UNVEILING THE SECRET

ELECTRONIC TAGS

The tags above are different generations of archival tags. All collect depth, water temperature, body temperature and light level (used to calculate location) data every 1 to 60 seconds. The white bulbous tag has a float and an antenna, indicative of a pop-up satellite archival tag. This tag collects all the same data as the other tags, with the exception of body temperature since the tag is not surgically implanted in the fish.

LIFE OF AN OCEAN GIANT

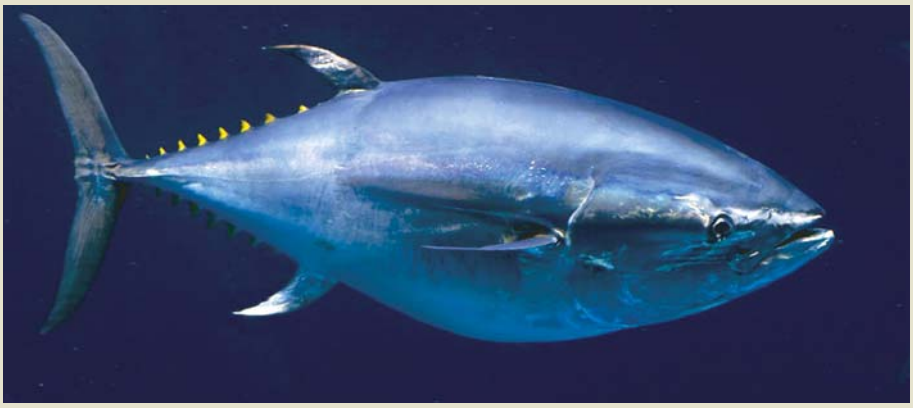
BY DR. BARBARA A. BLOCK AND SHANA MILLER

From New Zealand to Baja, North Carolina to Ireland, and the Gulf of Mexico to the Gulf of Maine, our scientific team has hunted for giant bluefin. The hunt is not to catch or kill, but to electronically tag bluefin. These tags are not your run-of-the-mill spaghetti tags but rather sophisticated microprocessor-based electronic tags that not only give deployment and recapture locations, but depth, seawater and body temperature, and the location of the tuna based on a calculation (or estimation made) from light data and sea surface temperature for every day in between.

Why all the fuss for a fish? Bluefin tuna are not just another fish. They are renowned for their immense size, power, speed and trans-oceanic migrations. Bluefin are also the target of a billion dollar global fishery. In 2001, a 444-pound Pacific bluefin sold for nearly $175,000 at Tsukiji Market, Tokyo's famed fish auction. With such a high price on their heads, it is not surprising that bluefin tuna have been severely overfished. Breeding populations in the western Atlantic have declined by nearly 90%, Southern bluefin tuna have been proposed for endangered species listings, and Pacific bluefin have also shown decreased abundance in the last decade.

Barb first glimpsed a giant bluefin tuna hanging from a scale, blood dripping from the bullet-shaped head, in Rock Harbor, Massachusetts in the 1960s. It was captivating to see a powerful fish, shaped like a submarine. Slick, dark blue skin, blending to chrome along the belly and canary yellow finlets. Fins that fit in grooves along the body to reduce drag, a thrust-producing lunate tail. As a child, the enormous size of these fish, which can weigh over 1600 lbs and grow to 10 feet, symbolized the power and mystery of the oceans. The steam often rising off an iced tuna reflected they were warm-bodied like us, the fact which led to Block's fascination with these fish as a scientist.

Block first began studying warm-bodied fish in the laboratory of her mentor Frank Carey of Woods Hole Oceanographic Institution in the late 1970s. She spent the next two decades studying tunas, swordfish and marlin, fascinated with how these "scombroid" fishes have evolved the capacity to warm a variety of internal tissues. Her move to Stanford University in the early 1990s facilitated our team's venture into bluefin tuna research full-time.



SINCE THE FIRST DAY

The TAG team has come together in the quest for knowledge about the secret lives of giant bluefin. Since the first fish was released with an electronic tag in North Carolina in 1996, 930 tags have been deployed in the Atlantic and 350 tags have been deployed in the Pacific. The resulting recoveries or transmitted data sets have led to a vast amount of tuna data (45,000 days in the life of northern bluefin from both oceans, with tracks as long as 4.8 years!). The results are providing information on the movement patterns, behaviors and environmental preferences of bluefin tuna to test the assumptions on which management is based. The hope is that with better science comes better management.

Block's team began conducting research on bluefin tuna in 1994 when we started keeping tunas in the captive facility at Stanford - the Tuna Research and Conservation Center - in partnership with the Monterey Bay Aquarium. Here we could study how to tag a tuna, including external attachment options and deployment techniques. We looked at what shapes worked best and interacted the least with swimming fish. The Tag-A-Giant (TAG) program began off Hatteras, North Carolina in 1996. Ten tags were placed in 200-300 lb tunas from a custom built Duffy called the *Bullfrog*, captained by Bob Eakes. Eventually others fishing the area joined in, and Captains Peter Wright and Gary Stuve, working aboard the boat *Raptor*, invented a method for transferring bluefin between the catch boat and the 'surgery' boat. Together we could tag far more fish in a day, as many as 39 on one splendid day off Hatteras, NC in the winter of 1997.

The TAG team is now composed of our Stanford University laboratory, the curators and technicians from the

CAPTIVE TUNA RESEARCH

Captive facility at Stanford - the Tuna Research and Conservation Center - in partnership with the Monterey Bay Aquarium.

Monterey Bay Aquarium who specialize in handling tunas, academic colleagues from other universities (including Duke and Dalhousie), recreational fishermen, commercial fishermen, and government scientists and policymakers.

TO TAG A BLUEFIN

Finding bluefin to tag is half the battle when it comes to TAG research. Each winter for ten of the last eleven years, the TAG team has hosted a bluefin "tournament" of sorts off the coast of North Carolina where over 85% of the electronic tags have been deployed. A tournament where points are based on the number of fish transferred to the surgery or tagging boat rather than the number on the scale at the weigh station. A tournament where the fish are the real winners.

If a pop-up satellite tag (PAT) is deployed, the tag is simply inserted into the tuna's musculature near its second dorsal fin. If an archival tag is deployed, tuna surgery is performed, inserting the tag into the abdominal cavity through a small incision before suturing it back up. In either case, the tuna is on the deck less than three minutes in this carefully orchestrated process. The entire maneuver is a challenge in calm seas, becoming an impressive feat in rough water. At the end of the big days when as many as twenty fish are tagged by an individual surgery boat, the team is exhausted.

Bluefin are also tagged off Southern California with the long-range vessel *Shogun*. The target fish are juveniles and oftentimes travel in larger schools, making baited lift poles or live-bait fishing the methods of choice. Here the fish are caught on barbless circle hooks, moved rapidly into a sling, lifted aboard the vessel and placed in a padded surgery station. The fish are tagged and released in less than two minutes and often can be seen swimming back into the school beneath the boat. The Pacific program began in 2002, has taken off rapidly, and has a 50% tag recovery rate. More recently, TAG scientists have taken advantage of the giants reported off the south island of New Zealand. In the winter of 2006, using the same skills developed in NC, TAG scientists released seven giant Pacific bluefin with pop-up satellite tags.

Commercial fisheries also participate in the tagging process. TAG scientists charter longline vessels for the best chance at catching bluefin on their Gulf of Mexico spawning grounds. Longline methods are altered, using fewer circle hooks and shorter soak times, to maximize survival of the fish. Bluefin are never brought onboard the longliners but rather tagged over the side; as a result, archival tagging is not an option, and PAT tags are used exclusively. TAG scientists have also done large-scale release of bluefin tuna with New England purse seiners and have successfully released bluefin tuna from ranching operations in Spain and Mexico. In these cases, fish are tagged and released into the captive net or pen before being released with a second lease on life.

BLUEFIN SECRETS UNVEILED

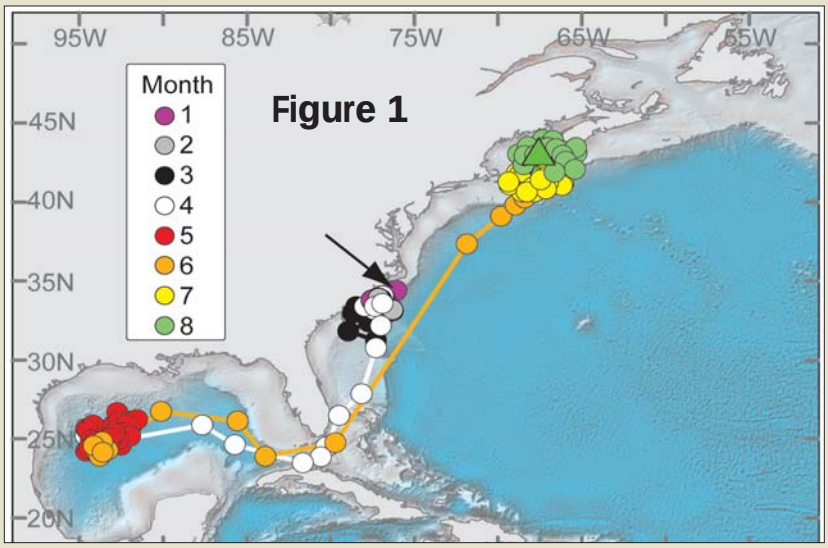
Our research has uncovered extensive knowledge about the lives of Northern bluefin, including seasonal migration patterns, favorite feeding locations, diving behaviors, physiology, and perhaps most importantly, how and where bluefin tuna spawn.

THE PULL COMMAND

On the well-choreographed "pull" command, the team eases the tuna into the boat on a slippery vinyl mat that acts like a slide. Acting quickly to minimize stress, the team irrigates the bluefin's gills with oxygen. The team rapidly measures, tags, and takes a tissue sample for genetic analysis before turning the fish and releasing it back through the transom door.

THE TEAMWORK OF TAGGING

Here's how it works. The scientists ride aboard the "surgery" boats, recreational boats chartered or donated to help with the tagging. Countless other boats troll the surrounding waters hoping to hook up with a bluefin. The surgery boats also troll, hoping to catch a fish of their own, but as soon as one of the participating "transfer" boats hooks a bluefin, the surgery boat reels in its lines, and the excitement begins. Often crossing as many as three miles in rough winter seas, the TAG surgery boat races to the transfer vessel. The bluefin is brought to leader, at which point the surgery boat throws their leader (weighted by anything from a tennis ball to a rubber ducky) to the boat. The transfer boat hooks their leader to the surgery boat's leader, and it's time for the scientist on the surgery boat to reel in the fish for tagging. Once the fish is at the boat, the "lip hooker" meets the tuna eye-to-eye through the transom door, with a hook that has to be carefully placed in the tuna's lower jaw to prevent injury. Cooperation among fishers and scientists has been at the core of the winter bluefin tuna fishery.



ATLANTIC BLUEFIN TUNA TRACKING

TAG movement data yield strong support for the existence of two populations of bluefin tuna in the North Atlantic - a West Atlantic population, which spawns in the Gulf of Mexico, and an eastern population, which spawns in the Mediterranean Sea. Annual movements of tuna tagged and released along the U.S. East Coast reveal distinct migratory patterns that vary by population and age class. Adolescent and mature bluefin tuna tagged off the North American coast from both populations travel to similar foraging grounds along the East coast of North America and into the North Atlantic. Mature western bluefin follow similar paths, traveling up and down the North American coast, but show annual movement into the Gulf of Mexico, most often in spring for short periods of less than 40 days. Mature eastern bluefin migrate to the Mediterranean Sea following a variable period of time foraging along the East Coast and in the North Atlantic.

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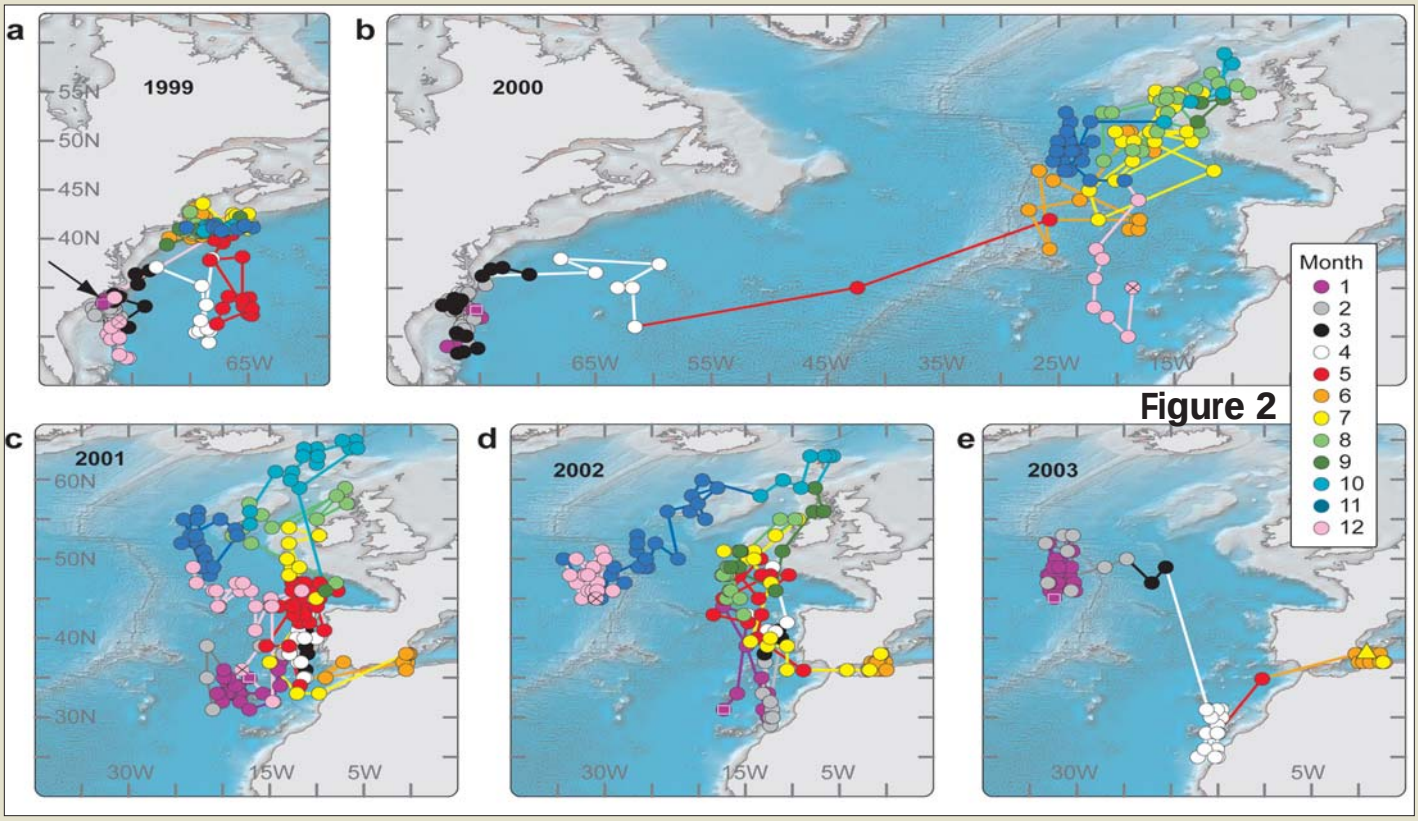
ATLANTIC BLUEFIN MOVEMENTS

Figure 1 shows movements of an individual Atlantic bluefin tuna's migration between the foraging grounds in the North Atlantic and the breeding grounds in the Gulf of Mexico. Color denotes the month of each position. The bluefin tuna was released off North Carolina on 16 January 2004 (arrow, 268 cm CFL). The tag detached from the fish on 27 August 2004 (green triangle). **Figure 2** shows movements over 4.5 years of one individual Atlantic bluefin tuna that was tagged in the western Atlantic in 1999 and demonstrated site fidelity to a known spawning area in the Mediterranean Sea (2001–2003). Each panel shows a year of the fish's track; color denotes month of each position. Start and end points for each year are denoted by a square and cross-hatched circle, respectively. **a**, The bluefin tuna was released off North Carolina on 17 January 1999 (arrow, 191 cm CFL) and showed a year of western residency. **b**, In 2000, the bluefin tuna showed transatlantic movement to the eastern Atlantic. **c–e**, Three consecutive years of movements from the eastern Atlantic into the Mediterranean Sea, to the vicinity of the Balearic Islands, during the breeding season: **c**, 2001; **d**, 2002; **e**, 2003. The fish was recaptured on 2 July 2003 (yellow triangle). Courtesy of *Nature* Publishing Group (2005).



One tuna spent three years on the North American coast prior to going into the Mediterranean Sea to spawn. Another spent a year on the U.S. coast and a year off the Irish coast prior to moving into the Balearics to spawn. We've learned that no one can really tell which tuna we have off the U.S. coast, a western Atlantic spawner or a Mediterranean spawner. Unless we get a complete track back, which includes a visit to one of the known spawning areas, it's impossible to know which population the fish is from. More recently, Stanford Ph.D student Andre Boustany used genetic techniques to verify that the bluefin tuna that show fidelity to either the Gulf of Mexico or the Mediterranean also harbor unique biodiversity in their genes, supporting the finding that they are separate populations

As any serious angler with "secret numbers" will attest, fish have favorite dining spots. Tagged bluefin show long residence times in four regions of the North Atlantic on a seasonal scale. The aggregations occurred off North Carolina during winter, in the Northwest Atlantic (Georges Bank, Gulf of Maine and Nova Scotia) during summer and fall, in the central Atlantic (North West Corner) during spring to summer, and in the East Atlantic (off Portugal) during spring and fall. These "hotspots" are likely linked to areas of abundant prey and are believed to represent critical foraging habitat.

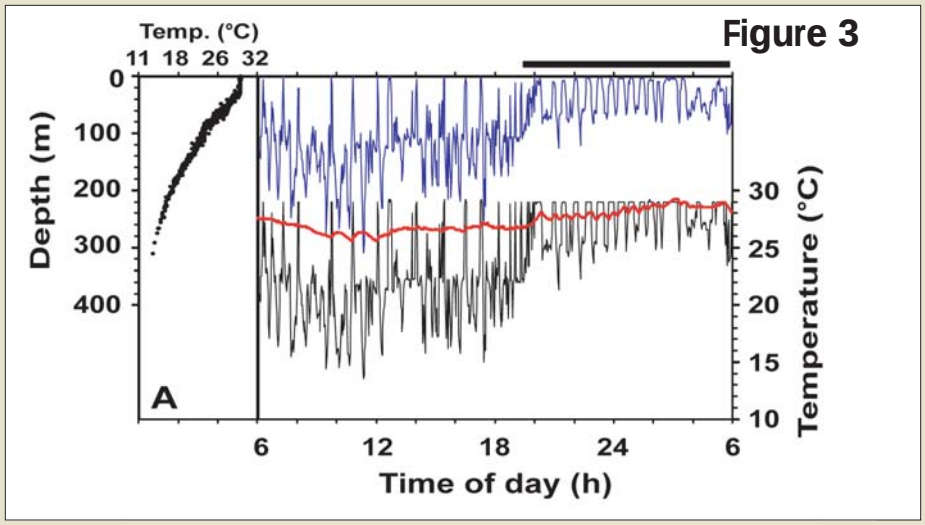
In the North Atlantic, mean diving depth was correlated with the depth of the thermocline (*i.e.*, the depth at which the water temperature changes rapidly, separating the mixed surface layer from the colder, deep waters). Tagged Atlantic bluefin tuna experienced a wide range of ambient water temperature (0.1° - 31.0°C).

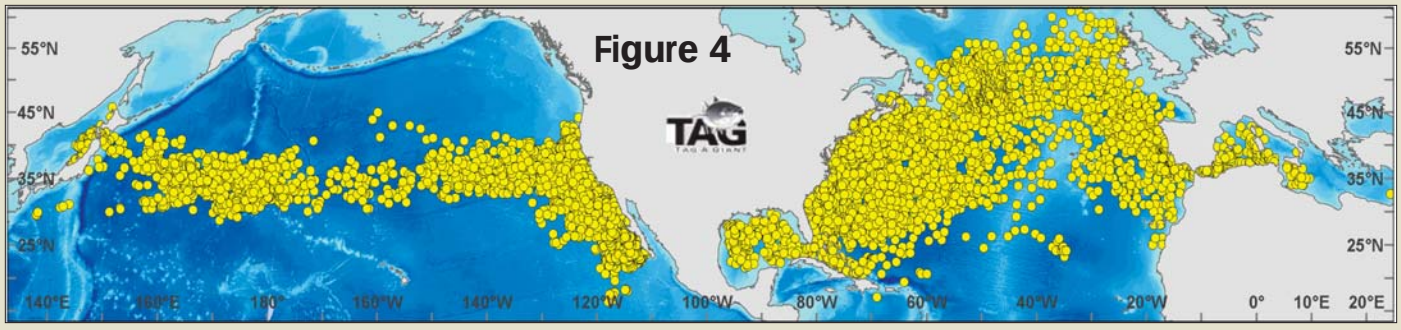
PACIFIC BLUEFIN TUNA TRACKING

As in the Atlantic, tagged Pacific bluefin exhibit repeatable seasonal movements, being farthest south in the spring (off southern Baja California) and farthest north in the fall (off central and northern California). North-south movements coincide with bursts of coastal upwelling, which lead to high productivity and thus abundant food. Sea surface temperature does not appear to limit movement. In the winter months, tagged bluefin tuna were found in areas with lower productivity compared to other regions along the coast, perhaps because they were feeding on spawning sardines and anchovies that preferentially spawn in areas of low coastal upwelling.

Figure 3: Daily depth and temperature profile of a female bluefin tuna on the Gulf of Mexico spawning grounds. A pronounced nighttime (black bar) oscillatory diving pattern with prolonged surface intervals occurs for 14 days in June. Diving before and after spawning is not diel and is associated with deeper dives. Temperature-depth profile at left is for a 24-hour interval on the same day. Blue, depth; black, seawater temperature; red, body temperature.

Figure 4: The electronic tagging of northern bluefin tuna is providing new knowledge of how these ocean giants use the Atlantic and Pacific oceans. Yellow circles are the estimated positions calculated from light and temperature data collected by each tuna's tag. The figure has over 40,000 days of positions on *T. thynnus* and *T.orientalis*, collected from over 550 fish tagged in the western Atlantic and eastern Pacific. Courtesy of *Science* Magazine.





Nine of the tagged bluefin made trans-Pacific crossings toward the only known spawning ground near Japan. Interestingly, the fish traveled the same path at the same time of year. The westward migrations were initiated primarily in the winter and early spring along a narrow corridor along the northern edge of the North Pacific Gyre. The bluefin moved relatively fast across the eastern Pacific, traveling approximately 2,500 nm in 31-45 days, and then slowed down just west of Hawaii, timing their arrival to correspond with the spring pulse of productivity in this area.

MANAGEMENT IMPLICATIONS

Information gleaned from Tag-A-Giant research has the potential to greatly influence and improve fisheries management for bluefin tuna. TAG scientists are actively engaged in the fisheries management process and work to ensure that the best available science is used in fisheries assessments. As Atlantic bluefin populations continue to decline, it is clear a change is in order to ensure a future for giant bluefin is in order. A management system is under development in the Pacific, making the expanding tagging effort particularly timely.

In the Atlantic, managers base regulations on separate eastern and western populations, divided by a line at 45ºW meridian. TAG data illustrate that, while the populations do indeed sort to separate spawning grounds in the Gulf of Mexico and Mediterranean, there is extensive mixing of the juvenile and mature populations on North Atlantic foraging grounds. Western fish feed in the Central North Atlantic and even along the West Coast of Europe, and eastern fish are even more likely to visit West Atlantic waters to feed as juveniles before returning to the Mediterranean to breed. As a result, the more severely depleted western fish are vulnerable to eastern fisheries, and eastern fish feeding in western waters are artificially inflating estimates of the western stock size. Current management is based on mixing rates around 2%; TAG data suggest mixing rates will significantly higher, as high as 20-30%, and management assessments will have to be revised to account for the transfer of the fish populations from one side of the ocean to the other. Managers should also take precautions to prevent targeted fishing pressure on bluefin when they're in large aggregations at the identified feeding hotspots.

TAG science has also shown that bluefin tuna that travel to the Gulf of Mexico tend to be very large, 94" curved fork length (240 cm cfl) and above, on average. This suggests that western bluefin spawning in the Gulf of Mexico have a mean age of 12, rather than 8 years old, the current spawning

age used in assessments. This difference could be contributing to the lack of rebuilding, despite projections for an increase in the population.

Data related to spawning in the Gulf of Mexico are among the most intriguing TAG findings. Spawning appears to occur in cyclonic eddies and is focused in the northwestern Gulf of Mexico to the west of the warm loop current. Oscillatory diving at night is a likely signal of spawning behavior. It's as if the bluefin dive to get rid of heat during their surface courtship dance; this theory is supported by the body temperature data. Although targeted bluefin fishing has been prohibited in the Gulf since 1982, bluefin are vulnerable to high mortality on longlines targeting other species because the warm surface waters in the Gulf are lower in oxygen. With information on the location and timing of spawning provided by the tags, a discrete time-area closure could be designed to protect bluefin during the critical reproductive period. Conserving Gulf bluefin tuna is a major key for keeping the DNA that codes for the larger giant bluefin tuna circulating in the Atlantic population.

In the Pacific, the TAG effort has led to a better understanding of the distribution, abundance and mortality of bluefin along the West Coast of North America, critical information for designing the emerging management regime. As quotas limit the capacity in the Southern and Atlantic bluefin tuna populations, the world will increasingly turn to the Pacific to meet the demand for bluefin tuna resources. Getting ahead of the curve will promote sustainable fisheries and has the potential to prevent the severe overfishing experienced in the other bluefin tuna species.

New tagging data come in every day, confirming what we've already learned and revealing new insights into the secrets of bluefin. We must act soon to incorporate the vast knowledge acquired over the last decade of electronic tagging into management.

Bluefin tuna are too valuable - both to the economy and the pelagic ecosystem - to let the current declines continue. Thankfully the tagging data provide a roadmap for recovery; we just need to join together as nations and fishers to ensure that giant bluefin have a sustainable future.

PHOTO CREDITS: Barb Block, Scott Taylor, Gary Stuve and Randy Wilder.

SUPPORT TAG-A-GIANT FOUNDATION

Join us to save one of Earth's most majestic species: The northern bluefin tuna. Atlantic bluefin populations have declined by nearly 90% since the 1970s. Fisheries for Pacific bluefin are expanding as stricter quotas for the other bluefin species are limiting the supply of bluefin to raw fish markets, threatening to tip the delicate balance to unsustainable levels.

Painfully aware of the precarious state of northern bluefin populations, and armed with the scientific data to improve management, a dedicated group of scientists led by Stanford University biologist Dr. Barbara Block and recreational fishers founded the Tag-A-Giant Foundation (TGF) in 2006. Our mission is to reverse the decline of northern bluefin tuna populations by supporting the scientific research necessary to develop innovative and effective policy and conservation initiatives. We will engage scientists, policy makers, fishermen and citizens to chart the course towards rebuilding and maintaining sustainable populations of northern bluefin tuna in the Atlantic and Pacific oceans.

If you have experienced the scream of a reel after hooking a bluefin, if you've felt their strength at the other end of the line, or if you're simply captivated by this remarkable species - please join us. The next five years are critical to the future of northern bluefin tuna, and we ask for your support in our efforts to help steer bluefin onto the road to recovery.

Visit us at:
www.tagagiant.org or call us at (631) 539-0624 or toll-free at (866) 533-3580 to make a donation and learn more.