One man's swamp is a fish's nursery

The ear bones of fish provide clues to help protect critical habitats for juvenile coral reef fish

By Kelton McMahon

A parade of schoolmaster snappers swim by me, their neon yellow fins directing traffic. Echoing in the background is the rhythmic crunch of striped parrotfish nibbling on coral polyps. I'm chasing brightly colored coral reef fish through turquoise waters during a childhood vacation to the Cayman Islands. Back on land, the hotel I just left begins construction of a new tennis court where a mangrove swamp had flourished.

Like most tourists, I've come for the main show: magnificent coral reefs and the rainbows of fish that dance through them. As I diligently scour the reef for every fish on my checklist, I never stop to question where those fish came from or how they got there. Who would have guessed that it's what goes on behind the scenes, in mangrove swamps like the one my hotel just paved over, that keeps the main show on coral reefs going?

E. Paul Oberlander, WHOI

Mangroves are like nursery schools for many colorful fish that populate coral reefs. Among the roots and nutrient-rich waters in coastal mangrove swamps, juvenile fish get food and protection from predators until they mature and can migrate offshore to the reefs. These valuable nurseries are disappearing at an alarming rate, and so are the fish they support.

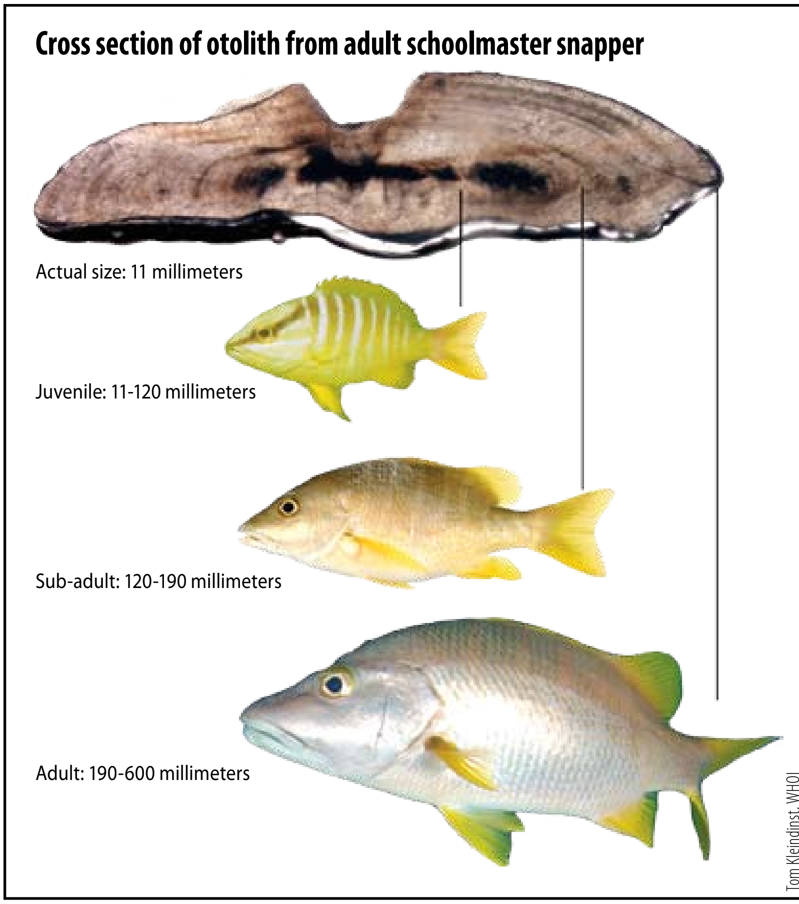
Mangroves are like nursery schools for many of the "celebrity fish," such as snappers, parrotfish, and barracuda, that attract millions of tourists to the Caribbean each year. Amid the mangroves' tangled undersea roots, juvenile coral reef fish are well-fed and protected from bullies and predators until they mature and can migrate out to populate coral reefs. These valuable nurseries are disappearing at an alarming rate, and so are the fish they support. It's ironic: Replacing sweltering, mosquito-filled mangroves with tennis courts and martini bars ultimately may be far more detrimental to tourism.

Scientists estimate we've already lost 30 to 60 percent of the world's mangroves. Meanwhile, more than 70 percent of all reefs are threatened by human activities—from farming and fishing to boating and coastal development. Coral reefs offer people living resources, from fish to ecotourism, worth more than $375 billion each year, according to the United Nations Environment Program. Such dollar figures emphasize the need for management practices and marine reserves to protect these reefs and their resident fishes.

Which swamps should we protect?

It's been more than a decade since my childhood vacation to the Cayman Islands, and I'm still diving in the Caribbean. This time, however, it's as a Ph.D. student in the MIT/WHOI Joint Program. I study the migration of schoolmaster snapper from their juvenile nurseries in mangroves to coral reefs.

Unfortunately, we can't save all the mangroves. My goal is to determine which and how many mangroves need to be included in marine reserves to safeguard cor-



Tom Kleindinst, WHOI

With a scalpel and microscope, graduate student Kelton McMahon carefully removes fish's delicate otoliths, or ear bones, each smaller than a grain of rice (right). Much like tree trunks, otoliths form sequential rings (top left) that correspond to different times in a growing fish's life. Each ring in the otolith gets imprinted with chemical isotopes from waters where the fish was living at the time the ring formed.

al reef fish for generations to come.

One of the biggest obstacles to protecting coral reef fish is identifying which juvenile nurseries supply the most fish to coral reefs. Let's suppose there were several schools that had fantastic teachers and ample resources. However, no one knew how many students from which of these schools graduated into successful adults. That's the problem we are facing right now with coral reef fish. I am developing a method, using chemical tags in the ear bones of coral reef fish, to identify which juvenile nurseries are supplying the most fish to the adult populations on coral reefs.

Tracking the movements of marine animals has led to incredibly inventive techniques that would make Sherlock Holmes proud. Scientists studying big animals such as whales, sharks, and giant tuna can use sophisticated electronic tags that beam data directly to their offices via satellite as these animals make spectacular ocean migrations.

Leah Houghton, WHOI

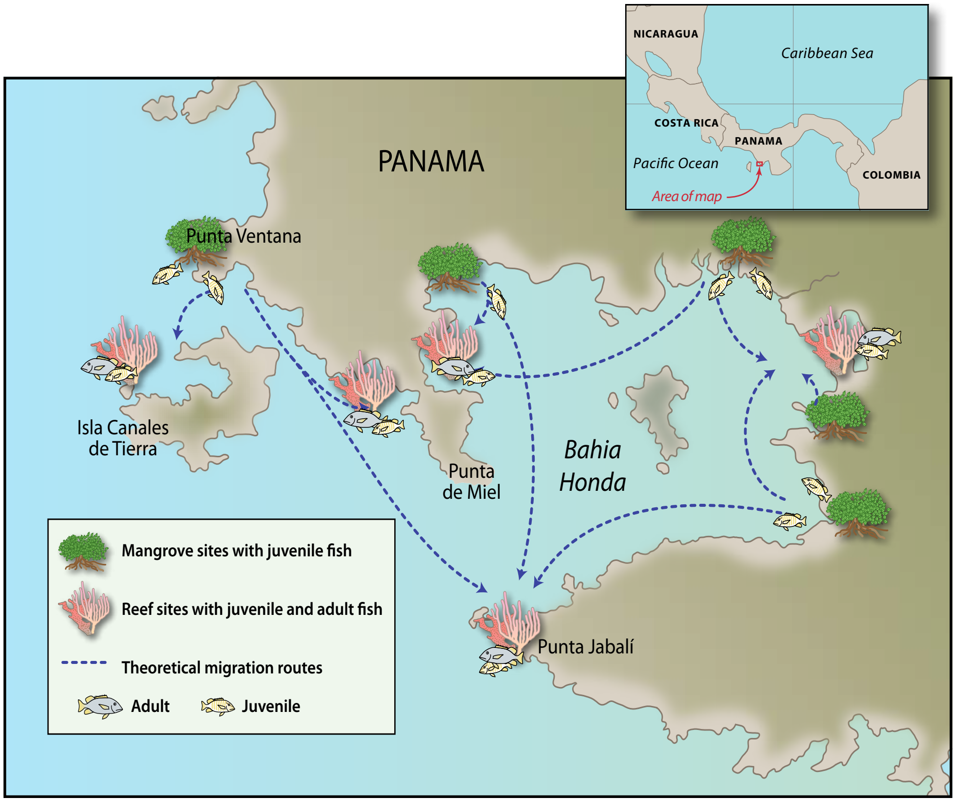
Kelton McMahon dives on an offshore reef near Alith, Saudi Arabia, in the Red Sea in November 2008.

The fish I study are far too small for that: If I put such tags on a juvenile snapper, it would sink to the bottom like a rock. To find out where my fish have traveled, I need something a little more subtle.

Chemical addresses

Studying biology and chemistry as an undergraduate at Bates College in Lewiston, Maine, gave me the idea to approach ecological questions such as fish migration from a chemical perspective. Mangrove swamps contain carbon, oxygen, and sulfur with distinctive stable isotopes—natural, nonharmful variations in elements. The old adage "you are what you eat" applies to snappers, too; the tissue of snappers living and feeding in a mangrove system gets imprinted with that mangrove system's stable isotope values, which gives the tissue a unique chemical address.

The tissue I'm interested in is called an otolith. It's an ear bone made of calcium



Jack Cook, WHOI

Working at the Liquid Jungle Laboratory on the west coast of Panama, MIT/WHOI graduate student Kelton McMahon has been trying to determine which mangrove swamp nurseries provide adult fish to which coral reefs. The answer will help coastal managers make decisions on the most important swamps to protect.

carbonate and protein that helps fish maintain their balance. As a fish grows, its otoliths form sequential rings, much like a tree trunk, corresponding to different times in the fish's life. The chemical makeup of each ring tells us where the fish was living during that period of time—a fishy chemical address book.

Over the past two years, I have been figuring out how to decipher chemical addresses stored in otoliths using stable isotope chemistry. As it turns out, some of the smallest compounds may tell the biggest stories. I am identifying specific compounds in otoliths whose stable isotope signatures will say, "This fish grew up in this particular mangrove system before it migrated out to a coral reef."

The non-tropical side of research

It all starts with some very small fish and some even smaller otoliths. Armed with a scalpel and microscope, I carefully remove the delicate otoliths from fish. Each otilith is smaller than a grain of rice. I subject the otoliths to a series of chemical processes to identify compounds that reflect the chemical address of the nursery in which that fish lived. This typically involves countless hours of injecting samples into a Gas Chromatograph-Combustion-Isotope Ratio Mass Spectrometer.

This often-temperamental machine tells me the stable isotope values of the otolith material. I match these values to those of potential nursery habitats to determine where that fish spent its juvenile life. If I do this enough times, I'll be able to say how important those mangrove swamps are to supporting coral reef fish populations.

I used to think studying coral reef fish would be all fun in the sun. However, for every day I spend in a wetsuit under the golden sun of the tropics, I spend at least 10 more in a white coat under the fluorescent glow of a windowless lab. I've often run samples for 72 hours straight with only 20-minute naps in my office chair, using my keyboard as a pillow, to keep me going.

A little sleep deprivation is well worth it if it means I can provide the scientific basis to select marine reserves that protect coral reef fishes. With dynamite fishing on reefs and mangroves being paved over for tennis courts, coral reefs and mangroves have become some of the most degraded environments on Earth. I hope my research will guide the conservation of coral reef fish, so that by the time my children take a Caribbean vacation, they can pack their snorkels as well as their tennis rackets.

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Tom Kleindinst, WHOI

Kelton McMahon said he knew he wanted to be a marine scientist from a young age. In fact, his first word was "boat." Growing up in southeastern Connecticut, McMahon spent summers helping his neighbor, a Connecticut College botany professor, assess the ecological impacts of local salt marsh restorations. McMahon pursued marine research at Bates College, Lewiston, Maine, earning his B.S. degree in 2005. For his honors biology thesis, he used an interdisciplinary stable isotope geochemistry and field ecology approach to assess the impacts of a changing food supply on the Arctic benthos. As a Ph.D. candidate in the MIT/WHOI Joint Program, he continues using geochemical tools to assess ecological questions, but in a much warmer climate. In his spare time, McMahon is an avid rock climber and photographer, traveling around the world looking for the next hard route or photo opportunity.