Electronic tagging of marine animals

The tagging of marine animals with electronic sensors is increasingly being undertaken by scientists worldwide to track their movements. Electronic tags such as archival, pop-up archival and satellite positioning tags are revealing when, where and how marine animals travel, and how these movements relate to the ocean environment. The ability to predict the movements of marine animals, based upon an understanding of what drives their movements, has a key role to play in marine conservation and fisheries management.

Archival tags

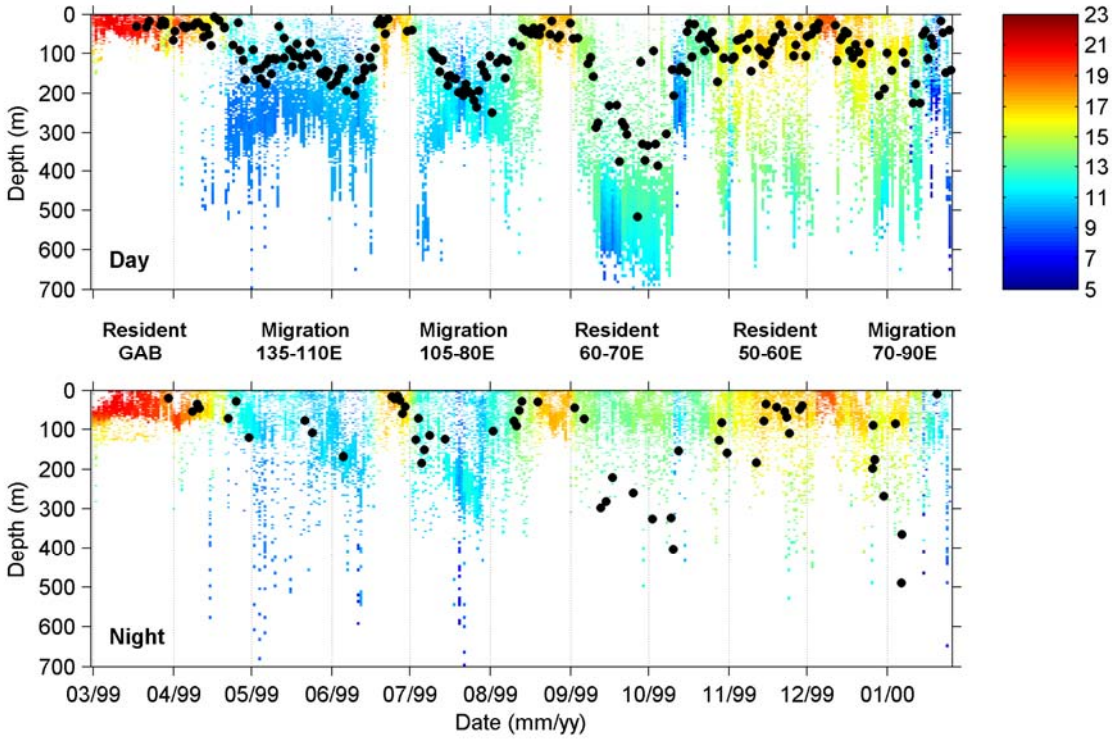
Archival tags are small data loggers that record dates, times, swim depths, water temperatures, body temperatures and light levels. They can record data every few seconds for up to 10 years, depending on the tags' sampling frequency and battery life. Light levels are used to calculate an approximate daily position of the tagged animal based on the time of dawn and dusk and the angle of the sun. Reliable estimates of latitude, however, usually require the use of sea-surface temperature, which can also be recorded by the tag and subsequently matched with relevant data sets obtained by satellite.

Archival tags can be attached externally or internally, and must be retrieved for their data to be downloaded. They are used most commonly on species that have a high likelihood of recapture – either through fishing, or upon return visits to breeding and feeding grounds – such as fish, seabirds, sea turtles and marine mammals. Archival tags that detach from the animal, either prematurely or at the pre-determined time, may drift ashore. These are commonly retrieved by beachcombers and the tags and their data can often be returned for a reward.

Archival tags have been used to track return migrations of juvenile southern bluefin tuna from the Great Australian Bight to the Indian Ocean, including details of their diving patterns and feeding events (marked by sharp drops in body temperature as food and cold water enter the stomach). Archival tags have similarly revealed pan-oceanic migrations of juvenile and adult Atlantic bluefin tuna between spawning grounds in the Gulf of Mexico and the Mediterranean Sea, and feeding grounds off the US and European coasts, as far north as Iceland.

Miniature archival tags have revealed trans-equatorial, post-breeding migrations of sooty shearwaters from New Zealand to feeding grounds off Japan, Alaska and California. Tracks show that shearwaters fly across the entire Pacific Ocean in a figure-of-eight pattern that entails an annual migration circuit of 55 000–75 000 kilometres.

In shelf seas, archival tags have traced the migrations of demersal fish, such as plaice and cod, and revealed new information on behaviour, temperature, population distribution and the likely effects of climate change.



Daily diving and feeding behaviour of a southern bluefin tuna during 11 months at sea recorded by an archival tag. The colours indicate water temperature at depth and the black circles indicate a feeding event.

Credit: CSIRO Australia

Pop-up satellite archival tags

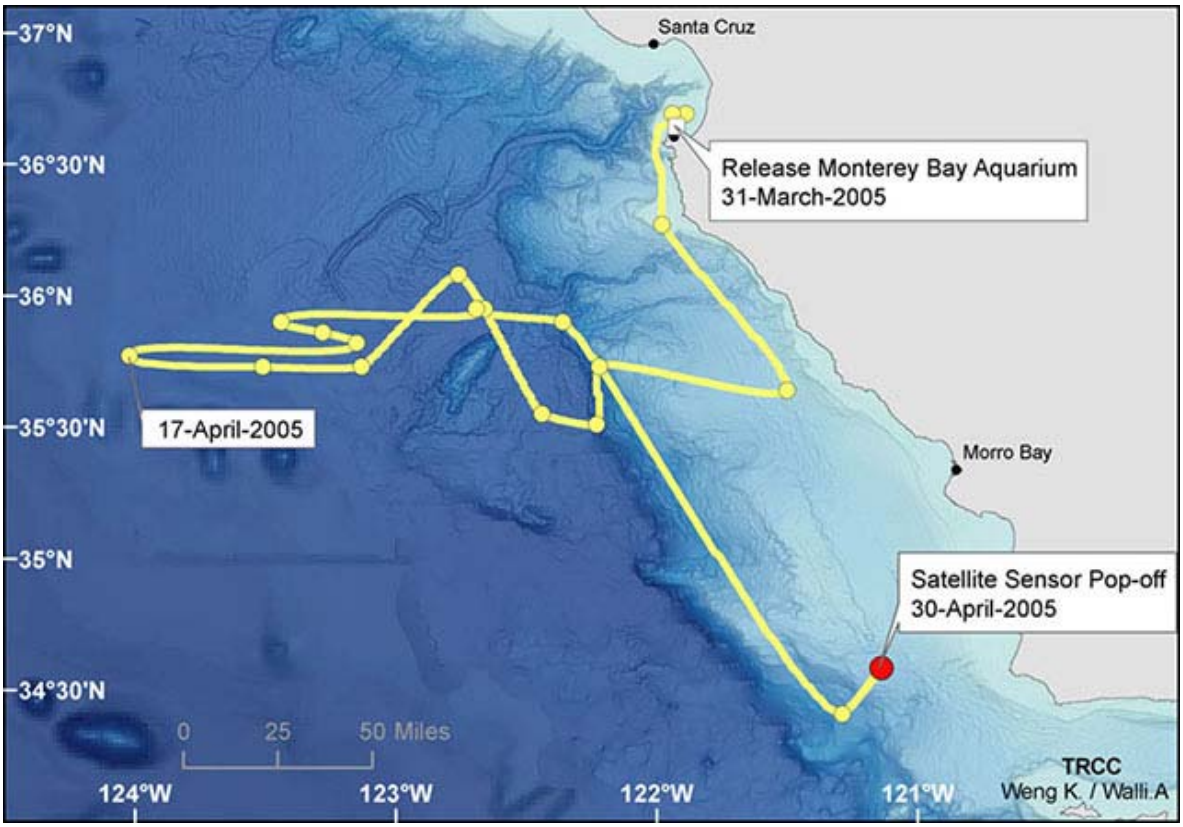
Pop-up archival transmitting (PAT) tags are externally placed tags that are pre-set to detach, rise to the surface and transmit data summaries by radio to the Argos satellite network. This network collects, processes and disseminates environmental data, and has a special channel dedicated to wildlife telemetry. PAT tags provide a means of collecting fishery-independent data, and have been deployed on animals such as tuna, marlin, sharks, swordfish, mola mola, halibut, eels and sea turtles.

Tags tracking the movements of white sharks off South Africa, California, New Zealand and southern Australia are revealing a mixture of coastal 'patrolling' behaviour and prolonged, direct coastal and ocean migrations. White sharks tagged in South Africa exhibit return breeding migrations to Australia and some individuals tagged off California migrate as far as the Hawaiian Islands. Building a picture of regularly used white shark migration routes may help to reduce the incidental capture of this threatened species by commercial fisheries and minimise undesirable interactions with humans.

PAT tags have also been used to study the movements of plankton-feeding basking sharks in the north-east Atlantic Ocean, where active habitat selection has been investigated by combining tag data with a dynamic prey landscape of copepod biomass. Observed behavioural patterns, which

may be based on learned responses, are consistent with basking sharks using search tactics structured across multiple scales to exploit the richest prey areas available in preferred habitats.

The pop-up tag used on a white shark tagged by Monterey Bay Aquarium contains data that can be downloaded in the lab.
Credit: TOPP – Tagging of Pacific Pelagics



Movements of the juvenile white shark during the month following her release from Monterey Bay Aquarium.
Credit: TOPP – Tagging of Pacific Pelagics

Satellite positioning tags

Satellite positioning tags are attached externally on animals and transmit a signal either to the Argos satellite system or the GPS satellite system which determines the position of the tag, providing near-real-time tracking of the animal's movements. Because the tag antenna must be above the water to transmit a signal, these tags are deployed on animals that spend sufficient time at the ocean surface. They are most commonly used on animals such as marine mammals, sea turtles, seabirds and some species of sharks.

Some versions of these tags transmit summaries of data on swimming depth, water temperature and salinity. They are deployed on marine mammals such as elephant seals to track diving behaviour and foraging activity, and to build profiles of oceanographic features in remote parts of the world's southern and northern oceans. Dive profiles from these tags can be used to calculate the buoyancy of the seals and derive an index of body condition (percentage fat and protein) at sea. This allows the energetic state of the animals to be recorded and successful foraging locations to be identified.

A satellite positioning tag fitted to a juvenile white shark off southern Australia. The shark was tracked for a distance of 2946 kilometres over a 129-day period.

Credit: CSIRO Australia

GSM tags

GSM tags use the ubiquitous GSM (Global System for Mobile communications) network to transmit recorded data. They can do this when the tagged animal enters coastal waters within the range of a GSM receiver and have so far mainly been used with marine mammals, although trials have been conducted with basking sharks. For animals that come to the surface, accurate positions can be obtained by using a GSM tag in conjunction with Fastloc GPS, which collects the data required for a GPS location within a fraction of a second. Development is less advanced than with tags that transmit to satellite.

Acoustic tags

Acoustic tags can be attached externally or internally. They transmit a unique code at regular intervals which, when in range, is logged by an electronic receiver on the seabed, or a hydrophone operated from a vessel. They also can transmit water temperature, depth and swim speed.

Acoustic tags commonly are used to record the extent to which an animal uses a particular area, and how this behaviour may change over time. They are suited to research on any species to which a transmitter can be attached or implanted without modifying its behaviour, such as fish, sharks, crustaceans and squid.

Acoustic receivers, or ‘listening stations’ can record the presence of hundreds of animals tagged with acoustic transmitters with a location accuracy of one to two metres. Their range can be

extended to hundreds of kilometers by placing multiple receivers in grids or lines. Tag-to-tag data transfer is likely in future.

The Pacific Ocean Shelf Tracking project is a major acoustic tagging initiative which aims to have an array of 2000 receivers along the west coast of North America between Baja and Alaska by 2010. Distributed in 30 lines extending out to 50 km from the coast, the array will have the capability of listening to 250 000 coded tags at any instant. After successful tests with Pacific salmon smolts in the Strait of Georgia and southeast Alaska, the system is now being expanded geographically and to study a wider range of migratory species. Proposals have been made for similar arrays in other parts of the world, particularly at key nodes such as the Straits of Dover and the Strait of Gibraltar, as well as coastlines with narrow continental shelves.

A scientist implants a tag into an anaesthetized steelhead trout smolt as part of the Pacific Ocean Shelf Tracking project.

Credit: Vancouver Aquarium

Digital acoustic recording tags

The digital acoustic recording tag (D-tag) is a motion and acoustic recording tag attached to the animal by a suction cup (most commonly to whales). It records all sounds made and heard by the tagged animal(s), and also contains a digital compass, a temperature sensor, a pressure sensor to measure dive depth, and a three-axis accelerometer to measure pitch and roll.

D-tags are being used to characterise whale movements and sub-surface behaviour, including the kinds of vocalisations used while diving and foraging, and their responses to human activities. Data visualisation software can combine D-tag data with geospatial data and bottom topography, giving a three-dimensional picture of how whales react to sounds. The information assists in forming plans to reduce threats from fishing gear, ship strike, and sonar.

Tracks for the future

As new software and hardware is developed, electronic tags will become smaller, yet more complex, recording in greater detail a wider range of physical and physiological variables such as:

- magnetic field strength and magnetic dip;
- acceleration and tail-beat frequency;
- heart rate and cardiac output;
- feeding rate, feeding behaviour and growth rate;
- gonad development and related levels of blood enzymes and hormones; and
- water chlorophyll concentrations and nearby acoustic prey fields.

Methods of tag application, geolocation, data transmission, and the analysis, integration and visualisation of biological and environmental information, for individuals and populations, also are being improved.

Weblinks

Tagging initiatives

NOAA satellite and information service (Argos Data Collection System): http://noaasis.noaa.gov/ARGOS/
Census of Marine Life Pacific Ocean Shelf Tracking project: www.postcoml.org
Tagging of Pacific Pelagics: http://www.toppcensus.org/Default.aspx?bhcp=1
Tagging of Pacific Pelagics, technology: http://www.toppcensus.org/web/Background/technology.aspx#PAT
Collaborative white shark research program, Wildlife Conservation Society: http://www.sharkresearch.org/pages/sattagproject.html
The Ocean Tracking Network, http://www.oceantrackingnetwork.org/index.html
seaturtle.org: http://www.seaturtle.org/
Pelagic Fisheries Research Program, University of Hawaii at Manoa: http://www.soest.hawaii.edu/PFRP/overview.html
Sea Mammal Research Unit, St Andrews University: http://smub.st-and.ac.uk/
Data visualization research lab, University of New Hampshire: http://www.ccom.unh.edu/vislab/index.html
Wood Hole Oceanographic Research Institution Biology Department, Marine Mammals: http://www.whoi.edu/science/B/dept/working_groups/marinemammals.htm
Southern Elephant seals as Oceanographic Samplers (SeaOS): http://biology.st-andrews.ac.uk/seaos/index.html
Census of Marine Life Mid-Atlantic Ridge Ecosystem Project (MAR-ECO): http://www.mar-eco.no
CODYSSEY (EU-funded R&D project), Spatial dynamics and vertical movements of cod in European waters: http://www.codyssey.co.uk Euro Census of Marine Life, European

Tracking of Predators in the Atlantic (Eutopia): www.eurocoml.org and follow link via European Projects

Tagging information

CATAG, Tagging Methods for Stock Assessment and Research in Fisheries, (Report of EU Concerted Action): http://www.hafro.is/catag/

Equipment providers

Starr-Oddi Marine Device Manufacturing: http://www.star-oddi.com/
Sonotronics Underwater Ultrasonic Tracking Equipment: http://www.sonotronics.com/
Wildlife Computers: Electronic tags for Wildlife research: http://www.wildlifecomputers.com/
Microwave Telemetry Inc. Bird and Fish Tracking Transmitters: http://www.microwavetelemetry.com/
Sirtrack Wildlife Tracking Solutions: http://www.sirtrack.com/
Lotek Fish and Wildlife Monitoring Systems: http://www.lotek.com/
Vemco underwater acoustic telemetry transmitters and receivers: http://www.vemco.com/index.php
Sea Mammal Research Unit: http://www.smru.st-and.ac.uk/
Cefas Technology Ltd (CTL): http://www.cefastechnology.co.uk