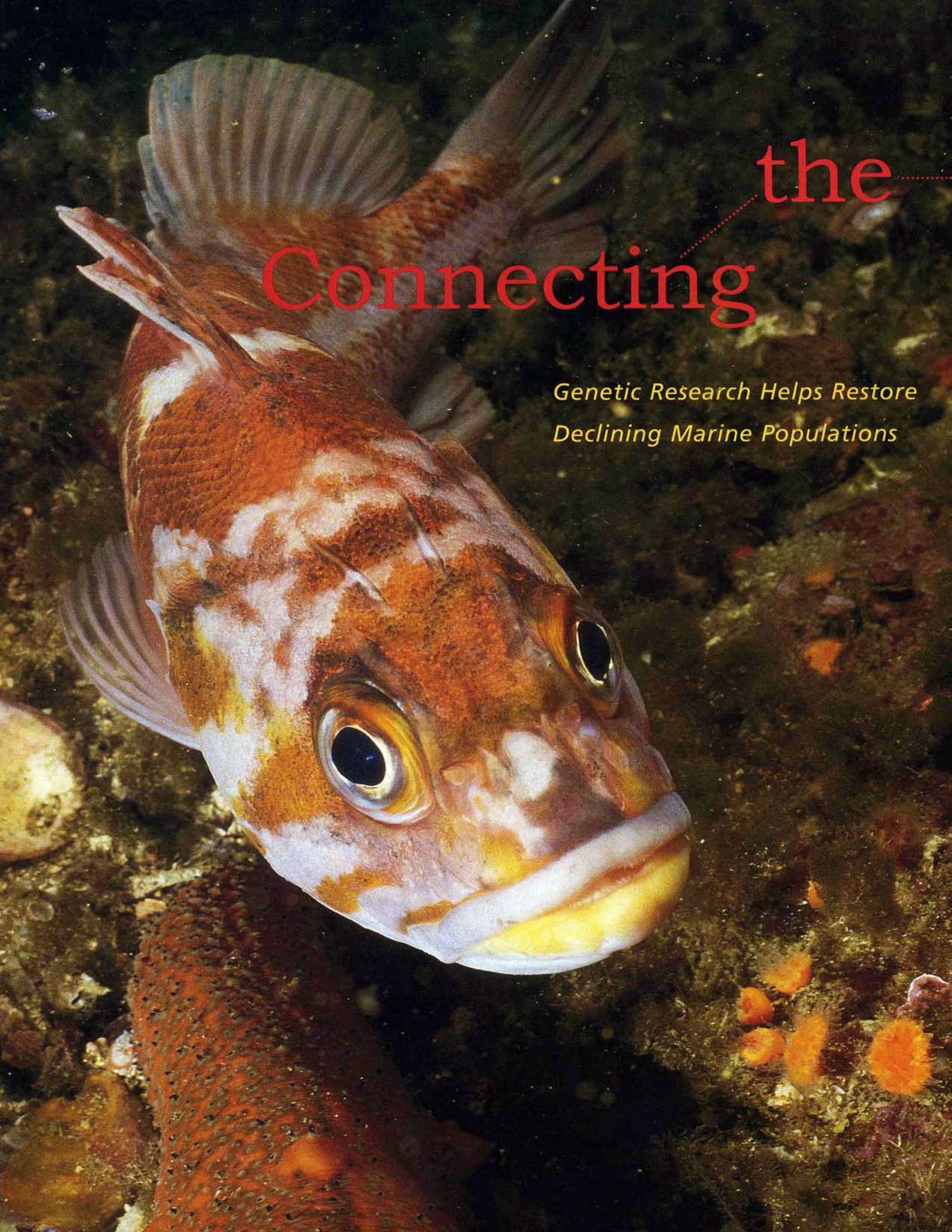


Connecting the

Genetic Research Helps Restore Declining Marine Populations

Dots

BY ROBERT MONROE

It's quite possible that rockfish is your favorite dish at the local seafood restaurant and you don't even know it.

Through the magic of marketing, species of the fleshy West Coast native often get sold as red snapper or even as exotic offerings like "red salmon grouper" by restaurants and supermarkets. Never mind that true red snapper is a fish caught in the Atlantic and the Gulf of Mexico.

Rockfish is also a staple at select high-end restaurants that let patrons pick live specimens for dinner the way they can select lobster from tanks. Nearshore species of rockfish are among the few plate-sized fishes that fishermen can keep alive after they are caught and brought to the surface.

But for that popularity, the rockfish has paid a heavy price. Several rockfish species, like cowcod and bocaccio, are among the country's most commercially important fishes and are also now among the most threatened. Their dramatic decline led federal regulators to adopt in September 2002 new, sweeping catch limits for the entire West Coast fishery.

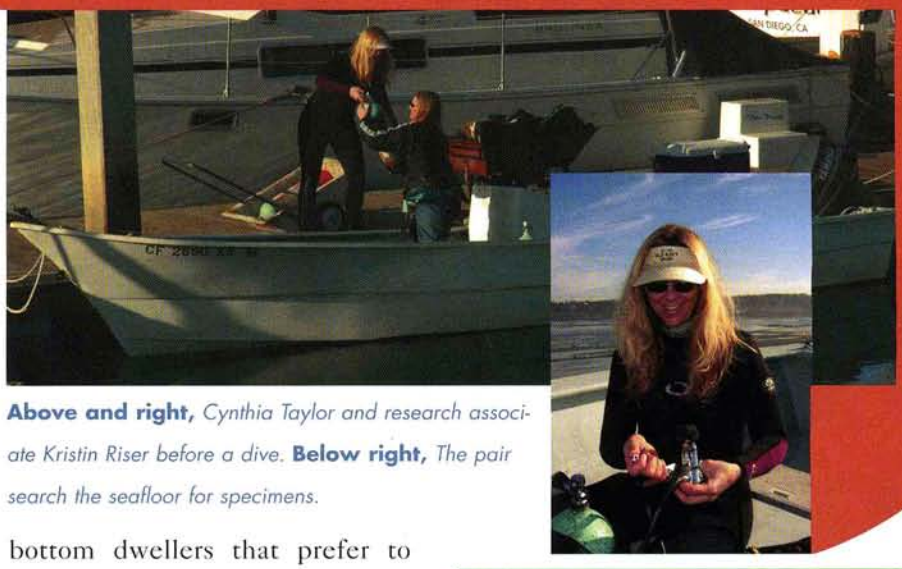
Above, *Scripps graduate student Cynthia Taylor encounters a rockfish on a sampling dive off San Diego's Point Loma, near Scripps.*

Scripps Institution of Oceanography graduate student Cynthia Taylor began studying rockfish in part to help determine the extent of the decline. A former high school marine biology teacher, Taylor became a student again to parlay her love of diving into a full-time research pursuit. As she earned her master's degree in evolutionary biology at San Diego State University, she came upon a colorful fish with a mysterious early life.

She muses that if she had the chance to ask God a question, she would want to know definitively how many rockfish there were to begin with before people started fishing them. Current estimates suggest cowcod have been reduced to two percent of their original population, what scientists call their "virgin biomass."

Increasingly, California officials are turning to the establishment of marine

ROCKFISH ARE AMONG THE OCEAN'S MOST UNUSUAL BREEDERS, WITH SOME INDIVIDUAL FEMALES RECORDED TO HAVE GIVEN BIRTH TO AS MANY AS TWO MILLION LIVE YOUNG AT ONCE.



Above and right, *Cynthia Taylor and research associate Kristin Riser before a dive.* **Below right,** *The pair search the seafloor for specimens.*

reserves—areas off-limits to fishing—to protect rockfish and other threatened rocky-habitat species. Protecting fishes, however, is a complex endeavor. It's difficult to count how many of a particular fish there are and how many there should be in the presence of fishing. Additionally, the ideal size and location of reserves are seldom clear cut. At stake are the livelihoods of commercial fishermen as well as the survival of marine creatures.

Taylor is one of several researchers at Scripps and around the state who are trying to understand the life story of rockfishes and other commercially important marine life. In the process, she hopes to contribute to the design of marine-reserve boundaries that take into account the incredible journey the fish make as larvae.

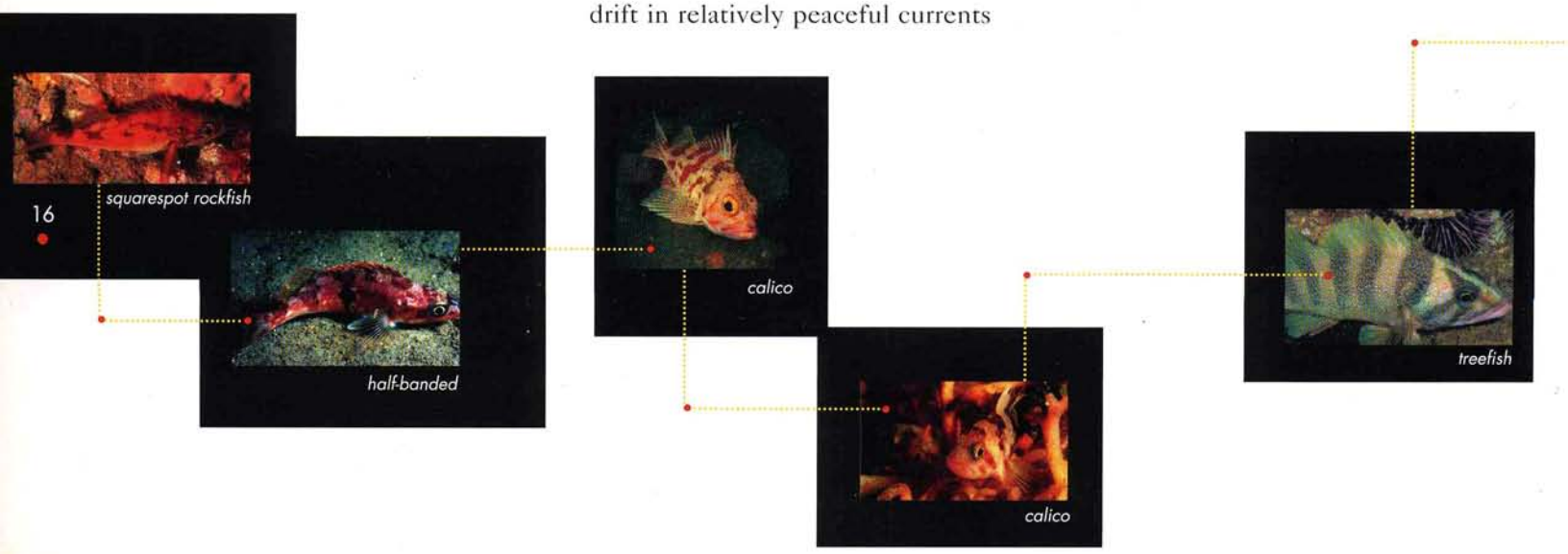
DRIFTING ALONG

There are about 60 species of rockfish along the West Coast, members of the genus *Sebastes*. They bear colorful common names—such as swordspine, vermilion, and chilipepper—and most display vivid markings to match. They are bottom dwellers that prefer to spend their adult lives at the floor of kelp forests or near offshore seamounts usually at depths of 18 meters (60 feet) or more.

Some species can live up to 100 years and for most of that life span they will never venture much farther than two kilometers (one mile) in any direction. Taylor, however, is interested in what she calls the "black box" of their existence—the time when they are larvae only a few weeks old.

After a live birth, which makes them unusual among fishes, the very youngest of rockfish are swept along by ocean currents that transport them far from home at a time when their ability to swim is least developed. Only a few millimeters long, some are swept out to the open ocean never to return; others drift in relatively peaceful currents just off the coast and are able to return to kelp beds where they will live out their lives.

To track the dispersal of squarespot rockfish larvae, Taylor collected them at a number of locations off the California coast and mapped where she found them at various ages. As size is not always a foolproof method to determine age, researchers such as Taylor remove otoliths, structures in the inner ears

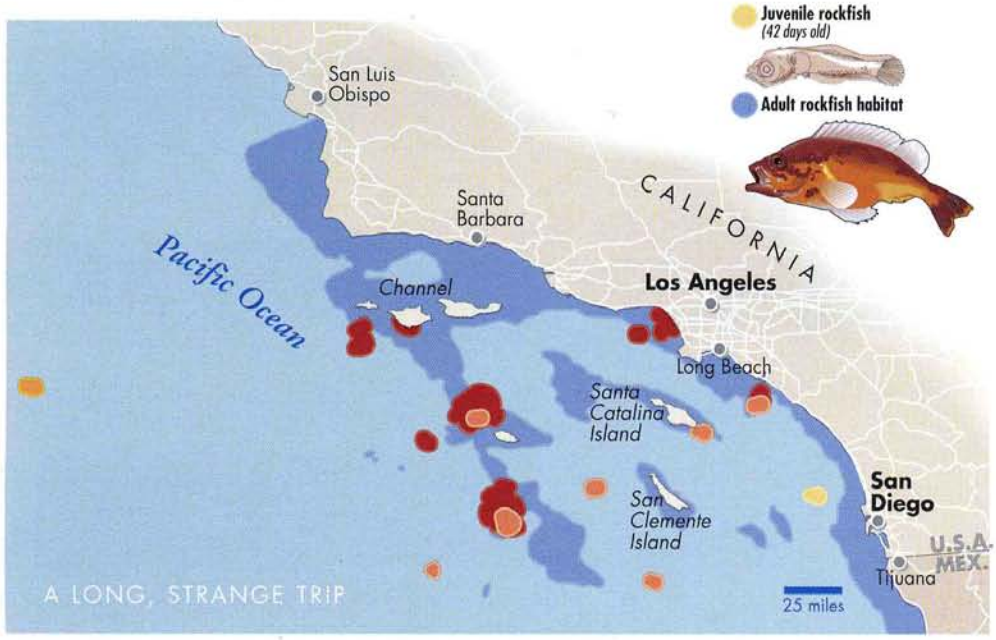


of fish that grow in daily layers as they age, much like the annual growth of tree rings. She made the location of the very youngest larvae a proxy for the spawning grounds, assuming that they could not have drifted far in only a few days.

She found squarespot larvae two to three weeks old several miles away from the spawning grounds and four-week-old larvae even farther from home.

Taylor describes the possibilities as she points to various places several miles apart on a map of the Southern California Bight, the coastal indentation that extends from Point Conception to Baja California.

"The larvae might make a beeline for home," Taylor said. "They can swim after 30 days, but they can't control their direction much before then, and nobody knows the extent to which a larva that's one or two months old can swim."



Graduate student Cynthia Taylor tracked the journey of squarespot rockfish larvae during their first seven weeks of their lives. She found that ocean currents can transport them several miles before they make their way back to the shallow waters where they live out their adult lives. The dispersal suggests most are routed to calm eddies just off the coast but well south of the spawning grounds. Her difficulty in finding larvae older than 28 days, though, leaves lingering questions about how they make their way home.

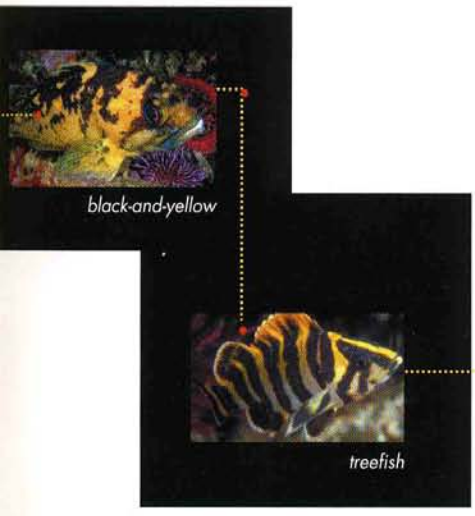
Above, *Cynthia Taylor holds a specimen caught on a research cruise.*

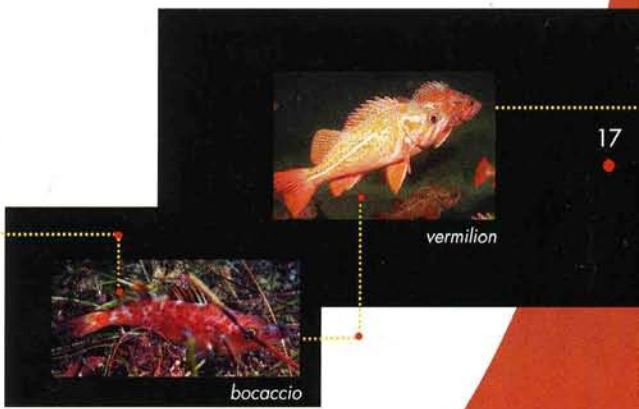
Knowing what's happening at the larval stage is crucial to understanding the concept of rockfish connectivity—the genetic similarity shared among members of a population that produces stock strong enough to rebound from intensive fishing. Disrupt connectivity and you can effectively isolate a population out of existence.

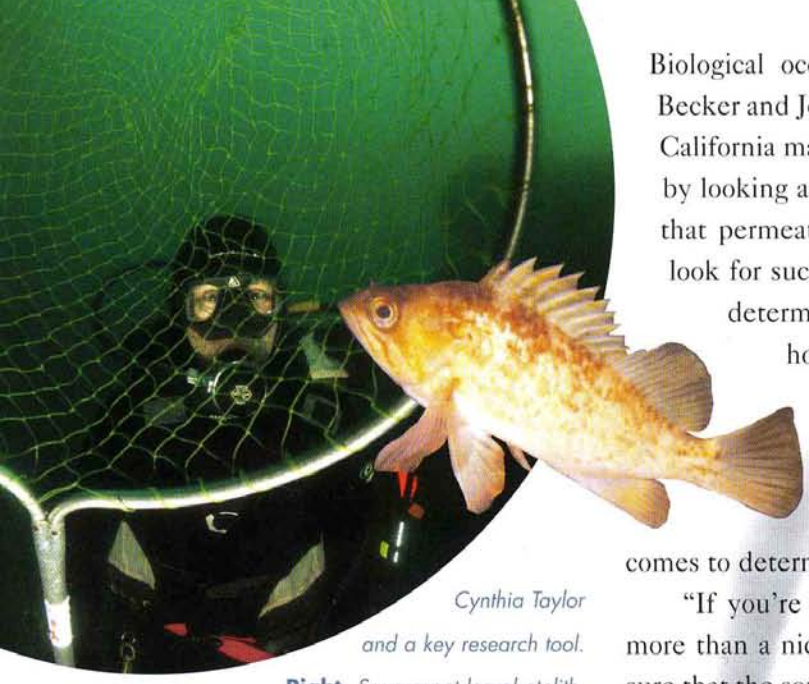
"You can't manage a population unless you know the levels of connectivity between the areas being fished," said Ron Burton, Taylor's adviser and director of Scripps's Marine Biology Research Division. "If there's no connectivity, and you overfish in an area, it won't recover for decades."

In a related branch of research, Taylor found that rockfish connectivity is shaped by geography and distance. There are populations of rockfish along the southern and

WEST COAST ROCKFISH SPECIES BEAR COLORFUL NAMES LIKE VERMILION AND CHILIPEPPER AND DISPLAY VIVID MARKINGS TO MATCH.







Cynthia Taylor and a key research tool.

Right, *Squarespot larval otolith.*

central California coasts that do not seem to be connected, though there exists a gray area between the two regions in which they apparently mix in a limited fashion. The boundary is possibly demarcated by differing water temperatures in the two regions.

"We appear to have two genetically distinct groups, so that if we were to set up marine reserves, we would want to be sure to capture the scale of genetic differentiation or biodiversity that's out there," Taylor said.

Elsewhere at Scripps, other inferences are being made about how habitats should be defined. Biological oceanographer Lisa Levin and graduate students Bonnie Becker and Joel Fodrie are trying to understand the distribution of other California marine creatures that are fished for food. One way to do so is by looking at the metals—whether natural or introduced by humans—that permeate parts of marine creatures' anatomy. Levin and Becker look for such trace-element concentrations in the shells of mussels to determine, as closely as possible, where they were spawned and how far they might have traveled in their lifetime.

While some mussel larvae in the back of a bay may never leave, others at the mouth of a bay could be swept 19 kilometers (12 miles) up or down the California coast. This is an important consideration, Levin said, when it comes to determining which areas are best to include in marine reserves.

"If you're thinking about the design of marine reserves, you want more than a nice place for animals to live," Levin said. "You want to be sure that the source areas of new young are protected, and to be sure about that, you have to know where they're coming from."

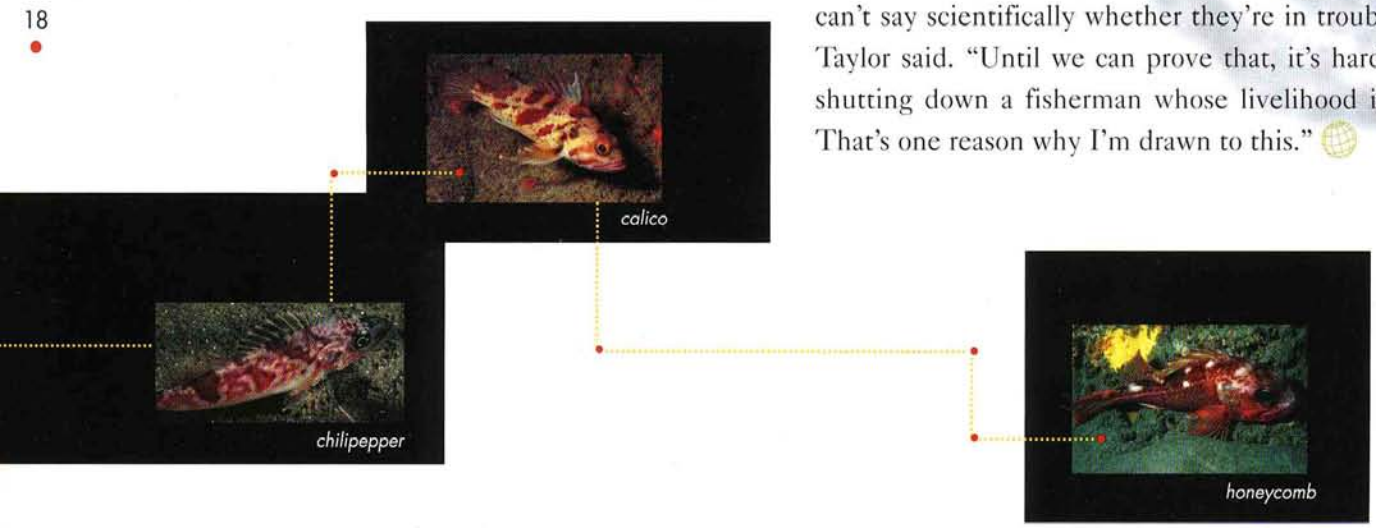
Fodrie studies trace-element concentrations in the otoliths of halibut in an attempt to map the number and value of the fish's nursery habitats. Unlike rockfish, halibut larvae develop in bays, estuaries, and surf zones.

The answers to such questions could help determine the future placement of fisheries, coastal development, or habitat restoration projects that affect fishes for better or worse.

"In the case of nursery habitats, you may want to know the number of juvenile fishes that a particular site or type is contributing to an adult population," Fodrie said, "so my approach is to use this trace-element tracking method to figure out which habitats are occupied by those juveniles that successfully recruit to adult stocks."

For now, halibut do not face the immediate threat posed to rockfish. Taylor, whose research results will be included in her doctoral dissertation, still feels the urgency that turned her attention to rockfish while earning her master's degree. Her research, to date, conforms to the data that state officials are using to draw the marine-reserve boundaries currently being proposed. With the controversy and political pressure mounting, policy makers need such science to make informed decisions.

"The burden of proof is on fisheries managers to say rockfish are endangered, and we know so little about these nearshore fisheries that we can't say scientifically whether they're in trouble or not," Taylor said. "Until we can prove that, it's hard to justify shutting down a fisherman whose livelihood is affected. That's one reason why I'm drawn to this."



A BAD CONNECTION

A SINGLE PAIR OF ABALONE CAN produce millions of offspring, so it might seem odd that all abalone species in southern California are becoming rare.

Overharvesting, disease, and climate change have devastated abalone populations. Extensive regions of the ocean floor that were once carpeted with these edible mollusks may now harbor only a single specimen in an area the size of a football field. The white abalone, once the focus of a lucrative fishery, is now infamous as the first marine invertebrate to make the federal endangered species list.

The sparse abalone population is especially devastating given how the creatures reproduce. Abalone are broadcast spawners, releasing sperm and eggs into the water column, where fertilization takes place. For reproduction to be successful, the distance between spawning males and females cannot be more than a few yards. At present densities, spawned eggs cannot be fertilized.

So why not just collect remaining white abalone and bring them closer together to improve their reproductive success? This is one of the strategies now under consideration by the White Abalone Recovery Team, an advisory panel created by the National Marine Fisheries Service. Ron Burton, director of Scripps Institution of Oceanography's Marine Biology Research Division, agrees that this is an attractive strategy, but warns that wholesale movement of animals across the range of the species would be ill advised. Burton, a population geneticist and recovery team member, says that little is known about the natural connectivity of abalone populations.

Because abalone eggs and larvae may drift with ocean currents for five to 10 days before settling into their adult habitat on the ocean floor, it is possible that distant populations share a common gene pool, as the young successfully "connect" populations by maturing and breeding at sites distant from their parents. Although possible, such connectivity between populations is difficult to prove.

BY THE 1990S, LANDINGS OF ALL MAJOR ABALONE SPECIES EXCEPT FOR RED ABALONE HAD DROPPED TO LESS THAN FOUR PERCENT OF EARLY 1970S LANDINGS: FROM 882 METRIC TONS TO 32 METRIC TONS.

Resolving these mysteries is crucial to the recovery effort. If natural connections do not exist, separate populations may become genetically adapted to their local environments. Moving animals among populations may then result in poor survival and reproduction of transplants—and possibly poor fitness of hybrid offspring.

Understanding connectivity of populations also allows researchers to predict how events in one part of the species range will affect other parts of the range. If connectivity is high, restoring a single white abalone population could, in time, lead to widespread recovery as young produced in one population drift to neighboring habitats and help reestablish other populations.

Above Left, *Biologist Ron Burton.* **Above,** *Burton with graduate student Kristen Gruenthal.*

One of the greatest research challenges in marine biology is to determine levels of connectivity among populations. Burton, Scripps graduate student Kristen Gruenthal, and UCSD undergraduate student Lauren Acheson are using genetic fingerprinting techniques much like those used by police to link suspects to crimes. The concept is simple: When animals move, they take their genes with them, so connected populations will show high genetic similarity. Recent studies in Burton's lab indicate that abalone species differ substantially in levels of population connectivity, with red abalone showing higher connectivity than black abalone.

"We would, of course, like to study connectivity among white abalone populations, but we don't even know if there are multiple populations left to study," Burton said.