spillover, particularly in coral-reef systems[4,6], and some evidence for recruitment subsidy, in particular from a recent study of larval dispersal from marine reserves within the Great Barrier Reef Marine Park in Australia[7]. This study found that 55% (for stripey snapper; *Lutjanus carponotatus*) and 83% (for coral trout; *Plectropomus maculatus*) of all juveniles produced in reserves dispersed to subsidize recruitment to surrounding fishing grounds.

Now, Januchowski-Hartley and colleagues take the evidence for spillover a step further. They report that, in three Philippine locations, fish that live in the safety of a reserve are less vigilant than fish living outside the protected area, and that they bring their less-vigilant behaviour with them when they wander across a reserve boundary.

The researchers looked at the behaviour of three families of reef fish: butterflyfish (Chaetodontidae), which are not a target for fishing, and surgeonfish (Acanthuridae) and parrotfish (Scaridae), which are fishery targets (Fig. 1). The study design involved spotting individual fish engaged in feeding or swimming behaviour (not in social activities). A snorkeller (Januchowski-Hartley) would then descend to about 8–10 metres away from the fish, and swim towards it at constant slow speed. When the fish fled or sought shelter among the coral, the snorkeller recorded the linear distance between himself and the fish just before it fled — the flight initiation distance (FID). The authors also recorded the estimated total length of the fish. They classified each encounter as within one of eight 50-metre-wide zones that spanned from 200 m inside to 200 m outside the reserve boundary. Finally, they repeated the same procedure around control 'boundaries' within the fishing zone and away from marine reserves.

The main results are straightforward: the FID increased for each of the two fished families in all three reserves as the location of the encounters moved from inside to outside the boundary. No such trend was seen across control boundaries or for the non-fished butterflyfish. Because fish are easier to spear if they have a shorter FID, these results mean that fish just outside the boundary of a marine reserve will be easier to catch (at least by spearfishing) than those farther from the boundary.

The obvious explanation is that fish learn to adjust their FID according to the level of risk, that FIDs are shorter within reserves (where risk is low) and that fish that spill over into the fished area take time to increase their FIDs. These findings imply that the presence of a marine reserve is even more beneficial to a fishery than previously expected — not only do fish spill over, but also those that do are naive and more easily caught. Marine-reserve advocates will be delighted by this suggestion.

Are these results surprising, and are they important? Yes, and yes. I suspect that they will surprise those fishery scientists who use catch statistics as their primary data, and who tend to think of fish as hanging around waiting to be caught, although they will not surprise biologists who watch fish before the fish are caught. Fish are behaving beings, and are highly capable of adapting their behaviour to particular circumstances. Their behaviour as larvae, for example, gives them amazing control over their dispersal[8], and, as juveniles and adults, behaviour adds much of the complexity that builds up fish social structures and contributes to the challenges of managing some fisheries. Januchowski-Hartley and colleagues' results are a direct demonstration of an unexpected consequence of adaptive fish behaviour, and they will be relevant to anyone seeking to quantify the effects of a marine reserve on fishery yields. ■

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MATERIALS SCIENCE

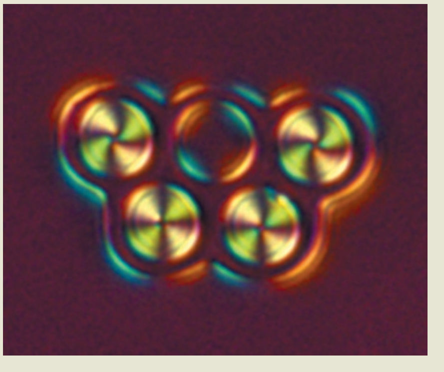
Topology matters

The effects of topology have been investigated in systems as diverse as molecules and the cosmos, but rarely at the micrometre scale. In this issue, Senyuk *et al.* explore how topology affects the alignment of micro-scale particles suspended in a 'nematic' host matrix — a liquid crystal in which the molecules are aligned but do not form well-defined planes (B. Senyuk *et al. Nature* **493,** 200–205; 2013).

The particles in naturally occurring colloids — systems of tiny particles of one material suspended in a different material — are often spheres or faceted crystals. Such particles are said to have a topology of genus (g) zero. To explore the effects of different topologies on colloid particles, Senyuk *et al.* synthesized particles constructed from rings 5–10 μm in diameter. These ranged from simple hoops ($g = 1$) to 'Olympic rings' ($g = 5$; pictured).

The authors found that when the particles were dispersed in a nematic liquid crystal, they typically aligned with their ring planes perpendicular to the direction of alignment of the liquid crystal (the 'director'). Each particle of genus g generated at least $g - 1$ defects in the liquid-crystal matrix, in agreement with topological theorems. These were either point defects in the rings' holes, or loop defects that could run around the inside or outside of the rings. What's more, the orientation of the liquid-crystal molecules around each particle was dictated by the particle's topology.

Senyuk and co-workers went on to show that the particles could be aligned parallel to the director by melting and rapidly cooling the surrounding liquid crystals. In this case, defects appeared in the liquid crystal both within and next to the particles. And by applying an electric field at different rates, the authors could switch either the orientation of the colloidal particles or the configuration of the liquid-crystal molecules around the particles; the



resulting states were stable when the electric field was removed.

Finally, the researchers found that the particles diffused more easily along the nematic director than in other directions, and that the rate of diffusion decreased with increasing genus number. Taken together, these findings open up fresh opportunities for colloidal organization and self-assembly, as well as potential applications — in electro-optic or photonic devices, for example. **Rosamund Daw**