Juvenile Moorish Idols (*Zanclus cosnutus*) as seen off Shelly Beach, Sydney, March 2009. Credit: Andy Donnelly

Tropical Fish Follow *Nemo* South

BY PETER POCKLEY

Tropical fish are successfully migrating to temperate waters, thus joining bleaching of coral reefs as harbingers of global warming.

A colourful damselfish named *Nemo* (*Amphiprion percula*) may have provided a fetching storyline for a popular animated movie, but to the critical mind it seemed a fanciful fiction. However, Australian marine scientists have been showing that not only are such migrations real but they are now prevalent and important indicators of climate change.

Dr David Booth and his Fish Ecology group at the University of Technology, Sydney have been conducting a lengthy study to track the remarkable journey of fishes from the tropical reefs of Queensland southwards. Booth says there is no doubt that the driving force behind this phenomenon is the 2°C rise in the temperature of the East Australian Current (EAC), which sweeps vast volumes of water from the Coral Sea southwards along the coast of Queensland and NSW (*AS*, May 2009, pp.17–20). What were once temperate waters have, through warming, become conducive to the lives of larvae and growing fish up to 1700 km south of their traditional grounds in the Great Barrier Reef (GBR).

Working from the Sydney Institute of Marine Science (SIMS) based at Chowder Bay on the north shore of Sydney Harbour, Booth directs a program with research students and volunteers at 11 study sites from Red Rocks near Nambucca in the north of NSW to Bittangabee near Merimbula in the south of the state.

An astonishing variety of tropical fishes has been recorded – around Sydney there are probably 70–80 species. Hotspots are at Camp Cove in the Harbour and, outside it, ocean reefs at Clovelly, Long Reef and Shelly Beach. Colourful damselfish and butterflyfish are among those most frequently found nowadays in Sydney Harbour, to the surprise of recreational divers. Booth has even seen cleaner wrasses at work scouring large fish like blue groupers, just like on the GBR.

The most dense populations were seen in the sites in the north of the state, while prevalence had tailed off by the southern sites. These observations are consistent with the weakening of the EAC, which breaks up into giant eddies as it nears Sydney Harbour.

Meticulous Surveys and Experiments

Due to the rarity of the tropical species, special survey methods had to be developed to ensure statistically significant results. The surveyors – comprising scientists and "lay volunteers", including some from Earthwatch – were trained to identify species and estimate their size under water. Large sections at each location were identified using landmarks to define their borders, and the total areas being surveyed were determined using GPS coordinates. The same sections were surveyed on successive visits. The surveyors, swimming with snorkel (mostly) or scuba gear, would transit an area, noting on waterproof paper the species and size of the tropical fish seen.

Booth, his PhD graduate Will Figueira, and students Peter Biro and Vanessa Valenzula have recently shown that the warming of coastal ocean due to climate change is increasingly allowing those tropical fishes transported to temperate latitudes to survive across the cooler winter months.

In a study that is more detailed than simply identifying species and counting their numbers, the group examined in the lab how well one tropical damselfish, *Abudefduf vagiensis*, performed with regard to survivorship, feeding, growth and ability to swim fast in bursts (as a measure of their ability to escape from predators). They conducted these tests in tanks where the water temperature was varied to match those in the open sea in summer and winter.

They found that the tropical fishes' performance was "significantly reduced" in winter temperatures. In contrast a co-occurring, year-round resident of the same family, *Parma microlepsis*, performed at much the same level between the two temperature conditions.

These experiments showed that the processes leading to early mortality of the migrating tropical fishes are complex and require more research for a better understanding of the factors involved.

Marine fishes survive by producing voluminous numbers of larvae that move with the ocean currents augmented by their own swimming ability until they settle. As a result the fish may settle in areas well outside the breeding range of their parents.

Booth and others have shown that it has been quite common for tropical fishes to inhabit temperate waters during the summer months. But despite quite substantial levels of settlement, the resulting populations have not attained survival year-round as there has been nearly 100% mortality over the winter, when the EAC had average temperatures of only 13–16°C.

However, in the past 6 years the EAC has had two of the warmest winters since 1848, resulting in "very high levels of survival" of tropical fish species at temperatures of 16.5–17.5° C. This is consistent with global ocean temperatures, which are predicted to be rising by 1–3°C up to the year 2100 – a range already reached in the Coral Sea and hence in the EAC.

Booth says that the pressures of fish survival and mortality are very difficult to study in the open sea, leading to the need for studies under controlled conditions in the laboratory. His group has measured the metabolism, feeding, growth and movement performances of tropical fishes under ambient and elevated temperatures over 16-week periods. The results were compared with their measurements on the coral reefs of the One Tree Island Research Station on the GBR.

In the laboratory an ingenious mechanism was designed to measure the velocity of a fish's response to a startling intrusion. A small weight was dropped near a fish and a video taken. Analysis of the movie's frames showed how fast and far the fish swam to escape the threat. The scientists found that the maximum speed of burst swimming was reduced by 60% at reduced temperatures.

In their overall analysis, Booth and colleagues conclude that the predicted rise in ocean temperatures of 1–3°C "is likely to severely stress many species which may already be at or near their thermal maximum".

Mighty Little Swimmers with Homing Instincts

Juvenile tropical fish start their journey south about 5 days after hatching, and spend 14–60 days in the EAC as larvae. "We've found some up to 70 days old," Booth says. "A lot of even the tiniest larvae have the ability to swim of their own accord at 0.1 knots. If you scaled them up according to size this would be the equivalent of Ian Thorpe doing a 50-metre lap in 5 seconds. They can swim against small currents. The EAC travels at about 1 knot. Larvae can swim for days without food. Near the end of their stay they swim towards the edge of their cell of water, but a fish that swims out of that cell would experience a temperature drop of about 2°C and would turn back.

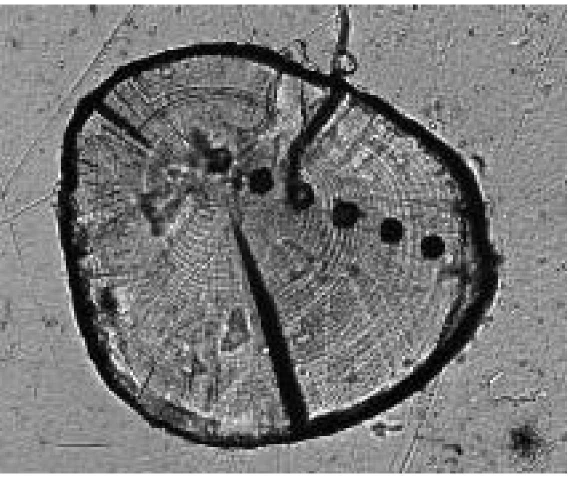
"We find certain species drop off in northern NSW, while others survive further south to near Eden and Merimbula. There is no clear explanation why some of the more common species last longer in the current than others. We think it may be something to do with the way they spawn and release their eggs, and the behaviour of those larvae."

This 50 mm butterflyfish (*Chaetodon cintrinellis*) was collected in NSW waters during the vagabond fish study. Photo: David Booth

By extracting the little ear stones, or otoliths, in a fish Booth and graduate students can tell its age by polishing and counting the rings that are formed each year, rather like the annual rings in the trunks of trees. The width of the rings gives a measure of daily growth.

Nobody had studied the movement of fish on the EAC before, and Booth realised that this could inform the issue of climate change. "The water had been getting warmer: there is no doubt about that at all," he says. "These guys could well be a

David Booth (left) and Will Figueira tagging damselfish at One Tree Island Research Station, Great Barrier Reef, as part of the tropical vagrants study. Photo: Gigi Beretta



A 0.3 mm otolith (earstone) from a damselfish reveals the daily growth rings added to the bone. Its duration as a pelagic larva was about 30 days. Small holes have been made by a laser to remove tissue for chemical analysis. Photo: Kerryn Parkinson

harbinger of what is to come. We are interested in them for their own sake but also as a bio-indicator or biomonitor of the EAC changes."

From the 1920s there has been a steady rise of a couple of degrees in the sea water temperature. Booth says this might not sound like a lot but it is really influential in terms of the EAC and the arrival of these fish.

The vagabond butterflyfish, found commonly as far south as any of the tropical species, is being studied at James Cook University in Townsville where studies of their otoliths have revealed a homing instinct. Booth puts this in context: "The old belief was that when the little larvae are formed they all take off and disappear, but the JCU scientists have shown that it's the same fish which we see thousands of kilometres away by coming back to the reefs of their birth. These guys have been in the plankton for months.

"For little anemone fishes that we also study it had been suggested that this homing instinct follows chemical signals. We do know from other studies that fish have very sensitive noses. We don't yet know how this vagabond butterflyfish finds its way back. These fish don't breed here and most of them die in April to June as the water temperature drops."

The Bengals Sergeant-Major damselfish doesn't breed down south and has come a long way from the north. In the unusually warm winters of 2001 and 2006 Booth found increasing numbers of these fish over-wintering. Up on the GBR these fishes would normally live 5–7 years. He says that there seems to be a threshold temperature of 17–19°C, against the backdrop of the mean temperature which is going up. "We have seen them breeding at the Solitary Islands – the northern-most of our sampling areas. They seem to be quite happy on temperate rocks away from the coral reefs."

Although the group has been engaged in this study for 9 years, Booth says it has not yet been long enough, what with the variability of nature in the marine environment, to determine long-term trends in numbers. "They are rare and there's a lot of 'noise' in the system when you only see one or two specimens per hundred square metres," he explains.

Booth says the research has been "quite a struggle to sustain". However, despite a lack of funding, he managed to continue doing the minimum necessary for gathering basic data over the uninterrupted years required to obtain significant figures on trends in populations. Now, some financial relief is near at hand (see box).

SIMS on Sea Legs after Budget

Four years since four Sydney universities linked to jointly pursue marine research in the waters of NSW (*AS*, May 2009, pp.17–20), the Sydney Institute of Marine Science (SIMS) has received its first substantial public funding with $19.6 million ($10.5 million in the first year) from the 2009–10 federal Budget's Education Investment Fund.

According to veteran marine scientist and SIMS Chairman and public champion, Prof Frank Talbot: "The funding will help to transform SIMS into a unique research aquarium facility, a new multi-institutional training for marine scientists and a one-stop shop for policy advice and management consultation to government agencies".

SIMS will gain a protected marine aquarium facility and associated laboratories, the first of its kind in southern Australia, complementing equivalent tropical facilities at the Australian Institute of Marine Science (AIMS) in Townsville. It will merge modern molecular biology and biotechnology with an environmentally realistic seawater facility.

Currently lacking adequate boats for field work, SIMS will acquire two special-purpose vessels. The first will be a 12-metre workboat capable of travelling 30 nautical miles offshore and covering all aspects of marine research at SIMS. The second will be a rigid inflatable boat for sampling and field work in more restricted estuarine environments.

Studies that were not previously possible will now be enabled, such as shore erosion, inshore coastal waves, speed of currents, wave surges and inundation from climate change.

Fish ecologist Dr David Booth says: "The new SIMS windfall is wonderful. We will all benefit. Personally, the upgrades to the aquarium will allow us to expand our studies of temperature effects on fish physiology and ecology."

Tropical marine science has also been boosted with $55 million in new infrastructure funding for AIMS in Townsville and Darwin.

Prof Frank Talbot is ready for the expansion of the Sydney Institute of Marine Science at the Chowder Bay site on Sydney Harbour. Photo: Peter Pockley