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Science News Online

Week of Nov. 6, 2004; Vol. 166, No. 19

Hide and See

Conflicting views of reef-fish colors

Susan Milius

A lot of things can be said about a shirt that sports images of coral-reef fish, but "subtly colored" isn't one of them. Oddly enough, that characterization does get used when biologists talk about the reef creatures. Although the fish may dazzle the human eye with scarlet, rose, yellow, turquoise, emerald, and dozens of other shades, some theorists have proposed that, in the complexity of a reef, the riot of fish colors serves as camouflage.



POPULAR HUES. Calculations based on fish vision suggest that from a distance yellows blend in with a generic reef background, and the blues fade into vistas of water. A fish among branching corals would be hidden like a soldier wearing camouflage.
PhotoDisc

Then again, some scientists have suggested the opposite notion—that brilliant colors send big, bold messages that may be come-ons or warnings or both. People can theorize till the cowfish come home about what they see on a reef, but what matters is what fish see, and that's been hard to determine.

Improvements in cameras and in equipment for analyzing light and color are now inspiring new approaches to approximating a fish-eye view of the reefs. Looking at the abundant coloration from a fishy perspective, the new work demonstrates that people can be quite wrong about what's showy and what's subtle. The old questions are giving way to more-sophisticated new ones. Colors aren't just a matter of either hiding or flaunting. It may be possible to whisper and shout at the same time.

Chasing rainbows

"My interest is, what's all the color about?" says N. Justin Marshall of the University of Queensland in Brisbane, Australia. A child of marine biologists, he says he was 6 years old when first dazzled by the magnificent underwater hues.

He has since joined a long line of reef watchers musing over the dramatic displays.

One proposal had colors developing through sexual selection, the process favoring traits that bewitch a mate. However, the fact that colors often look the same on males and females undercut that notion.

Another hypothesis was that the visual drama on a reef represents conspicuous warnings that certain fish bear distasteful or toxic flesh: "Eat at your own risk." This idea dwindled in popularity as a widespread explanation when reef viewers recognized that many brightly colored fish are tasty and quite safe.

Another approach suggested that the colors represent quirks of fish metabolism. A fish might be shunting excess, colorful products of biological processes to its skin just to get them out of the way. That view hasn't found supporting evidence.

When Austrian animal behaviorist Konrad Lorenz turned to reef colors during the middle of the past century, he proposed that the fish colors act as bold color-coding that lets the abundant fish species sharing a reef keep track of who's who. "It's a very good idea," says Marshall. People may not appreciate the difficulty of identifying species mates "because we're not living among a hundred other hominids."

But perhaps the colors that stand out to us actually work as camouflage for fish. Marshall argues that people analyzing fish coloration need to consider what fish look like to each other, not to us. Human visual powers do well in distinguishing many kinds of yellows from greens. "We're very good at bananas," says Marshall. A reef fish's visual system, however, typically doesn't pick out fine distinctions in the yellows but is especially sensitive to shades of blue green.

Also, almost half the fish analyzed so far, says Marshall, seem to see ultraviolet light (UV). Species with small body size, such as damselfish, are more likely to perceive UV than big, fast-moving predators are. Jill Zamzow of the University of Hawaii in Kaneohe reports that the light-screening mucus covering reef fish typically includes UV-absorbing compounds picked up from food. However, her videotapes and calculations indicate that the sunscreen should not keep fish from seeing each other in the UV range.

Testing stealth

To switch to a fishy perspective, consider the many yellow fish, such as the yellow form of trumpet fish (*Aulostomus chinensis*). "To us, they're bananas," standouts against the blue green of reefs, Marshall says.

At the wavelengths in which fish see the world, the yellow of a trumpet fish swimming along 3 meters or more away becomes a "very good match" for the average reef background, says Marshall. He, George Losey of the University of Hawaii at Manoa, and their colleagues recently pieced together analyses of fish-eye pigments and measurements of background colors in various reef habitats, to perceive a bay at the island of Oahu the way its fish do. They described their work in a series of three articles on the visual biology of Hawaiian reefs, published last year in *Copeia*.

These researchers measured the wavelengths bouncing off various parts of the reef to come up with what they call an average reef color. They found, for example, that a common light-blue color, familiar to fish fanciers in the bands on the blue-and-yellow angelfish *Pygoplites diacanthus*, matches the general bluish background a fish sees when looking into the distance through relatively deep water.

"What's surprising is that some of the colors that look bright to us are for camouflage," Marshall says.

Evolutionary forces aren't pushing fish toward conspicuous colors, according to the findings of Gil Rosenthal of the Boston University Marine Program. He uses Panamanian geography to evaluate evolutionary pressure.

The Isthmus of Panama formed a complete bridge between North and South America some 3 million years ago. Today, on the west of the isthmus, in the Pacific, upwelling currents churn nutrients that feed clouds of plankton, but reefs don't flourish. To the east, in the Caribbean, waters flow clearer and multicolored reefs thrive in the brighter environment. Many fish species on one side of the divide have close relatives on the other.

Rosenthal and his colleagues measured the reflectivity of captured fish and calculated its effect under dim, blue-green Pacific light or whiter Caribbean illumination, he explained last June in Oaxaca, Mexico, at the annual meeting of the Animal Behavior Society. The researchers then looked at how fish collected from each side of the isthmus would stand out against the background of both regions. So far, the team hasn't adjusted for fish perception.

Overall, the fish were less conspicuous in their home conditions than they would appear if flipped into the alternative environment, Rosenthal concluded. Because fish 3 million years ago spanned both locations, the current distinction suggests that camouflage is more important than attracting attention with bright colors.

Fish chat

Neither Rosenthal nor Marshall argues that disguise is the only role for fish coloration. Other work is turning up cases in which the fish seem to send visual signals that come through loud and clear.



COLOR TILES. Close-ups of fish skin reveal the abundance of dramatic colors that has inspired theorists for more than a century, though plenty of their ideas about the evolutionary forces behind the colors haven't held up.
Marshall

What might fish communicate with their color signals?

Marshall's lab is investigating the possibility of a reef version of international signs for rest stops. Marshall found several species of cleaners, creatures that nibble the parasites off other fish, that share a similar shade of blue, whether or not they're closely related. He speculates that a special color, "cleaner blue," might proclaim, "Stop here for service."

Signals can not only promote fish survival but also lure the unwary into scams. The species of predatory fish *Pseudochromis fuscus* shows up in both yellow and brown forms around Lizard Island in Australia's Great Barrier Reef. The yellow form is most common in relatively deep patches of branching coral favored by two kinds of yellow damselfish, Philip Munday of James Cook University in Townsville,

Australia, and his colleagues reported in the December 2003 *Oecologia*.

The brown form of *P. fuscus* dominated in shallower spots with less branching coral and more damselfish of two darker species. Both the yellow and the brown *P. fuscus* prey on young damselfish, and Munday and his colleagues propose that these underwater wolves are mimicking sheep's colors.

Another predator, the fang blenny, sometimes develops the coloring of a young, harmless, cleaner wrasse, notes Geoffrey P. Jones, also of James Cook University. When genuine cleaner wrasses were removed from a test plot, the former look-alikes changed color, his team reports in the August *Oecologia*. And even more incriminating, the blennies' hunting success then dropped about 20 percent, the researchers estimate.

Mixed messages

When reef fish balance their need to broadcast against their need to hide, they may demonstrate a solution more elegant than the simple trade-off of doing an incomplete job of each. Four years ago, Marshall published an analysis of showy (to human eyes) blue-and-yellow patterns on the angelfish *P. diacanthus* and multicolor complexities on the moon wrasse (*Thalassoma lunare*).

Estimating what a typical fish would see, Marshall proposed that the angelfish could be either conspicuous or cryptic, depending on where it swam. Against a backdrop of coral, the yellow would blend in as reef colored (to a fish), but the contrasting watery blues would jump out. And a piscine audience looking at the display against background water would likewise see stand-out stripes, this time the yellow ones.

However, when something scary, such as a diver, approaches an angelfish, it often darts among coral branches, Marshall notes. Against a background of jumbled images of coral and water, the stripes could work as the irregular blotches of military camouflage patterns do, hiding a body by confusing the view of its outline.

The moon wrasse illustrates another possibility for using the same colors for both vamping and vanishing, says Marshall. Adjacent colors on the moon wrasse's body often contrast sharply, especially in the blue-green range where fish vision excels. Marshall calculated how well fish can distinguish between contrasting elements at a distance. To envision the problem, stare at the page of a book on the other side of a room. The black letters on a white page blur into gray streaks for us, although an eagle with literary leanings could be expected to distinguish letters perfectly.

For an audience of typical small fish, the purple-pink and blue of the moon wrasse's pectoral fin blend starting at distances between 1 and 5 meters, says Marshall. That blend creates a color blur that he calls "an astonishingly close match" to the hazy blue of open water. Therefore, a moon wrasse swimming in the water above its home reef could make an eye-popping impression on its neighbors but blend into the watery distance for predators scouting from afar.

Patterns visible in UV raise similar possibilities, according to Losey. He analyzed videos of young damselfish, a prime snack for larger predators. The damselfish gather to feed near coral outcrops, behind which they retreat in a virtually simultaneous dash when a predator looms.

One species, the two-bar damsel (*Dascyllus reticulatus*), looks like a white fish with black stripes to the human eye. Losey's equipment revealed a UV patch on its dorsal fin, he reported in the August 2003 *Animal Behaviour*. Since many bigger, prowling hunters of the reef, such as barracudas, don't see UV, the patch should be more visible to the young damselfish schoolmates than to their enemies.

Also, UV doesn't travel as far in water as longer wavelengths do, so near neighbors get the best views of UV decorations. Losey cautions that little is known about which fish can and can't see UV, so it's premature to propose secret channels of UV communication. However, he does suggest that flashes of UV from neighbors fleeing predators could rapidly spread a general alarm.

In all analyses of visual communication on the reef, water matters, notes Elizabeth Neeley of Boston University. The quirks of its transmission of light shape how one fish views another, and changes in water's transmission properties can affect visual communication among fish.

Working with Rosenthal, Neeley has compared several dozen fish species with close relatives on the other side of Panama. In the murkier Pacific water, she generally found simplified color patterns, with fewer and bigger elements than those in the clearer Caribbean.

The finding worries her because pollution is changing water clarity in many locales. Nobody knows what the effects may be on visual communication, Neeley says.

There is evidence that in some African lakes, an increase in murkiness is preventing fish from distinguishing between species for mating.

Neeley points out an irony: Just as people are finally tuning in to the remarkable communications system on the reef, we may be overwhelming the system with static.

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<http://www.sciencenews.org/articles/20041106/bob8.asp>

From *Science News*, Vol. 166, No. 19, Nov. 6, 2004, p. 296.

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