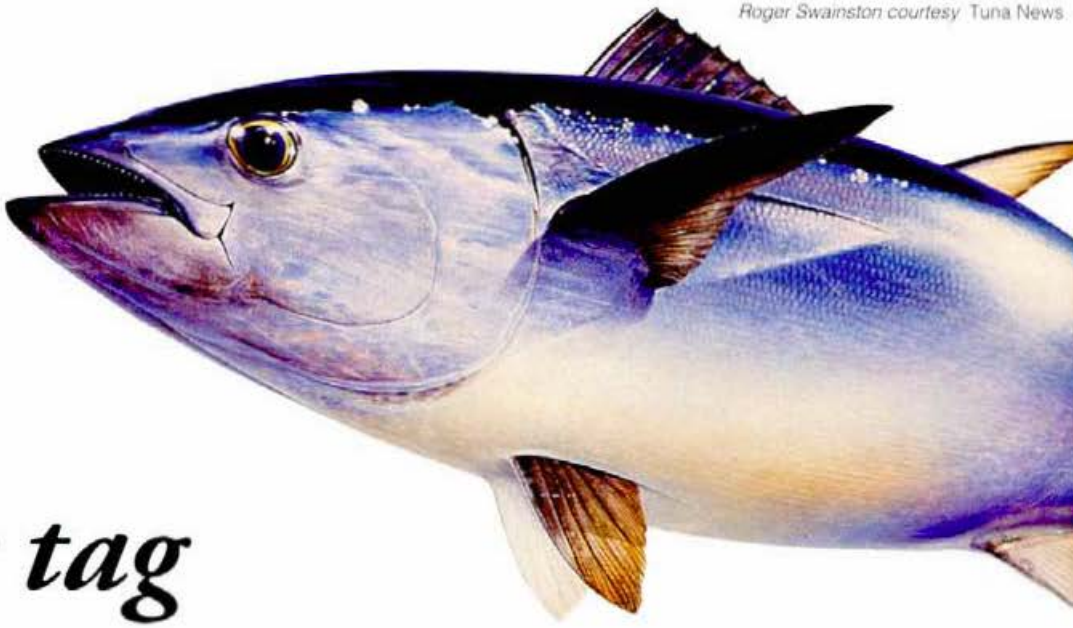


Roger Swainston courtesy Tuna News

Playing tag with the tuna

Mal Malony and Christine Ward describe the innovative techniques used to track the southern bluefin tuna from the tropics to the Southern Ocean, and back again.

A sleek, powerful, southern bluefin tuna slices through the waters of the Southern Ocean. As it dives deep to feed on squid, a tiny computer in its body measures and records data on both the fish and its environment . . .

. . . In the Great Australian Bight, aerial spotters count surface schools of juvenile tuna. At the same time, individual fish travelling underwater are tracked acoustically to help establish a relationship between the number of fish seen on the surface and the total number passing through the Bight . . .

. . . Elsewhere in the 200-nautical-mile Australian Fishing Zone, tuna are caught and dye-marked in a study which will provide the first irrefutable data on the relationship between age and growth rate . . .

The computer, the aerial and acoustic surveys and the dye-marking are part of a program to enhance our knowledge of the southern bluefin tuna and to help breeding stock recover from 40 years of over-fishing.

The program, led by CSIRO's Division of Fisheries at Hobart, has made the southern bluefin tuna the most researched fin fish in Australia. It has also sparked the development of innovative techniques for tracking and recording the tuna's long-distance travels through the sea.

Sophisticated tracking methods are needed because the southern bluefin tuna is a migratory species. Its only known spawning ground is in the warm, tropical waters north-west of Western Australia and south of Java.

As juveniles, the tuna stay close to the Australian coast. As they mature, they range the globe between the cold water latitudes of 30°S and 50°S.

According to Division of Fisheries scientist John Gunn, the southern bluefin has evolved as 'one of the most efficient biological heat pump systems in the sea'.

'They are able to warm their whole body by using a heat produced by swimming and pumped through a large blood-circulation system,' Gunn says.

'Its amazing migratory range is likely to be a result of their ability to tolerate increasingly cold water as it gets older. This is a fish that swims happily in 30°C temperatures as a baby in the tropics, moves into cooler water down the Australian coast as a juvenile, then as an adult, chooses the 6 to 8°C temperatures of the Southern Ocean.'

The smart tag

To help learn more about tuna's migration, Gunn and his team at the Division of Fisheries have developed an 'archival' tag: a small torpedo-shaped computer that is inserted into the body of the tuna.

The tag acts as a sophisticated datalogger, recording the fish's movements over an eight-year period. It collects information about depth and light; the internal temperature of the fish; and the external water temperature.

In short, it's an electronic eavesdropper, travelling the globe with the tuna to report where it goes, how it goes and, ultimately, why.

CSIRO's tag technology came under the spotlight at a gathering of international scientists and fishing industry representatives at the 45th Tuna Conference at Lake Arrowhead, California in May.

Gunn was invited to present a paper to the conference detailing the development of the archival tag. His colleague, Tim Davis, gave details of another tuna tracking device, the ultrasonic or acoustic tag.

The concept of an archival tag for fishes has been around for a number of years, yet little work had been done until the CSIRO team decided to turn it into a reality.

Detailed work began in 1992 under a joint CSIRO and Japanese tuna research program. The CSIRO scientists – Tom Polacheck, Matt Sherlock, Keith Sainsbury, Tim Davis and John Gunn – approached electronics firms in the United States, the United Kingdom and the division's home state of Tasmania, inviting them to put forward a time frame and production cost for the manufacture of the device.

The Tasmanian company, Zelcon Technic Pty Ltd, came up trumps, beating its international rivals with a tag that was smaller and cheaper than either of the overseas companies. In addition, Zelcon had the added advantage of being able to maintain daily contact with the scientists during the important production phase.

Gunn says some companies in the US are developing their own archival tags for tunas, but none are as advanced as the Australian team, which is the only one to have a device 'in the water'.

The CSIRO team implanted the first 150 tags during the division's 1994 summer tagging program off the coast of South Australia. Further tagging has taken place off Tasmania and New South Wales. By the end of June, 230 tunas were to have been fitted with the device. The Japanese industry has made a direct contribution of $112 000 to the project to help underwrite the cost of tag releases.

The scientists, having fitted the tags (at a cost of about $1200 each) were anxious for some feedback on their success. This came sooner than expected, with the recapture of a tuna fitted with an archival tag during the summer tagging operation in the Great Australian Bight.

Gunn says the device performed well. ⇨

Above: Fishermen pull in a southern bluefin tuna as part of the CSIRO tagging operation. It will be fitted with a tag in a split-second operation before being returned to the sea.

Left: Division of Fisheries scientist John Gunn makes an incision while his colleague Noami Clear calms the tuna in a operation to insert an archival tag in the abdominal cavity.

Information from the tag, when analysed by computer, gave a clear picture of the tuna's travels, its surfacing habits and its response to the environment during the month since the tag had been fitted.

The tag was developed specifically to monitor the southern bluefin tuna, yet it has the potential to be used in broadening our understanding of other fish species as well. Scientists are now modifying the tag to make it smaller and even easier to use. Eventually, they hope to devise a way of attaching it to the fish externally.

'The archival tag represents a quantum leap forward in our ability to understand the tuna's natural behaviour,' Gunn says. 'As we improve its performance, we will be able to take many more measurements.'

Surveying the scene

Aerial survey work and acoustic tracking are two other key elements in the southern bluefin tuna research program.

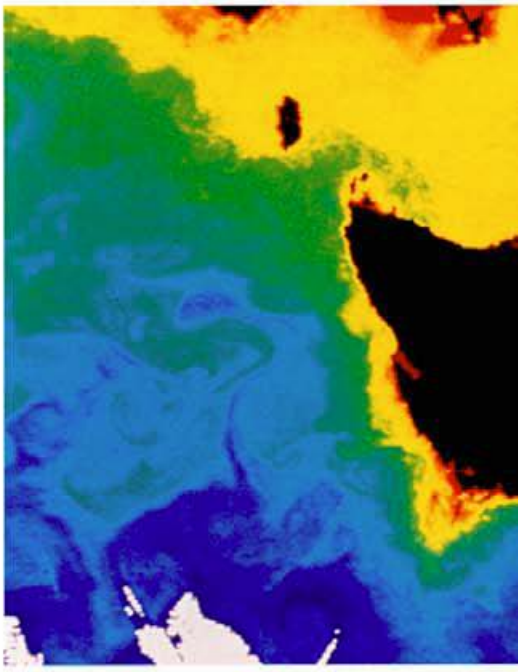
CSIRO scientists, in collaboration with Japanese researchers, conduct aerial surveys of the Great Australian Bight to assess the level of recruitment, that is, the number of new fish joining the total stock each year. Big schools of young tuna surface consistently in the Bight.

Last year, experienced fish spotters flew over 19 000 km^2 of ocean, sighting 273 schools of tuna. But that is just part of the picture. The question still to be answered is: how many tunas didn't they see because these fish weren't on the surface at the time?

Scientists are attempting to discover the proportion of young tunas in the Bight, when they surface, why and for how long. This involves another game of tag called acoustic tracking.

This complicated and labour-intensive operation allows for studies of vertical and horizontal small-scale movements of tunas which have been fitted with an ultrasonic device.

When a tuna is caught, it is fitted with a pressure-sensitive tag that



measures and transmits depth information. The tagged fish are tracked by a boat that constantly monitors the direction and depth of travel, day and night. The system can track up to four fish in a single school for up to two days.

The acoustic tracking is coordinated with an aircraft flying day-time transects over the tagged fish. This provides a link between the surfacing behaviour of the tracked fish, sea conditions, weather and visibility.

Both the archival and acoustic tagging methods represent advances in tuna research, yet the conventional tag continues to play an important role in the program.

This spaghetti-like tag provides critical recruitment, migration, growth and mortality information. When a fish is first caught and tagged, its length and capture location are recorded. These same measurements are taken when the fish is recaptured, to monitor its growth and migration patterns. This level of detail is essential in improving understanding of the southern bluefin tuna.

The earbone's connected . . .

Part of that understanding will come from another aspect of scientific research that uses tuna earbones, or otoliths, to accurately measure age and growth patterns. The earbone is located where the head joins the backbone. Every day of the tuna's life, a new band is laid down on the otolith (similar to a growth ring in a tree) recording daily and seasonal growth.

How the archival tag works

The archival tag is a mini computer with control software, set up to record and store information.

Its key components are a light sensor and water temperature sensor, both trailed on an external cord, a tiny depth sensor, which responds to water pressure, and a second temperature sensor to measure changes in the body heat of the tuna, which is warm-blooded.

A lithium battery provides a trickle of energy for nine years and two 128-kilobyte memory chips store the information measured by the sensors. The tag has a super-accurate clock which, when used in conjunction with the light and temperature sensors, will help scientists to plot the changing locations of the carrier fish as it ranges the oceans.

The time of sunrise changes by four minutes for every degree of longitude. The light sensor reports sunrise and sunset and the clock notes the times, enabling scientists to work out the fish's longitude to within a degree or two.

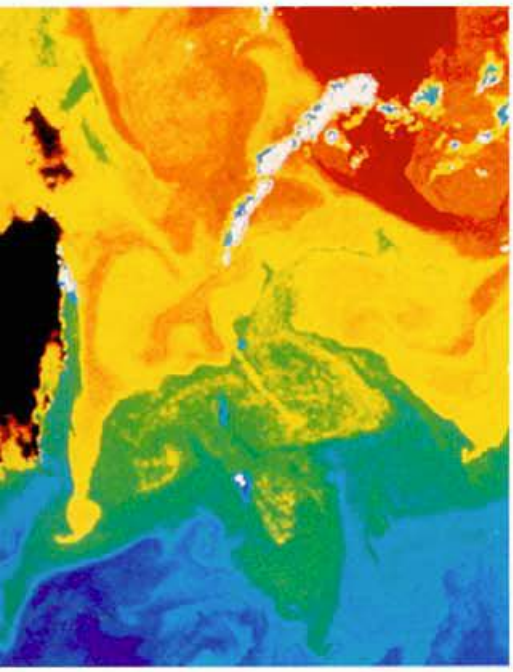
Day length, that is the time between sunrise and sunset, provides a clue to latitude, particularly at high latitudes. The water temperature reading provides a further positional cross-reference.

The depth sensor measures the tuna's diving behaviour, which, along with large-scale global movement, is one of the two most important puzzles CSIRO scientists are hoping to solve using the archival tag.

Information on the time fish spend on the surface, and the relationship this 'surfacing behaviour' has to weather and sea conditions, are critical inputs into the interpretation of data gathered by aerial surveys.

Every measurement recorded by the tag's sensors burns up four bytes of memory. That means the current tags have the capacity to store about 60 000 data measurements.

To achieve the best results, scientists have programmed a series of closely-spaced measurements, plus some well-spaced ones. This translates to one measurement every four minutes for the first 90 days, with similar measurements just two days a week for the remainder of the battery life.



Satellite pictures indicating plankton distribution and ocean productivity are used as a guide for the fishing industry in its search for the southern bluefin tuna.

In the past three years the CSIRO team has injected 12 000 southern bluefin tuna with a dye, placing a narrow band on their otoliths. The fish were then released with an external identity tag. It is hoped that a large proportion of these tunas will eventually be caught by Australian and Japanese boats and the otoliths returned for examination.

Scientists know the time that has elapsed between the tagging and the date of recapture. They relate this information to the number of additional rings on the otolith to deduce the fish's growth pattern.

This information will be used to develop not just one, but a number of age indicators including age at length; age at recruitment; age at maturity; and age at spawning.

The dye-marking project together with the CSIRO's other tagging and aerial survey programs will vastly improve knowledge of the southern bluefin tuna's biology and our ability to assess stock levels to ensure its future sustainability.

The consummate athlete

Southern bluefin tunas (*Thunnus macoyii*) begin life in the warm waters of the tropics as eggs of about one millimetre in diameter. They float in the ocean's upper layers, where wind and wave action keeps temperatures uniform.

Once hatched, the tiny fish are about 2.5 mm long, and barely distinguishable from other types of tuna. As adults, they weigh about 200 kilograms and measure more than 200 centimetres.

They live for 20 years, but only reach sexual maturity after nine years. It is not clear whether all adults spawn each year, every few years, or even only once in their lifetime. A single female, however, can release up to 15 million eggs during a spawning period.

The southern bluefin is one of 13 other species of tuna in the Scombridae family and is related to the billfishes. These include swordfish, marlins and spearfish.

One of the fastest ocean swimmers in the world, the tunas often travel in speed bursts of up to 70 kilometres an hour during their migrations over thousands of kilometres of ocean. They recover from these exhaustive activity bursts about 10 times faster than any other fish species, due in part to the fact that tuna hearts are several times bigger than the hearts of other fish.

This incredible physical stamina comes in part from a healthy diet of fish, squid, krill and salps. In offshore waters they also eat small crustaceans and much larger fish. A skilled ocean hunter, the tuna uses its highly developed senses to hunt prey in areas where warm and cold waters meet, where there is more food.

The tuna's highly advanced circulatory and respiratory systems work to keep the temperature of its warm-blooded body constant. It can vary its heat dissipation, depending on its activity, and can tolerate a wide range of water temperatures.

In general, there are more females in younger generations, but males outnumber females almost two to one as adults. As they grow, the young fish move south toward major feeding grounds in the colder Southern Ocean. The warm Leeuwin Current, which begins near the spawning ground and is strongest in April, right after the spawning period, helps to sweep the tuna down from the West Australian coast to the Great Australian Bight and beyond.

More about tuna

Caton A McLoughlin K & Williams (1990) *Southern bluefin tuna: scientific background to the debate*. Bureau of Rural Resources Bulletin No. 3. AGPS, Canberra.

Guide to current CSIRO tuna research projects (1993) Ed: W Whitelaw. CSIRO Division of Fisheries, Hobart.

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The acoustic or sonar tag measures and transmits depth information. It can be inserted into the tuna or attached externally. The fish are tracked by boat, day and night, for up to two days.