emerges from recent studies by Taylor and Hellberg reported in the Jan. 3 issue of *Science* (1). They show that there are remarkably strong patterns of genetic structure in the mitochondrial genes of a small Caribbean reef goby: patterns that not only show that distant islands harbor genetically distinct populations, but also that there are sharp genetic breaks between island groups that are relatively close together. Additional recent studies buttress the suspicion that conventional wisdom about marine dispersal should change. Mantis shrimp in Indonesia show genetic differences similar in spatial scale and genetic depth to the gobies studies by Taylor and Hellberg (2). Trigger fish within closed Polynesian lagoons are genetically different to those outside (3). And crabs, fish, oysters and mussels, a veritable genetic paella, show gene frequency differences across biogeographic boundaries between the Gulf of Mexico and the West Atlantic (4), or between the Mediterranean and the East Atlantic (5).

These emerging empirical data are telling us the same thing: that in some times and places marine larvae are capable of maintaining close links to home despite the ocean highways of the sea. Of course, many other marine species seem to disperse broadly, and the challenge will be to predict the nature of ocean neighborhoods for a wide range of species. Yet, these examples of fine-scale patterns in genetic or chemical signatures tell us that the conventional wisdom of marine biology – that the ocean road is a long one for larvae – may prove to be a coarse generalization. It turns out that most hobbits do not take the long road either – Bilbo was an exception – and in the end many marine species, and hobbits, like to stay home.

- (1) Taylor, M and M Hellberg. 03 Jan 2003 *Science*.
- (2) P. H. Barber, S. R. Palumbi, M. V. Erdmann, and M. K. Moosa. 2003. *Nature* 406: 692-693.
- (3) S. Planes, P. Romans, and R. Lecomte-Finiger. 1998. *Coral Reefs* 17: 9-14.
- (4) J. C. Avise. 2000. *Phylogeography*. Harvard University Press, Cambridge, Massachusetts.
- (5) H. Quessada, C. Zapata, and G. Alvarez. 1995. *Marine Ecol. Progr. Ser.* 116: 99-115.