WHEN CORALS DIE AND FISHES BECOME FEARLESS

Marine ecologist **Mark McCormick** explores what happens to young reef fishes when coral dies.

One of the reasons for the startling diversity of fishes living on healthy coral reefs is the patchiness of this habitat providing for lots of shelter sites and niches. It also provides for lots of predators. Identifying and avoiding predators relies on fishes being able to decode alarm chemicals in the water. *Photo: Robin Jeffries*

Bleaching is deadly for ambon damselfish, and presumably many other fish species, in part because the chemicals emanating from degraded coral somehow alter the structure of the ambon damselfish's alarm pheromone. This prevents young damselfish learning the identity of predators.
Photos: ARC Centre of Excellence for Coral Reef Studies (left), Robin Jeffries

Summer temperatures are already close to the limits for survival of many corals. In March and April this year a strong El Niño event pushed temperatures on the northern Great Barrier Reef beyond what many corals could bear. The stress caused them to evict their zooxanthellae, the algae-like protozoa that provide their food and colour. Bleached corals can survive on energy reserves and the small amount of food they capture with their tentacles for about 10 days to a month, depending on temperatures. This year the water stayed hot for too long, and many corals died – more than a third of those in the northern Great Barrier Reef.

Within days of death the white coral skeletons were tinged green by algae. Within weeks they became blanketed by algae, and invertebrates started reducing them to rubble.

What happened to the fishes on these reefs? We know that as reefs degrade, the fish communities change. Some species thrive, but the variety is diminished. Fishes that have strong associations with coral are the worst affected, and often die faster than expected.

I am part of a team from the ARC Centre of Excellence for Coral Reef Studies at James Cook University, the University of Uppsala and the University of Saskatchewan investigating how fishes respond to degradation. With tropical reefs all over the world being degraded or destroyed from bleaching, poor water quality due to run-off from land, a higher frequency of severe storms, and outbreaks of the crown of thorns starfish, it is important to understand why some fishes do well and others die. Our studies are also revealing a lot about the secret lives of baby fishes.

Learning to survive

Adult reef fish get together around summer and spawn to produce fertilised eggs. After hatching, the larvae of most species spend two to three weeks in the open ocean, where they develop into fish that look like small adults. Most are thought to succumb to predators. Those that survive have amazing swimming and navigational abilities. As their larval phase ends, they travel tens to hundreds of kilometres, using magnetic and sun-compass information to navigate to a reef of their choosing, sometimes their natal reef.

But they cannot rest easy once they arrive at a reef. The average little fish is dead within hours, because sitting in wait for an easy meal are predators such as rockcods, wrasses and dottybacks. These typically take more than half the new recruits within the first couple of days.

The rates of loss slow dramatically after that. It could be that the most vulnerable young fishes have been eaten, or that the young learn very quickly who among the diverse reef inhabitants they need to avoid.

Young fishes arrive at the reef with little knowledge of who to avoid. We have found evidence that their parents are able to transfer some information to them about predators (by non-genetic pathways), which influences their decision about which habitat patches to settle on, but it does not appear to help them survive when they first join the reef community. Instead, they have surprisingly sophisticated ways of learning about predators.

The most dangerous way to learn is through near misses and escapes. A safer method is to decode public information about predator activities and motivation. When the skin of a fish is lacerated it releases chemicals that trigger anti-predator responses (such as increased vigilance or retreat to shelter) in similar sized individuals of the same or closely related species that are downcurrent.

In a type of Pavlovian conditioning known as 'associative learning', a fish can learn to link these alarm pheromones with the smell or sight of a predator. Just one coupling of a pheromone and a new stimulus is enough for learning to occur. In experiments fishes can be readily trained to fear lights, golf balls or vanilla essence. But because there are initially so many unknown stimuli on a reef, a young fish needs to learn which are important, by repeated conditioning. It can't afford to spend too much time hiding or being super-vigilant, so constantly updates information and forgets stimuli that seldom signal threats.

Ambon damselfish (*Pomacentrus amboinensis*) live in small groups of one mature male and several females on reefs across the western Pacific. All start out life as females and some later turn into males. Research by the author and his colleagues has revealed that the survival of young damselfish relies on them rapidly learning the identity of predators by linking alarm pheromones released by other fishes with the smell or sight of a predator. The chemicals in these alarm pheromones have not yet been identified but minute amounts can be detected. ***Photo: ARC Centre of Excellence for Coral Reef Studies***

Losing the ability to detect alarm pheromones in degraded habitats makes ambon damselfish much more vulnerable to predators, such as this coral cod (*Cephalopholis miniata*). ***Photo: ARC Centre of Excellence for Coral Reef Studies***

Lemon damsels (*Pomacentrus moluccensis*) are always associated with live hard coral and are one of the first to die when the hard coral dies. ***Photo: Mark McCormick***

Reef fishes also learn socially. A fish that has learned to associate a particular smell or sight with a predator can pass this information, wittingly or otherwise, to others. By being attentive to neighbours, including other species, a fish can learn that particular behaviours indicate danger.

Learning quickly and frequently updating information is vital in an environment where new predators often arrive, or when a fish migrates to find a mate or new sources of food. When we taught young damselfish about two main predators using associative chemical learning, two thirds were still alive after three days, but more than 90% of the naive fish we tested died.

We have recently shown that the ability of young fishes to learn is coupled with changes in behaviour when they first settle on a reef. In response to all the new sights, vibrations and smells they develop great caution, a condition known as neophobia, in which they fear everything they don't know to be safe. A profusion of alarm pheromones reliably triggers neophobia. Becoming neophobic at this vulnerable time in their life is advantageous because it increases their reaction speed and level of lateralisation – fishes can be left or right finned – which means they instinctively turn to one side to escape a predator, saving on decision-making time.

The chemical miasma emanating from degraded habitats somehow alters the structure of the ambon damselfish alarm pheromone.

When reefs become degraded

Our earlier studies had shown that fishes which normally stay close to shelter among the branches of coral retreat from bright bleached coral, and move even further from dead coral. This greatly increases their risks of being eaten. We speculated that they are repelled by the startling whiteness and necrotic odours of bleached coral and the overwhelming smell of dead coral. We wondered whether the noxious smell of dead coral may also impede their use of chemical information to judge risk.

To test this, we captured young ambon damselfish (*Pomacentrus amboinensis*) as they were about to settle on a reef. This species is common on the Great Barrier Reef, particularly in shallow waters with sand, rubble and live hard coral, and shares many of the life history features of commercially important species. After allowing them to rest and feed for one or two days we placed them in the sea around Lizard Island on live or dead coral in background habitats that were healthy or degraded. We then taught them the identity of a novel predator by releasing into the water a mixture of damselfish alarm pheromone and the odour of dusky dottybacks (*Pseudochromis fuscus*), which are voracious predators on newly settled damselfish. A few hours later we tested how well the damselfish had learned their predator lesson.

Those on live corals responded to an alarm pheromone by seeking shelter or reducing the area they used, but those on the dead, algae-covered corals did not respond and had lost the ability to learn about predators through chemical associative learning. They were almost three times more likely to be eaten than the damselfish on healthy corals.

The chemical miasma emanating from degraded habitats somehow alters the structure of the ambon damselfish alarm pheromone. We found that even a small amount of seawater that had been in contact with dead algae-covered coral was sufficient to deactivate the alarm.

Fortunately, other species appear to be immune to the chemistry of degraded habitats. A close relative that we also tested, the neon damselfish (*Pomacentrus coelestis*), learned about a novel predator from alarm pheromones, whether coral was dead or alive. This species lives among rubble in lagoons or seaward reefs. We do not yet know why some species are affected and others are not.

We also don't know whether affected fish may be able to compensate by learning from other fish species still able to detect alarm cues. Perhaps ambon damselfish can learn by observing the reactions of related species such as neon damselfish to alarm cues. This is unlikely to fully compensate, however, for visibility is often limited due to topography, turbidity and darkness, while chemicals are detectable all the time.

The ability of fishes to learn in future may also be undermined by increasing carbon dioxide. At the levels CO_2 may reach by the end of the century it may alter the function of neurotransmitters in fishes, reducing their ability to detect alarm cues. However, there may be enough variability in fish responses at lower CO_2 levels for them to adapt through natural selection. Adaptation to degraded corals is much less likely because the mechanism (alteration of the chemical cue) is external to fishes, and all affected individuals seemed to be similarly impacted.

The many questions still to be answered give us cause to keep watching pretty fishes in the waters of the Great Barrier Reef. What we learn will help us predict the shape of future communities and how resilient they are to change. ■

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