



Fishy Sex

Uncovering the wild ways of fish

By TINA ADLER

Male bluehead wrasse.

Denise Goulet/State University of New York at Buffalo

The public has had an unusual number of sex stories to mull over of late. Scarcely a week goes by without a report of another politician's scandalous sexual foray or a gossip column piece on some star's in vitro fertilization.

But for science buffs with an appetite for bizarre sex yarns, new findings on the antics of fish may prove more satisfying.

For starters, that grouper you dined on at the beach this summer had probably undergone a complete sex change. What's more, studies suggest that a few species of fish living in and around coral reefs reverse gender as many as 10 times. Some species have two kinds of males—the family man and the run-around. Yet others, such as the common bluehead wrasse, reverse sex *and* have two very different types of males.

Why this prurient interest in piscine sex? Scientists hope that investigating what goes on in the brains and bodies of these mutable creatures may help uncover some of the mysteries of human sexuality.

Sex-changing fish are known as successive hermaphrodites—each fish can make either testes or ovaries and produce either eggs or sperm. The simultaneous hermaphrodite, however, comes equipped with both testes and ovaries. These fish would have to check both the male and female boxes on a personal questionnaire.

One species of sea bass, *Serranus tortugarum*, releases eggs during about half of its 14 or so daily spawns and contributes sperm for the other half, explains

Christopher W. Petersen of the College of the Atlantic in Bar Harbor, Maine. It can switch from providing sperm to releasing eggs within 30 seconds.

S. tortugarum develops more female gonadal tissue as it grows bigger, causing it to release more eggs and fewer sperm, assert Petersen and his colleague Eric A. Fisher, now with the National Academy of Sciences in Washington, D.C. The fish's spawning behavior remains the same, however. Its increased egg production may boost reproductive success, since almost all eggs get fertilized but not all sperm find eggs. Petersen and Fisher will report their findings in an upcoming issue of *EVOLUTION*.

Other simultaneous hermaphrodites develop more male tissue as they grow. These fish eventually change sex completely, however, becoming successive hermaphrodites. Scientists have studied more than 100 species of successive hermaphrodites but suspect that many more exist, says Douglas Y. Shapiro of Eastern Michigan University in Ypsilanti. Most of the species found so far reside in shallow ocean waters.

In the most common type of sex reversal, females mature, reproduce, and then become males. Their ovaries disappear entirely (or almost entirely), they grow testes, and their hormonal systems switch. Many fish also change color. They act like males, which in some species includes protecting their nests, behaving aggressively, and courting females. Less commonly, some species change from male to female.

Either way, sex reversal "is a very dramatic change in almost all aspects of the life of the [fish]," Shapiro explains.

Most fish undertake the change only once. For many species, it occurs in response to an altered social environment, as when a dominant male dies or leaves his social group and one of the females becomes male and takes his place. Changing sex can take as little as 4 days. What keeps fish from doing it more often remains unclear. Some researchers suggest that the dominant male's aggression inhibits sex change in subordinates. Others argue that it's much more complicated than that.

Some females, for example, won't become male if their group includes fewer than two to five other females. The benefits of changing sex may not outweigh the costs when so few females exist for males to mate with, Shapiro speculates.

If, as ecologists think, a fish's primary goal is to reproduce as often as possible, then becoming a male makes a lot of sense. Females often outnumber males, so males get a good rate of return on their mating efforts, Shapiro says.

But becoming a female has benefits too. Anemone fish live in small groups. Only the largest female and male reproduce, and the female outweighs the male. If this female dies or leaves, her mate becomes a female; the largest juvenile fish in the group becomes male and mates with the new female, Shapiro

explains in *The Differences Between the Sexes* (1994, Cambridge University Press).

Despite its advantages, acquiring a new sexual identity takes a toll on fish. During the process, they can't reproduce, yet they probably expend a lot of energy and don't defend themselves well, Shapiro and others suspect.

Some fish don't stop with one sex change, Timoki Sunobe of the Natural History Museum and Institute in Chiba, Japan, discovered in 1993. Sunobe and other scientists have identified at least three species of reef-dwelling fish that change sex several times: *Paragobiodon echinocephalus*, *Cirrhilabrus aureus*, and *Trimma okinawae*.

No doubt other fish perform the same trick, says Sunobe's colleague Matthew S. Grober of the University of Idaho in Moscow. However, scientists know of no other vertebrate that undergoes multiple sex changes. Only one other vertebrate, an African frog, can reverse its gender, Grober says.

Sunobe's earlier laboratory studies revealed that the female *T. okinawae*, a tiny Japanese goby, becomes male in response to the departure of a dominant male. But such males revert back to female when a larger male comes on the scene. The frequency of gender changes depends on the stability of the social system.

The researchers wondered whether all these adjustments left the fish behaving and looking different from first-time males or females. In a new study of *T. okinawae*, Grober and Sunobe find that fish going for round two as a male or a female look just like fish that have never entered the ring. Grober will report these findings at the annual meeting of the Society for Neuroscience in San Diego next month.

Grober and Sunobe induced females to become males, males to become females, and females to become male and then female again—all by swapping their companions. The fish completed a single gender change in as few as 4 days. Unlike many other sex-changing species, *T. okinawae* always carry with them a remnant of the opposite sex's gonad.



Swimming off Japan's Pacific coast, a male goby, *Trimma okinawae*, emerges from a hole in the coralline red algae with a female to his right.

"The [gonad] cells are already there [and] can probably generate rapid changes in hormones," Grober speculates. Scientists don't know whether the other two fish that reverse their sex more than once retain such cells.

In just those few days, the fish's gonads, genital papilla (a flap of skin sensitive to steroid hormones), brain cells, and other anatomical parts changed. The fish's sex hormones adjusted, the authors assume, but they are only now examining them.

The scientists knew that the number and size of cells that produce peptides important to reproduction differ in male and female bluehead wrasse, one-time sex reversers. So they examined cells in *T. okinawae* that produce arginine vasotocin (AVT) neuropeptides, which regulate reproductive behavior in many vertebrates, to see whether they changed.

The cells enlarged when males became females and shrank when females became males. When these males went back to being females, the cells enlarged again, Grober and Sunobe find. The total number of cells didn't vary.

Behavior also served as a good indicator of the fish's current sexual status, Grober says. Males, even those new to the job, behaved aggressively, defended their nests, and performed a traditional courtship dance.

A trained eye couldn't miss the differences between the males and the females, he contends. "It's like walking into a singles bar: Is there any issue as to who is a male and who is a female? Absolutely not."

Sometimes, there's even a clear distinction between the males.

Take the saddleback wrasse, *Thalassoma duperrey*. Like salmon and many other species, it has two types of

males. They vary in size and take very different approaches to life, including mating.

Grober and his colleagues are finding clear differences in their brains as well. In one section of the brain, the larger male has many more cells that produce AVT than the smaller males or females do, Grober will report at the neuroscience meeting.

Among vertebrates, almost no other animals except certain fish species have two distinct classes of males, and no vertebrates are known to have two types of females, says Andrew H. Bass of Cornell University.

Over the years, Bass has compiled a detailed picture of the two versions of male midshipman fish living off the West Coast of the United States. He presented his most recent findings at the International Ethological Conference held in Honolulu in August.

The type I male midshipman takes longer to mature, which gives him time to grow bigger and develop a stronger vocal system for courting. Type II males put their energy into becoming sexually mature and developing their gonads, which make up 9 percent of their body weight. Type I males' gonads account for a mere 1 percent of their weight. The two males also have different types of testosterone, Bass explains.

Type I fish build and guard their nests, activities type II males never bother with. The nest builders also hum to attract females and grunt in defense of their home. Type II fellows avoid the courtship, trying instead to invade their neighbors' nests to mate with the females.

Midshipman males may resemble comical stereotypes of some human males, but marine scientists say that fish and people actually have enough in common to make the study of fish worthwhile.

Research on fish may shed light on how environment and stress inhibit human reproduction and on the role of the brain in human sexual orientation, scientists say. Fish also emphasize the inflexible nature of most other vertebrates' sexuality, Grober says.

"The speed of [sex changes in fish], the diversity of body systems involved, and their reversibility are remarkable, relative to the rigid nature of these characteristics in most vertebrates," Grober and Sunobe contend.

All of this sexual variation and gender gymnastics helps fish to reproduce more successfully, scientists suspect. But maybe another benefit exists. Maybe, having walked in each other's shoes, male and female fish get along better.

Would the battle of the sexes never have begun if humans had more fishlike qualities? □



A plainfin midshipman guarding his nest tucked among the rocks of the Northern California coast.