The lesson is that real-world monitoring for early warning signs would have to be tailored to each ecosystem, based on what models and real-world tests suggest are the most likely indicators present.

However, some argue that the haphazard appearance of warning signs in models may make them too unreliable to use at all. Alan Hastings, an ecologist at the University of California in Davis, showed last year that several early warning signals, such as variance, failed to show up as expected in some common ecological models[9]. Perhaps the models that do show early warning signs are exceptional, and maybe only a limited number of ecosystems will show useful indicators, Hastings explains. "We need data from lots of real systems [to put the models to the test]."

"False alarms or no warnings are a big problem," Dakos says. Carpenter agrees: "Before we put them into use, we need a lot more field trials."

Even if early warning signs don't give reliable evidence of an impending tipping point, they could still be useful to manage ecosystems better, Carpenter argues. "The real question is whether management with indicators has higher expected performance than management without indicators," he says. "Even an imperfect indicator can have a big expected pay-off."

Carpenter argues the effort is worth it because it could help prioritize spending on restoration and remediation work by steering efforts towards those ecosystems that seem under threat.

Reinette Biggs, an ecologist at Stockholm University in Sweden, thinks that they could also offer hope to those working to stem the tide of ecosystem collapse. "Sometimes it seems as though things aren't happening," she says. Improved indicators of resilience could show that intervention is helping to pull the ecosystem back from the brink. Instead of warning signs, they would be signs of success. ❐

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SNAPSHOT

# Swimming against the tide

Some reef fish will be so metabolically hampered by warmer waters that they won't be able to swim against typical ocean currents, suggests new research.

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Ocean temperatures are expected to rise by about 3 °C within the next century. Many studies have looked at the effects of climate change on corals, but only a few have assessed how reef fish might fare, says Jacob Johansen, a marine ecologist at James Cook University in Townsville, Australia. One recent study has found that clownfish and damselfish lose their ability to smell predators in waters made acidic by climate change, for example, and another has found that clownfish can lose their hearing.

Johansen and his colleague Geoff Jones tested the swimming performance of damselfish — a diverse group of finger-length or smaller fish found on all tropical coral reefs, at two different temperatures (*Glob. Change Biol.* doi:10.1111/j.1365-2486.2011.02436.x; 2011). These fish forage in open water, but typically hunker down in protected niches when currents exceed their swimming capacity. Like most reef fish, they usually manoeuvre through their coral habitat using only their pectoral fins. When currents increase, however, they have to use their tail fins for added propulsion.

The researchers collected ten different species of damselfish from a site in the northern portion of Australia's Great Barrier Reef, where the water temperature averages about 29 °C. In lab tests, damselfish swimming in 32 °C water had a maximum swimming speed that was 14% lower, on average, than damselfish at 29 °C. And they had to use the more energetically demanding tail-assisted propulsion at current speeds 24% lower than those swimming in the cooler waters.

Some species fared much worse than others. The neon damselfish (*Pomacentrus coelestis*), for example, took to tail-assisted swimming in currents of 37.6 cm $s^{-1}$ at 29 °C, but in currents of just 20.9 cm $s^{-1}$ (44% lower) at 32 °C.

Test results indicate that by the end of the century, some species of damselfish won't be able to swim fast enough to cope with the currents typically seen in their reef ecosystems. Reduced time spent foraging by individuals will probably lead to slower growth, increased mortality and reduced fecundity, the researchers note.

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