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Archival tagging of Southern Bluefin Tuna

Background to CSIRO's development of an tag suitable for use on tunas, and its use on SBT to study movement and behaviour in juvenile and adult fish*.

John Gunn, Tom Polacheck, Tim Davis and Matthew Sherlock

CSIRO Division of Fisheries
P.O. Box 1538, Hobart, 7001.

To provide an overview of CSIRO's progress and plans in the devlopment of an archival tag suitable for use on tuna, the following documents are copies of a report on progress made during 1993/93 and a funding proposal to support continuing their development and use in 1993/94 submitted to a JAMARC SBT Recruitment Monitoring Workshop in June 1993.

PART 1

Archival tag development during 1992/93

Introduction

At the 4th JAMARC- CSIRO Workshop on SBT Recruitment Monitoring and Tagging Programs, CSIRO canvassed support for the devlopment of an archival tag suitable for use on SBT. Following encouragement from Japanese and Australian science and industry representatives at this meeting , on 1 October 1992 CSIRO and Zelcon Technic Pty Ltd, a Hobart electronics company, began a collaborative R&D project to design and develop a first generation tag. Funding for this project has come from CSIRO and SBTMAC.

The objectives of the project were to design an electronic tag capable of measuring temperature, depth and light, for periods of one year or more and storing these data for up to five years. The tag needed to be small enough to be easily carried by SBT approximately 100cm in length (ie of a size commonly caught off South Australia and Tasmania). A complete list of the specifications for the tags developed under the collaborative R&D project are provided in Appendix 1.

Progress

i. Design and devlopment of a tag.

Initial design efforts focussed on the adaptation of circuitry used in a penguin data logger manufactured by Zelcon Technic Pty Ltd., and used successfully on penguins in the

Antarcttic. However, early in this stage of the project it became obvious that a complete reworking of the circuitry was necessary if the CSIRO's specifications were to be met. Thus, during the first three months of the project, Zelcon Technic and CSIRO engineers developed completely new analog and digital circuits for the SBT tags, which were to based on surface-mount technology (SMT).

Reported recaptures of dummy tags deployed in 1992 indicated that an internal tag placement may provide the best rates of return. Thus, a design was adopted with an internal core circuit board (incorporating memory, micro-processor etc) connected to an external sensor pod, in which light and water temperature data would be collected.

In February 1993, a prototype of the tag was built and fully tested in the laboratory. The prototype's performance was excellent; offering power budgets so low that battery life far exceeded that detailed in CSIRO's initial specifications. The new design allowed logging of data for periods of up to nine years and provided many features that meant memory space, rather than power availibility, was the limiting factor in how much information could be gathered and stored in the archival tags.

The first "generation" of CSIRO-Zelcon archival tags were produced in late March as a preproduction run of ten tags. These have been used to field-test the tag design and performance. In pressure chambers, tags have been tested to 500m and have provided estimates of depth accurate to within specifications over the complete range. Similarly, temperature testing has provided reliable and accurate results. Testing of the photo cells has focussed on measurement of the rate and nature of decay in light levels with increasing depth. An ability to accurately measure the point at which the sun rises and sets is critical to the estimation of geolocation.

Current testing and modifications of the gain specfiications used in the tags, have allowed accurate estimation of the times of sun rise and sunset at depths of up to 50m. All tesing has been conducted in shallow waters on the continental shelf, which are charcteristically more turbid that oceanic waters. It is expected that this performance will matched or bettered on SBT swimming in oceanic areas. The influence of cloud on light measurement has not been fully tested. However, there are indications that on days when there is heavy cloud the inflexion points in light level data, which characterize sunrise and sunset, are more difficult to estimate accurately. These complications, and the complex modelling of geolocation will be the subject of detailed analysis over the next 12 months.

ii. Fabrication of 100 tags.

In March 1993, using funds provided by CSIRO and SBTMAC,Zelcon Technic was contracted to fabricate 100 tags of the design developed under our collaborative R&D project. Thirty of the first generation tags were completed in early June and have been deployed in SBT off Port Lincoln in South Australia. The remainder are due for completion in early July and, if fish are available, these will be deployed on fish in south-east Tasmnania during July.

iii. Recaptures of dummy tags released in 1992

To date, four of 100 internal dummy tags released off Port Lincoln in March 1992 have been retruned to CSIRO. In contrast, only one of 100 external tags released at the same time have been returned. The return rate of internal tags is not significantly different from the return rates of conventional tags released in the same area during the summer of 1991/92. Thus, we are confident that the insertion of the archival tags will cause little to no mortality to fish.

Fish tagged in South Australia in June 1993 were slightly smaller than those fitted with dummy tags the year before (mean length approx 84cm compared with 92cm). However, the tags appeared to fit well within the body cavity. This year the incision made to allow insertion of the tag was sutured after injection of a dose of Amoxil (in 1992 steel staple sutures failed to close the wound and thus all fish were left with an open incision).

Despite this, reports back from boats catching the 1992 dummy tags suggest that the 6 cm long open wound healed to leave no visible scar.

iv. Promotion of the archival tagging project within the SBT industry.

The relatively low numbers of archival tags released require the complete co-operation of commercial fishermen in the return of all tags recaptured. To this end, CSIRO have produced promotional posters in English and Japanese (Appendix 2). These detail the objectives of the tagging project, tell fishermen what the tags do and provide information on what they should do when one is recaptured. Plans are also underway to co-ordinate tag recovery in Japan through NRIFSF port-samplers. A reward is offered for the return of the

tags and CSIRO's will provide a complete summary of the archival tag data to the crews and owners of boats returning archival tags.

PART 2
Proposal for further development and use of an archival tag in SBT

Introduction

What are archival tags?

Archival tags are miniature electronic devices, designed to measure and store data on a number of parameters within a fish's environment (eg. the depth at which a fish is swimming, the temperature of the water and the fish's body, light levels - from which it is possible to calculate the position of the fish, etc.). The tags are powered by small lithium cells that have a life of xxx mA. A microprocessor controls the tag's analog and digital functions, regulates the acquisition of data by sensors and controls the storage of these data on RAM chips.

Archival tags, or data loggers, are not a new concept; scientists studying seals and whales have been using various kinds of data loggers for a number of years. However, the units used in whale and seal research are much too large by for use on fish, and generally do not have the capacity to log data for periods of more than a year.

Since 1992, CSIRO and a partner, Zelcon Technic Pty Ltd., have been developing and testing an archival tag suitable for use on Southern Bluefin Tuna. The primary objectives of this R&D project have been to design a tag small enough to be attached externally, or inserted into the body cavity of juvenile SBT (>90 cm LCF), with enough memory and power to log data on a range of parameters within a fish's environment for more than a year. The progress of this development project is reported in Gunn et al 1993.

What can archival tags offer that conventional tagging and acoustic tracking can not?

Data from conventional tag and recapture experiments and tracking studies provide two ends of the spectrum in terms of our understanding of fish movement. For most marine fishes, and in particular the highly migratory species such as the tunas, a major information gap exists between the short (1-3 day), highly detailed paths of acoustically tracked tunas and the two position points recorded for marked and eventually recaptured fish (Hunter et al. 1986).

This is certainly the case for SBT. Conventional tag and release programs in Western Australia, South Australia, Tasmania and NSW over the last thirty-odd years, have produced a wealth of basic information on the movement of fish among Australian fishing grounds and between these and the Japanese high seas longline fisheries throughout the Southern Ocean. However, these data provide only points of release and recapture for each fish and recaptures are made only in areas where fisheries are operating. We have no idea of how fish get to their point of recapture. As all releases of SBT have been made in Australian waters, we can estimate the incidence of east-to-west movement across the Indian Ocean, but we have no idea of the nature or extent of movements from South Africa to New Zealand or Australia. Do fish that move east-to-west from Australia to South Africa make a return journey ? How often do fish migrate to the spawning ground(s) off Java? Have fish recaptured in the same area as they were released a year or more before remained in the locality, or have they undertaken large-scale migrations before returning to a "summer feeding ground"?

Conventional tag and recapture experiments can not provide answers to these questions. Yet with growing evidence of the contraction in the number of SBT fishing grounds and the effective area of over which effort is targeted on the remaining grounds, there is a critical need for accurate data on stock structure, the patterns and rates of movement in the species and on the interaction between fisheries. With the global SBT population at historically low levels, the spectre of localised depletion of SBT "stocks" has important implications for the development of management strategies during a period of population recovery. While there are a number of factors that may contribute to localised depletion (eg. separate genetic stocks or sub-stocks within the fished population, shifts in effort in response to a range of market or fishery-based influences, changes in the movement/migrations - either as a result of altered physical/environmental patterns and processes or density dependent factors), until data is available on the rates of mixing between fishing grounds we have

limited information with which to predict the impact of existing management strategies on grounds or stocks that have been depleted, or of formulating new strategies that respond to variations in spatial structure of the stocks.

At the other end of the spectrum in our understanding of SBT movement, CSIRO's current ultrasonic tracking project is, for the first time, providing data on the vertical and horizontal movement of juvenile fish in the Great Australian Bight (Davis 1993). Integration of tracking data with data on water temperature, bottom depth and weather conditions will allow us to examine the factors affecting surfacing/diving behaviour and fine-scale horizontal movement.

The large-scale aerial surveys to monitor recruitment of SBT in the Great Australian Bight, begun in 1992, urgently require accurate and extensive data on the species' vertical movement. From these data, the probabilities of when and where SBT schools are likely to be on the surface can be calculated and incorporated into the analyses of visual/aerial census data from which densities of schools, and ultimately abundance, are derived. Although the tracking project is providing precise and very detailed data on the behaviour of juvenile SBT, the cost of tracking vessels and the labour-intensive nature of tracking work, restrict tracking of individuals to periods from hours to a few days. The technique is also constrained by bad weather. Thus, to study the temporal variability in behaviour within and among individuals by tracking alone would require a very large number of individual tracks.

Archival tags provide solutions to some of the problems encountered by tracking studies. They provide a means of collecting data on the vertical movement of individual SBT for periods of months to years and, through incorporation of temperature sensors within the tag, also allow examination of the links between movement and the thermal structure of the water column. Archival tag depth data, collected every 4 minutes, are not as detailed as those produced by tracking, in which the depth of a fish is recorded every few seconds. However, despite the relatively high initial cost of archival tags they do not require a large investment in boat time for deployment, and they collect data regardless of the weather conditions.

When combined, tracking and archival tag data will provide a powerful tool in the quantitative study of the behaviour of SBT during summer feeding as juveniles in the Great

Australian Bight and during their migrations as both juveniles and adults through oceanic waters.

At the same time, archival tags will collect data on the horizontal movement of SBT over periods of months to years that will, for the first time, provide information on the routes used by SBT in their large-scale migrations and allow us to examine many of the "unknowns" in SBT biology and ecology discussed above.

The chance of recovery

An important consideration in the use of archival tags, each of which cost hundreds of dollars, is the likelihood of recapture of tagged fish. Our experience with dummy archival tags released during 1992 suggest that in the case of tags inserted into the body cavity, we can expect return rates in the same order as those seen from the 1990-93 conventional dart tagging program - ie. in the order of 7-8% after three years at liberty. Further recoveries could be expected after this period. The first generation of archival tags have a battery life of 5-8 years, and it is planned in later generations to extend this if possible, thereby maximising the opportunities for retrieval of data from tags returned many years after release.

The proposal in detail.

In this proposal we outline a plan for the first year's work within a five year project to design, develop and use archival tags within the SBT fishery. We believe their potential to readily provide data likely to impact on the assessment of SBT populations and the management strategies for SBT fisheries and the fact that recapture probabilities are as high now as they are likely to be at any time, will make archival tags an important research tool. Their potential for their use in other species suggests an investment in the development and application of an archival tag will have important flow-ons in many fisheries currently involving the Japanese and Australian fishing industries.

Objectives:

1. Analyse in detail data from first generation of archival tags deployed in 1993 and returned during 1993/94. This would include the development of models for estimation of geolocation, incorporating compensation for light attenuation with depth.
2. Develop a smaller and more efficient second generation tag design incorporating the capacity for additional sensors and memory.
3. Produce 200 "second generation" tags for release on SBT in South Australia in January 1994 and Tasmania in June 1994.
4. Using the tags released in South Australia, examine the surfacing/diving behaviour of SBT in the Great Australian Bight over extended periods (days to months).
5. Examine rate of movement and distribution of SBT within the aerial survey area, and migration out of this area.
6. Examine links between the vertical and horizontal movement of SBT and the temperature of the water in which they are swimming. Are they following temperature fronts? Do they use surfacing behaviour to control body temperature? If so, can we predict when SBT are likely to be on the surface on the basis of air and/or water temperature?
7. Examine broad-scale migration patterns of SBT throughout their geographic range.

Justification.

i. Tag Design

In early 1993, the first generation of archival tags developed by CSIRO and Zelcon Technic used state-of-the art surface mount technology and a selection of the best components available. However, even as these tags were being designed and fabricated, the rate of advance in miniaturised components and significant reductions in their cost, made it possible to improve on the performance, durability and flexibility of future generations of archival tags for use on SBT.

Thus, our plans for 1993-94 include the updating of hardware and software used in the tags. The principal objective of this redesigning will be to take advantage of the rapid advances in component performance. This will allow the tags to log data for longer periods with greater data security, to be more flexible in the way in which data is acquired, and to acquire data on more parameters of the fish's environment and physiology.

ii. Software development and analysis of data

At the same time as upgrading the tag design and capabilities, it will be essential to develop analytical procedures for data acquired by the tags. Thus, in this proposal we request support for a computer programmer/data analyst, who will assist in the development of methods and develop software for estimation of geolocation and processing of depth and temperature data.

One of the primary objectives of the archival tagging project is to trace the movement of SBT as they migrate throughout Australian and Southern Ocean waters. To do this we plan to use temporal changes in light levels to estimate geolocation. If the fish remain in surface waters throughout daylight hours, the calculation of geoposition is relatively trivial. However, data collected from tracking of SBT in the Great Australian Bight (Davis unpubl. data) suggest that fish characteristically undertake both diel and short-term vertical migrations. In that case, the effect of light attenuation with depth must be taken into account in the estimation of geolocation. This is a complex task and will require thorough modelling of light attenuation co-efficients.

iii. Deployment strategy.

South Australia and Tasmania have been chosen as sites for deployment of archival tags during 1993-94. The South Australian release will be in January, to coincide with both the CSIRO-JAMARC aerial survey and the acoustic tracking of SBT. Concurrent releases of the two different types of tags will provide essential comparisons of data from archival tags which will log depth only once each 4 minutes with that from acoustic tracking which gives a depth estimate each second. These analyses will provide a means of utilising both tracking data, which is generally available for only 24-48 hours for each fish, and archival data which should be for periods of weeks to months for each fish, when examining the surfacing behaviour of SBT in the aerial survey study area.

Archival tags will also be released during the autumn off the Tasmanian east coast, within the area fished from May-August by the Japanese longline fleet. It is planned to release at least some of these tags on large, mature SBT in the hope that these fish will undertake spawning migrations before recapture. The remaining Tasmanian releases will be of juvenile fish.

A two-stage schedule for data acquisition will be used for all tags. During the first stage, the duration of which will depend upon the available memory but will certainly cover at

least the first three months data logging, data will be collected by all sensors every four minutes. This will provide detailed information on the surfacing behaviour of fish and on their fine-scale movement. During the second stage, data will be collected for a 48 hour period each week to allow for estimation of geolocation and examination of seasonal changes in behaviour.

iv. Biological and physiological studies.

In addition to data on light and depth, from which position and diving behaviour can be examined, archival tags provide a unique opportunity to examine a range of biological and physiological traits of wild SBT. For example, using both internal and external temperature sensors, it is possible to examine the extent to which SBT thermoregulate and when and where they do so. These data also provide a means of estimating metabolic rate of fish. Links between metabolism and behaviour are likely to be important determinants of the movement patterns in SBT, and eventually data from archival tagging may provide a means of understanding the reasons for the broad-scale migration of the species and their apparent preference for different feeding grounds scattered across the Southern Ocean.

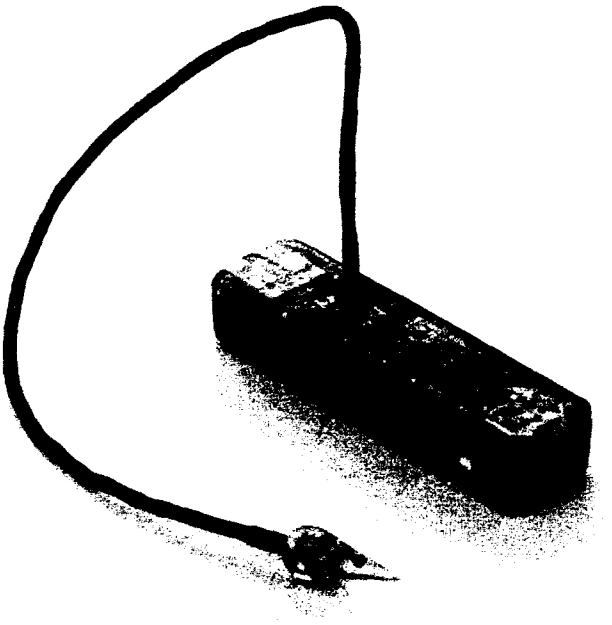
There is also a potential spin-off from archival tag data for those interested in farming of bluefin. Data on the influence of water temperature on body temperature and metabolic rate will be essential if farmers are to maximise the yield and efficiency of the "feed-lot" enterprises currently practised in Australia and Japan.

Work Plan.

July - Oct 93	Hardware design and software development for 2nd Generation tag.
July 93-June 94	Analysis of experimental data and data from tags returned. Modelling of light attenuation and geolocation.
Oct - Dec 93	Fabrication of 200 2nd Generation tags.
January 94	Deployment of 150 tags off South Australia.
May 94	Deployment of 50 tags off Tasmania.
June 94	Report on progress to 6th Recruitment and Tagging Workshop.

ARCHIVAL TAGS IN SOUTHERN BLUEFIN TUNA

Archival tags are electronic devices used to collect information on a fish's environment and behaviour. The tag's main circuit board is located inside the body cavity of the fish, just forward of the vent, and cannot be removed without making a small cut along the gut. Temperature and light sensors are located in a pod outside the body.



The SBT tags are programmed to measure the depth at which a fish is swimming, the temperature of the water, time and light levels for periods of up to nine years. By accurately monitoring light levels it is possible to calculate the position of the fish. Thus, using the tags it will be possible to examine in detail the migration routes of SBT as they move around the Southern Ocean and to study how their movement is related to the environment.

In 1993, 100 juvenile SBT will be fitted with archival tags in Australian waters. More tags will be released in the future. Fish with archival tags are easily recognised by the 30 cm sensor pod that trails behind the vent.

What to do if you find an archival tag

Please remove the tag carefully. **DO NOT** pull the tag out using the sensor pod cable.

The tag is well protected in an epoxy case, so after removal please wash it in fresh water and store it in a safe place. When you return to port, please contact the address below as soon as possible.

It is essential that all tags recaptured are returned quickly to CSIRO .

Attention Mr Wade Whitelaw: CSIRO Division of Fisheries, P.O. Box 1538, Hobart, Tasmania, AUSTRALIA, 7001. Phone 002-32 5222 Fax 002-32 5000

$250 **A REWARD OF $250 WILL BE PAID FOR EACH ARCHIVAL TAG RETURNED** **$250**