the planet real, we now know that it is a gas giant made mainly of hydrogen, not rock — a solid planet with a mass of 0.63 M_J would have to be three times smaller than Jupiter.

Our understanding of planetary science will be enormously increased by direct measurements of the physical properties of extrasolar planets. The detection of reflected light from a planet, if confirmed, is the first step towards spectroscopic studies of extrasolar planets that would enable us to study their chemical composition and atmospheres. A journey that begins with giant planets close to their primary stars should in time lead to a better understanding of Earth's place among the many planetary systems that seem to surround us. ■

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Population biology

The prodigal fish

Stephen R. Palumbi

When Captain Ahab left harbour to hunt the white whale, he did not know exactly where to start. Cruising the hard sea of the nineteenth-century whaling fleets, he hunted and waited, primed for the sight of his unpredictable prey. Meeting another whale ship he would shout his frustration "Hast seen the white whale?", thereby becoming one of the only North American males willing to ask directions.

Such is the fate of many ocean hunters — even those who drag the seas for real fish in modern commercial fleets. Understanding movement in the sea is one of the major unsolved problems of biological oceanography. In this issue, papers by Swearer *et al.*[1] (page 799) and Jones *et al.*[2] (page 802) take two large steps towards answering these questions. With different experimental approaches, they show that the larvae of reef fish, poor swimmers cast for weeks into the wide sea, are not always washed afar by ocean currents. Instead, some are retained near where they are spawned, and settle back onto the island reefs that their parents inhabited.

The secret life of fish has always held a geographical mystery. Most fish develop from planktonic larvae that drift for weeks or months in ocean currents. Diluted by the ocean's vast expanse, these larval fish have the potential to be transported thousands of kilometres, but whether they stay at home to produce the next crop of juveniles, or drift off to mature far away, is generally unknown. This information is critical to fisheries models and coastal-management plans, and the basic assumption has been that larvae drift the oceans like vertebrate clouds, travelling vast distances and seldom going home.

Swearer *et al.*[1] attack this question by showing that the larvae of a common coral-reef fish, the Caribbean bluehead wrasse (*Thalassoma bifasciatum*), often spend their planktonic lives close to shore. They base their conclusions on tiny chemical tags that accumulate inside the otolith — a calcareous ossicle in a fish's ear.

Daily growth rings in an otolith can be counted to provide an estimate of the age at which the fish left the larval stage[3]. Moreover, during otolith growth, trace minerals from the environment are included in the calcareous matrix. As a result each otolith is a chemical autobiography of a larva's life, recording which trace elements were available as the planktonic drifter grew and developed in the changing chemical sea[4,5].

Swearer *et al.* measured the elemental content of otoliths collected from settling wrasse larvae in the US Virgin Islands to estimate where larvae had drifted. Near-shore water masses contain higher levels of manganese, copper and barium than tropical, open-ocean waters. The otolith analysis showed that some larvae had high concentrations of these metals, as well as fast growth and large size at the transition from larva to adult. Other larvae had low metal content, slow growth and small size. The first syndrome is probably characteristic of larvae that were retained near shore and grew quickly on the thick planktonic soup that near-shore waters nurture. The second signature indicates larvae that were swept out to sea, but won the plankton lottery by being wafted back to shore at metamorphosis time. The big surprise in these results is that so many larvae — up to 50% in some of Swearer and colleagues' samples — had 'retention signatures'. These larvae developed without a long open-ocean voyage, and so must have settled on the reefs of their natal island.

Jones *et al.*[2] took a more hands-on approach, and spent three months laboriously tagging ten million fish larvae around Lizard Island on the Great Barrier Reef. They labelled larvae by placing nearly two thousand nests of the damselfish *Pomacentrus amboinensis* in a dilute solution of tetracycline, allowing the developing eggs to absorb the fluorescent dye. The tetracycline was incorporated into the calcareous matrix of larval otoliths, and could be seen as a glowing ring under ultraviolet light.

After the ten million larvae hatched and disappeared, Jones *et al.* deployed light traps, floating like neon jellyfish in a night-time sea, to collect larvae at the end of their three-week planktonic period (Fig. 1). They caught 7,327 juvenile damselfish, and the otoliths from 5,000 of them were carefully dissected

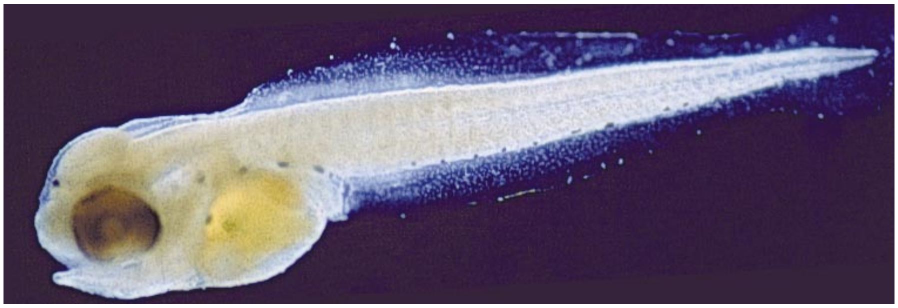

Figure 1 **On the Great Barrier Reef, many larvae of the damselfish *Pomacentrus amboinensis* stay near their point of origin. Jones *et al.*[2] found that they become juveniles on the reef that hatched them, despite a three-week period drifting in the plankton. (Picture courtesy of G. Jones.)**

and viewed with an ultraviolet microscope. It took a month to find the first labelled otolith, glowing spectacularly under the microscope light, providing the first objective evidence that planktonic fish larvae can settle back onto the same reefs from which they were spawned.

All in all, 15 of the labelled larvae were collected — about one in 330. This figure seems small until compared with the larval output of the reefs of Lizard Island. Damselfish on Lizard Island produced one to two billion larvae during the tagging effort. Thus, Jones and colleagues tagged about 0.5–1% of larvae. Because 0.3% of the captured larvae showed the tetracycline tag, a substantial proportion (between one-third and two-thirds) of settling fish were estimated to be derived from eggs hatched on Lizard Island, with the rest being imported from elsewhere. This is a surprisingly high value for retention of larvae on a local reef, and suggests that many larvae stay close to their natal site for the entire planktonic period.

These two studies refute the conventional wisdom that planktonic dispersal must be widespread, and echo increasing evidence that oceanic conditions might favour retention. Oceanic gyres and eddies a few kilometres across can gather larvae in vortex centres, transporting them slowly as the centre of the gyre moves[6]. Simulations of ocean flows often show retention of particles near the point of release, or show surprisingly little movement of simulated larvae along coasts[7]. Genetic signatures of population separation can be exceedingly sharp. There is a steep cline — a gradient in gene frequency — in American oysters that spans only 20 km and has been geographically stable for over a decade[8].

If long-distance marine dispersal is ecologically rare, this has profound implications for the management of global fisheries and the maintenance of biological diversity in the sea. Local populations of fish may require management on a much finer scale than was previously thought. In addition, attempts to implement networks of marine protected areas to improve fisheries or maintain regional biodiversity rely on assumptions about ecological connectivity among populations[9]. The sizes of successful marine protected areas need to be scaled to average larval dispersal distance, and the distance between replicated beads in a reserve necklace may need to take larval dispersal distance into account.

These results suggest that more direct measurements of dispersal will be crucial in refining the management of marine ecosystems. Understanding how often fish larvae are retained on reefs, and whether these results also apply to continuous coastlines, with consistent patterns in the currents that run along the shore, will require complementary studies of other species and other oceanic settings. But for the first time, we know the fish come home. ■

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Materials science

Injecting spin into electronics

Michael Oestreich

The operation of traditional semiconductor devices depends on the transport and storage of electronic charge. But electrons have spin as well as charge, and taking advantage of the spin could revolutionize electronics, leading to new devices such as spin transistors[1], spin memory storage or even spin quantum computers[2]. One requirement for such devices is the efficient injection of spin-polarized carriers (electrons, or their positively charged counterparts, holes) into a semiconductor. This has proved to be a huge challenge. Now two groups have independently achieved success with real electrical devices. On pages 787 and 790 of this issue, Fiederling *et al.*[3] and Ohno *et al.*[4] report the injection of spin-polarized electrons or holes into a light-emitting diode, with efficiencies of about 90% and 2%, respectively. In both cases the diodes emit circularly polarized light, confirming the spin polarization of the carriers. So far these devices only work at low temperatures, but the race towards commercial semiconductor spin electronics is on.

Why is spin electronics in semiconductors interesting? One motivation comes from the discovery that alternating layers of non-magnetic materials and ferromagnetic metals (such as iron) show large changes in their electrical resistance when a small magnetic field is applied. This change, known as giant magnetoresistance, can be greater than 60% at room temperature and results from the specific electron-spin orientation across the layers[5,6]. The effect is already exploited in many applications, such as in the millions of reader heads in high-density magnetic computer disks. Another example, which might have a huge economic impact in the future, is nonvolatile magnetic random access memory that can retain information when switched off[7]. The use of spin effects in metals has led rapidly to commercial applications. Even more enticing is the dream of spin electronics in semiconductors, where you can easily engineer the electronic properties, combine conventional and spin electronics on one chip, and build optoelectronic spin devices.

Spin injection is currently the biggest obstacle facing semiconductor spin electronics. Why is this? Many groups have tried to use ferromagnetic metal contacts to inject spin-polarized electrons directly into a non-magnetic semiconductor. This seems like a good idea because electrons in ferromagnetic metals already have a preferential spin orientation at room temperature, even without an external magnetic field. But so far experiments have shown little or no spin polarization of carriers injected from a ferromagnetic metal into a semiconductor[8]. Dead magnetic layers at the metal–semiconductor interface and the huge difference in the number and energy of carriers are possible causes.

At the interface between a magnetic and a non-magnetic semiconductor these problems are absent. This is good news because, as yet, spin electronics has produced all-metal devices or devices combining metals and semiconductors. The goal is to make an all-semiconductor device, which would make it easier to incorporate spin electronics with traditional semiconductor technology. The two experiments reported in this issue[3,4] show clearly that unpolarized carriers can become strongly spin polarized in a magnetic semiconductor and then electrically injected (that is, voltage driven) into a non-magnetic semiconductor with their spin orientation intact. Is the problem of spin injection in semiconductors finally solved?

Fiederling *et al.*[3] show that voltage-driven spin injection from a semimagnetic to a non-magnetic semiconductor is highly efficient: the device injects 90% spin-polarized current into a light-emitting diode, which is good enough for industrial spin devices. They use an unusual semimagnetic semiconductor (a group II–VI compound; BeMnZnSe) as the 'spin aligner' to polarize the electrons before they are injected into the non-magnetic semiconductor (GaAs). Because the GaAs device is configured as a light-emitting diode, the polarized current