Some fish species turn out to be surprisingly good problem solvers. At times, they even use tools

By Jonathan Balcombe

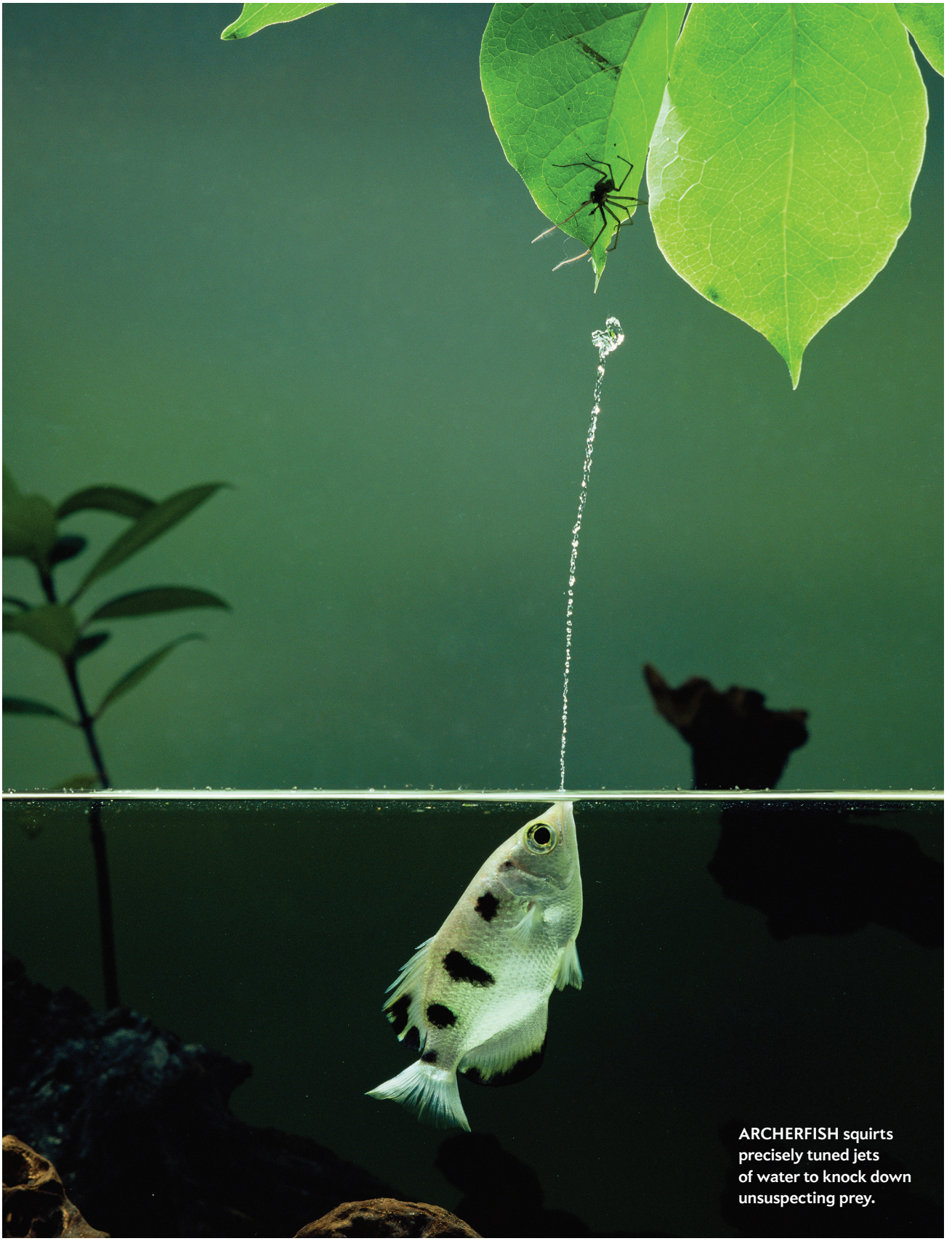
ZOOLOGY

EINSTEIN OF THE SEA

WHILE DIVING OFF THE MICRONESIAN ARCHIPELAGO OF PULAU, EVOLUTIONARY biologist Giacomo Bernardi witnessed something unusual and was lucky enough to capture it on film. An orange-dotted tuskfish (*Choerodon anchorago*) uncovered a clam buried in the sand by blowing water at it, picked up the mollusk in its mouth and carried it to a large rock 30 yards away. Then, using several rapid head flicks and well-timed releases, the fish eventually cracked open the clam against the rock. In the ensuing 20 minutes, the tuskfish ate three clams, using the same sequence of behaviors to smash them.

Bernardi, a professor at the University of California, Santa Cruz, is thought to be the first scientist to film a fish demonstrating tool use. By any measure, it is remarkable behavior from a fish. Tool use was long believed unique to humans, and it is only in the past decade that scientists have begun to appreciate the behavior beyond mammals and birds.

Bernardi's video unveils new gems every time I watch it. Initially I failed to notice that the enterprising tuskfish does not uncover the clam in a manner we might expect—by blowing jets of water from its mouth. The fish actually turns away from the target and snaps its gill cover shut, generating a pulse of water the same way that a book creates a puff of air when you close it. And it is more than tool use. By using a logical series of flexible behaviors separated in time and space, the tuskfish is a planner. This behavior brings to mind chimpanzees' use of twigs or grass stems to draw termites from their nests. Or Brazilian capuchin monkeys that use heavy stones to smash hard nuts against flat boulders that serve as anvils. Or crows that drop nuts onto busy traffic intersections and then



ARCHERFISH squirts precisely tuned jets of water to knock down unsuspecting prey.

WARREN PHOTOGRAPHIC

swoop down during a red light to retrieve the fragments that the car wheels have cracked open for them.

Halfway to its destination, our tuskfish stops to try out a smaller rock lying on the sand. It makes a couple of halfhearted whacks, then heads on its way again, as if it has decided this one is not worth his time. (Who can't relate to these misguided attempts and how they reflect the fallibility of a mortal life?)

These are impressive cognitive feats for any animal. That they are performed by a fish clearly upsets the still commonly held assumption that fishes are at the dim end of the animal intelligence spectrum. As does the realization that what Bernardi saw that day was not exceptional. Scientists have noticed similar behavior in green wrasses, also called blackspot tuskfish (*Choerodon schoenleinii*), on Australia's Great Barrier Reef; in yellowhead wrasses (*Halichoeres garnoti*) off the coast of Florida; and in a sixbar wrasse (*Thalassoma hardwicke*) in an aquarium setting. In the case of the sixbar wrasse, the captive fish was given pellets that were too large to swallow and too hard to break into pieces using only its jaws. The fish carried one of the pellets to a rock in the aquarium tank and smashed it much as the tuskfish did the clam. The zoologist who observed this, Łukasz Paśko of the University of Wrocław in Poland, saw the wrasse perform the pellet-smashing behavior on 15 occasions, and it was only following many weeks of captivity that he had first noticed it. Paśko described the behavior as "remarkably consistent" and "nearly always successful."

Hard-nosed skeptics might point out that this kind of thing is not *real* tool use because the fishes are not wielding one object to manipulate another, as humans do with an ax splitting a log for firewood or a chimpanzee does by using a stick to get to the tastiest termites. Paśko himself refers to the wrasse's actions as "tool-like." But this is not to demean the behavior, because, as he points out, smashing a clam or a pellet with a separate tool is simply not an option for a fish. For one thing, a fish is not equipped with grasping limbs. In addition, the viscosity and density of water make it difficult to generate sufficient momentum with an isolated tool (try smashing a walnut shell underwater by throwing it against a rock). And clasping a tool by mouth, the fish's other practical option, is inefficient because fragments of food would float away, only to be snatched up by other hungry swimmers.

EXPERT AIM

JUST AS THE TUSKFISH uses water as a force for moving sand, the archerfish (*Toxotes*) also uses water as a force—only this time as a hunting projectile. These four-inch-long tropical marksmen—sporting a row of handsome black patches down their silvery sides—mostly inhabit brackish waters of estuaries, mangroves and streams from India to the Philippines, Australia and Polynesia. Their eyes are sufficiently wide, large and mobile to allow binocular vision. They also have an impressive underbite, which they use to create a gun barrel of sorts. By pressing their tongue against a groove in the upper jaw and suddenly compressing the throat and mouth, archerfish can squirt a sharp jet of water up to 10 feet through the air—with an accuracy in some individuals of nearly 100 percent at a distance of three feet. Woe betide a beetle or a grasshopper perched on a leaf above the backwaters where these fish lurk.

The behavior is notably flexible. An archerfish can squirt water in a single shot or in a machine gun–like fusillade. Targets have included insects, spiders, an infant lizard, bits of raw meat, scientific models of typical prey and even observers' eyes—along with their lit cigarettes. Archerfish also load their weapons according to the size of their prey, using more water for larger, heavier targets. Experienced archers may even aim just below their prey on a vertical surface to knock it straight down into the water instead of farther away on land.

Using water as a projectile is only one of many foraging options for the archerfish. Most of the time this species forages underwater as ordinary fishes do. And if a meal is within just a foot of the surface of the water, they may just take the more direct route, leaping to snatch it in their mouth.

Archerfish live in groups, and they have fantastic observational learning skill. Their hunting prowess does not come preinstalled, so novices can make successful shots at speedy targets only after a prolonged training period. Researchers studying captive archerfish at the Friedrich-Alexander University of Erlangen-Nürnberg in Germany found that inexperienced individuals were not able to successfully hit a target even if it was moving as slowly as half an inch per second. But after watching 1,000 attempts (successful and unsuccessful) by another archerfish to hit a moving target, the novices were able to make successful shots at rapidly moving targets. The scientists concluded that archerfish can assume the viewpoint of another archerfish to learn a difficult skill from a distance. Biologists call this "perspective taking." What an archerfish does might not require the same level of cognition as that shown by a captive chimp that has carried a disabled starling up a tree to help launch it back to the air, but it is nonetheless a form of grasping something from the perspective of another.

High-speed video recordings reveal that these fish use different shooting strategies depending on the speed and location of flying prey. When using what the researchers describe as the "predictive leading strategy," archerfish adjust the trajectory of their jets of

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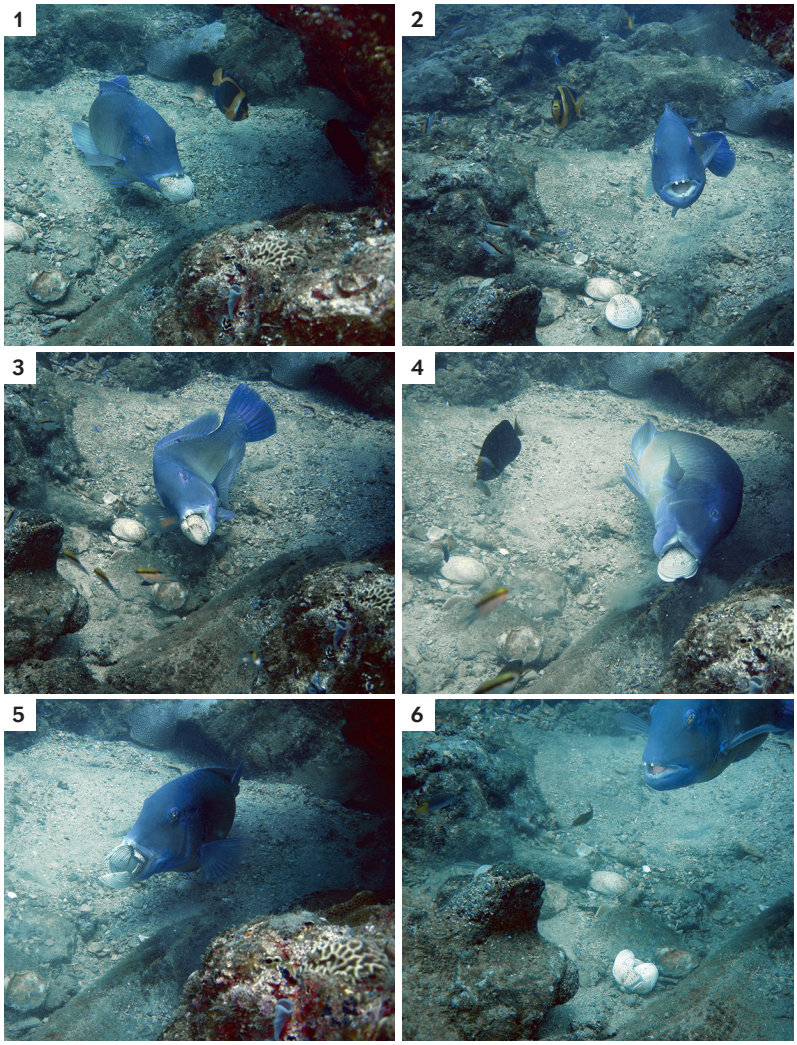
IN BRIEF

Fishes have long been dismissed as dullards, but new observations and studies are proving this assumption wrong.

One species of wrasse, for instance, has been filmed engaging in a marine version of tool use.

Archerfish, which capture prey with precisely calibrated jets of water, are showing how fishes can learn complex skills—and that they can mentally place themselves in the position of a fellow fish.

SCIENTIFIC AMERICAN ONLINE Watch a video of archerfish gunning down prey at ScientificAmerican.com/jun2016/archer-fish



BLACKSPOT TUSKFISH opens a cockle by smashing it onto a rock, which some scientists suggest is an example of tool use.

COURTESY OF SCOTT GARDNER

water to account for the speed of a flying insect—they aim farther ahead of the target if it is moving faster. If the target is flying low (usually less than seven inches above the water), archerfish often use a different strategy, which the researchers term "turn and shoot." This maneuver involves the fish firing while simultaneously rotating its body horizontally to match the lateral movement of the target, causing the jet of water to "track" the target on its airborne path. These fish would do any quarterback proud.

Archerfish can also compensate for the optical distortion produced by the water-to-air transition by learning the physical laws governing apparent target size and the fish's relative position to the target. Having such a generalizable "rule of fin" enables an archerfish to gauge absolute sizes of objects from unfamiliar angles and distances. I wonder if archerfish also practice entomology, visually identifying insects to know whether they are tasty, whether they are too big to eat or too small to bother with, or whether they sting.

Most likely, archerfish have been squirting water jets for at least as long as humans have been throwing stones, and I suspect that wrasses were using rocks to crack clams open long before our ancestors started bashing hot metal against anvils in the Iron Age. But can fishes spontaneously invent tool use, as we can when unexpected conditions require us to improvise? In May 2014 a study highlighted an example of innovative tool use by Atlantic cods being held in captivity for aquaculture research. Each fish wore a colored tag affixed to its back near the dorsal fin, which allowed the researchers to identify each individual fish. The holding tank had a self-feeder activated by a string with a loop at the end, and the fish soon learned they could release a morsel of food by grabbing the loop in their mouth and pulling on it.

Apparently, some of the cods discovered they could activate the feeder by hooking the loop onto their tag and swimming a short distance away. These clever cods honed their technique through hundreds of "tests"—and it became a finely tuned series of goal-directed, coordinated movements. It also demonstrated true refinement because the innovators were able to grab the pellet a fraction of a second faster than by using their mouth to get the food. That fishes are routinely expected to interact with a foreign device to feed themselves is impressive enough but that some devised a new way of using their tag, in this case, shows a fish's capacity for flexibility and originality.

Tool use by fishes seems confined to a limited number of fish groups. Australian fish biologist Culum Brown suggests wrasses in particular may be fishes' answer to the primates among mammals and the corvids (crows, ravens, magpies and jays) among birds in having a greater than expected number of examples of tool use. It could just be that living underwater offers fewer opportunities for it than living on land. But we do know the tuskfish and the archerfish are prime examples of evolution's boundless capacity for problem solving, and they might turn out to have plenty of company among other fishes. SA

MORE TO EXPLORE

The Use of Tools by Wrasses (Labridae). G. Bernardi in *Coral Reefs,* Vol. 31, No. 1, page 39; March 2012.

Innovative Behaviour in Fish: Atlantic Cod Can Learn to Use an External Tag to Manipulate a Self-Feeder. Sandie Millot et al. in *Animal Cognition,* Vol. 17, No. 3, pages 779–785; May 2014.

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FROM OUR ARCHIVES

The Archer Fish. K. H. Lüling; July 1963.

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