OCEANIC FISHERIES PROGRAMME
PROGRAMME PÊCHE HAUTURIÈRE

Seven months in the life of a Pacific bigeye tuna

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Introduction:

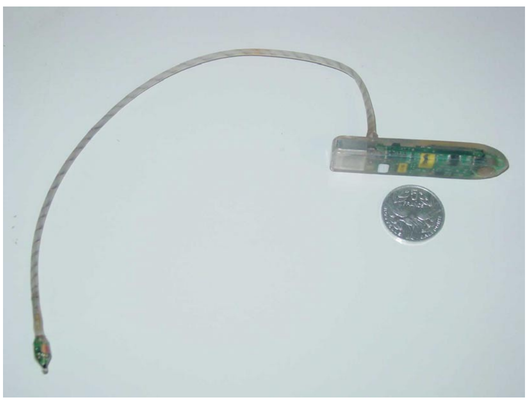
This article presents the initial results obtained through recovery of electronic tags placed in bigeye tuna (Thunnus obesus). This on-going study is being jointly conducted by SPC[i]/Noumea and CSIRO[ii]/Australia. The major part of the funding required has been provided by the European Community through the PROCFISH[iii] Project.

Archival tags, electronic spies

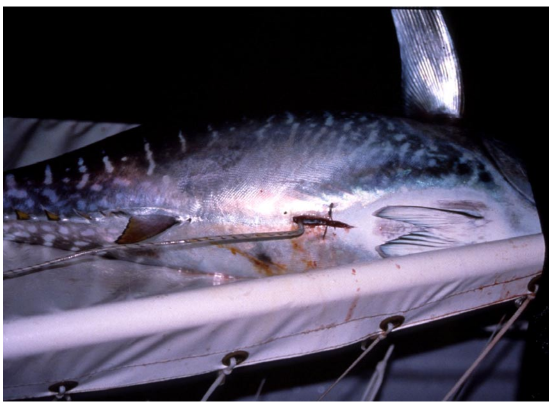
Up to now, conventional tagging has consisted of attaching numbered tags to the fish, releasing them into the wild and then waiting for them to caught again by fishermen. But as vital as the data collected in this way are, e.g. growth, migration, mortality, they do not give any indication of the fish's behaviour between the time it is tagged and the moment it is recaptured, e.g. the times of day it ate, the depths it swam at, etc.

Progress, particularly in the miniaturisation of electronic components, has made it possible to assemble several sensors linked to a data storage memory in a box the size of a cigarette lighter. This 'spy' is placed inside the tuna's stomach by means of a small surgical operation that does not affect the fish's everyday life. Once the fish has been released into the wild, the spy continues recording for several years the fish's temperature along with the water temperature, the depth and the intensity of the ambient light at a rate of several times an hour. Once the fish is caught again, the tag's memory can be downloaded into a computer and we can then see a slice of the life of a tuna in the ocean, information which has been secret up to now, e.g. the times of day it ate, the depths it swam at, its preferred swimming temperature, and the path it followed during all that time.

Due to their high market value, particularly on the Japanese market, bigeye tuna are subject to very heavy fishing pressure throughout the tropical Pacific. The information provided by these electronic tags will make it possible to better manage the future of this precious natural resource.



Electronic tag (or archival tag)



Tag inserted into the belly of the fish

Tagging

Since October 1999, 161 electronic tags have been placed inside the abdominal cavities of young bigeye tuna (Thunnus obesus) caught in the Coral Sea off the east coast of Australia.

The regular presence of banks of tuna at the surface was the reason why this zone was selected for tagging operations. In fact, the tuna caught must be in perfect condition in order to be able to support the surgical operation conducted during tagging. The price of the little marvels of technology that these electronic tags are does not allow us to take the risk of tagging a fish that has been damaged by a net or tired out by several hours on a longline.

So the fish are caught using hand lines after being attracted to the boat by bait and by sprinkling the surface of the water. The cooperation of commercial fishers is vital to the success of the operation both in regards to finding tuna banks (several boats intercommunicate in order to cover a large search area) and catching the fish.

Wherever possible, the hooks used to catch the fish do not have barbs so as to do the least damage possible. Once on board, the tuna is placed on a tagging table and a wet cloth is put over its eyes, as darkness calms the animal. An incision of about 2 to 3 centimetres is made with a scalpel across the abdominal wall to get to the peritoneal cavity. Care is taken not to damage any organs. The tag is then inserted into the fish's stomach, with the antenna holding the light and water temperature sensors left outside. The opening is closed with a stitch, the fish's size is recorded, and it is put right back into the water. The operation takes less than two minutes. During that time, the fish's behaviour is observed and if it shows any signs of weakness (change in colour, bleeding) the operation is abandoned. Scarring is very rapid and the incision closes within a few days. Its position is practically invisible 10 days later (according to observations made in captivity).

Australian longliner participating in the tagging campaign off the Great Barrier Reef

Tuna banks often include several species: here are a yellowfin tuna and a bigeye tuna (below)

The information obtained

A total of 12 archival tags have been recovered to date (January 2003); apart from one, they were all recovered by Australian longliners along the east coast of Australia at between 16 and 24 degrees of latitude. Unfortunately, breakdowns were noted in the first tags set, mainly due to the fact that bigeye tuna dive much deeper than had been expected. The recordings showed that tuna sometimes dive to depths of more than 1000 meters. Since the first versions of the tags were unable to resist the pressures at such depths, these tags stopped functioning. In certain cases, it was possible to recover the data stored before the breakdown, but the others were a total loss. The latest model of the tags has been redesigned to better resist such pressures.

Processing the data provided by the light level sensor made it possible to retrace the fish's general trajectory. The positions remain approximate, as the data processing mode, based on observation of the length of day and the times of sunset and sunrise, still needs some work. The fact that the light level sensor is attached to an animal which lives in an environment where the light level varies depending on depth does not make things any easier. In addition, sometimes the fish may remain for a certain period of time at depths where light is practically undetectable. The raw data was processed to smooth out plotting but errors persist and some positions situated the fish on land. It must be kept in mind that the latitude data are much less reliable than the longitude data.

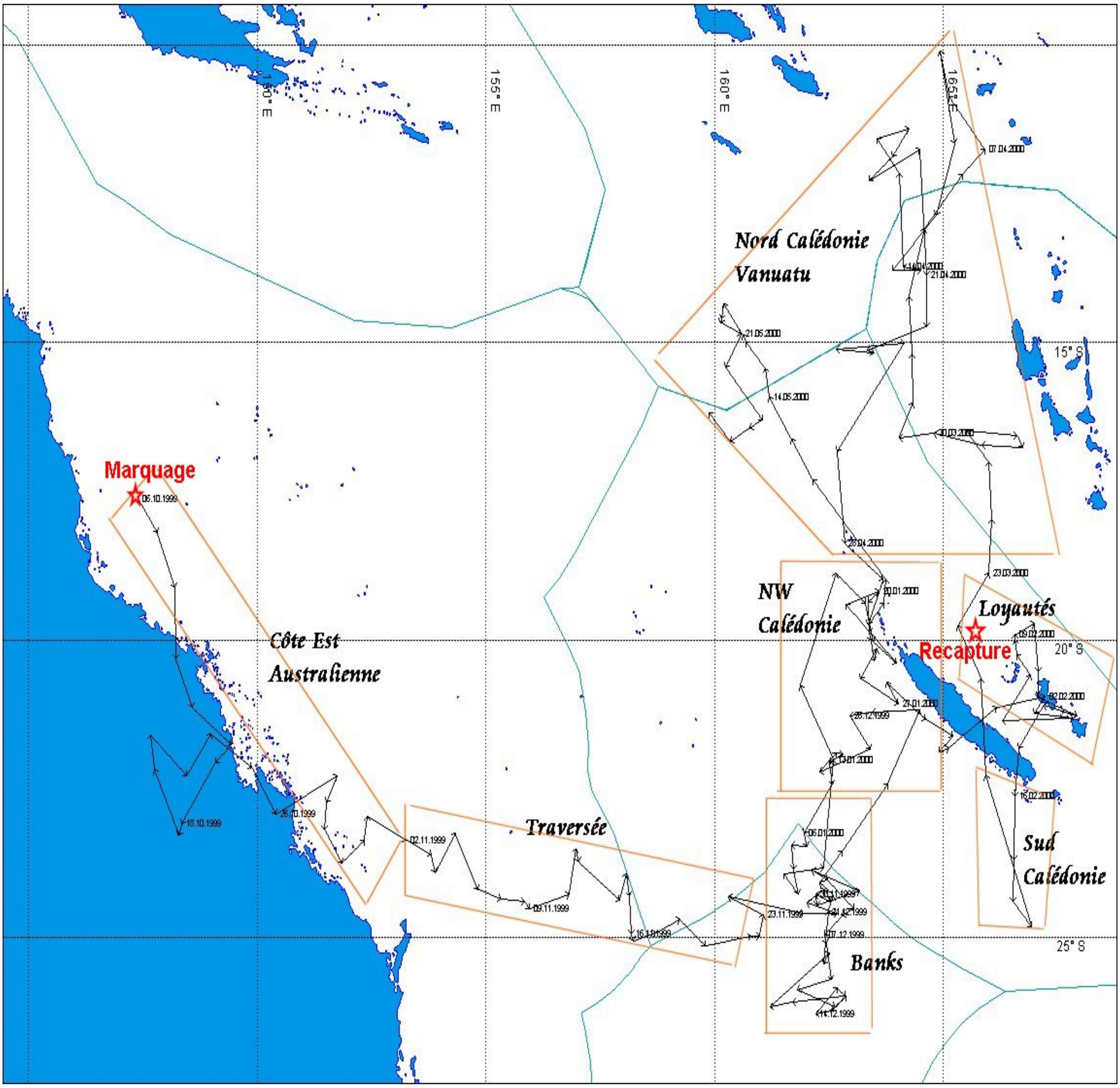
The tag recovered in New Caledonia

In this article, we present initial analysis of the data obtained from the recording in a tag recovered in the New Caledonia EEZ by a longliner from the company "Pêcheries de Nouvelle Calédonie", based in Koumac.

The tuna was tagged at a length of 80 cm on 6 October 1999 off the coast of Cairns, Australia and was caught the second time on 26 February 2002 about 150 miles north of New Caledonia (unfortunately the fish was not measured at that time). The tag only provided coherent data up to 26 May 2001, i.e. a little more than seven months of data.

Fish's trajectory (see map below)

The fish first swam south along the east coast of Australia, then in early November it migrated east between the 23rd and 25th parallels south. This crossing, which took about three weeks, ended at the 162 east meridian. The tuna then stayed 50 days in this area (called 'Banks' on the map), between 24 and 26 degrees latitude south, in depths of generally less than 1000 meters. The tuna then went through the zones 'NW New Caledonia', 'Loyalty Islands', Southern New Caledonia', to end up in the area 'Northern New Caledonia-Vanuatu'.

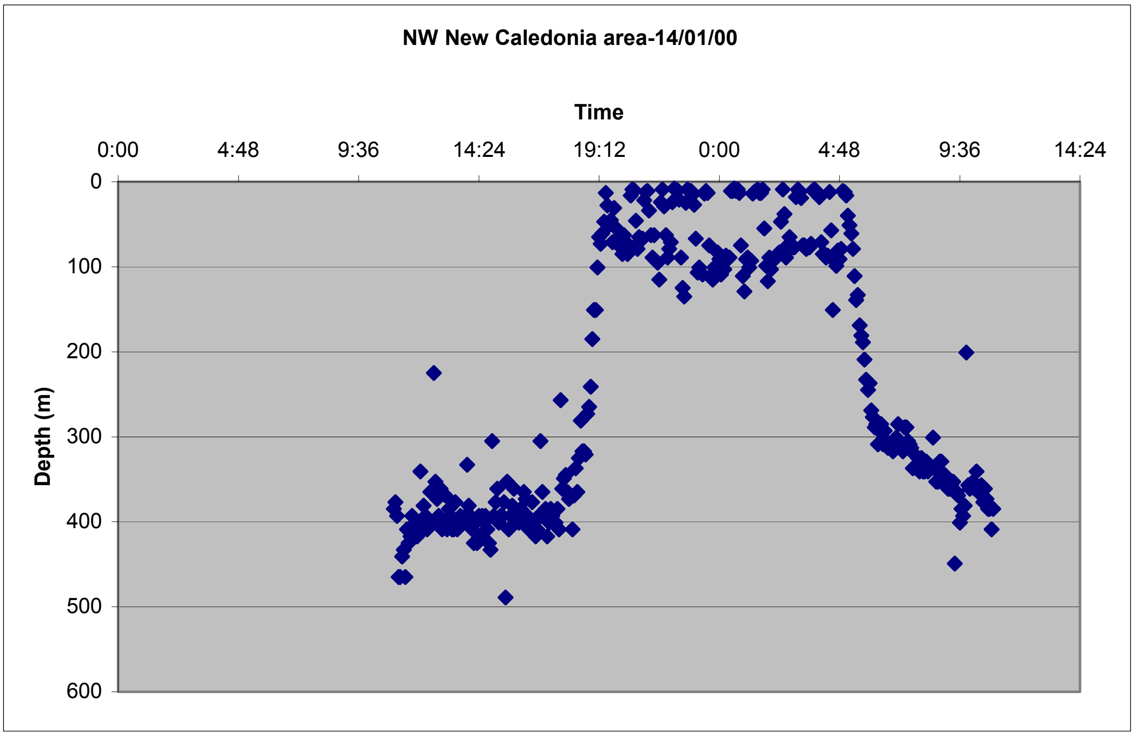


<u>Approximate</u> trajectory of the tagged tuna between 6 October 1999 and 26 May 2001

Analysis of temperature and depth data

The tag used its sensors to record data every four minutes and so it was possible to follow the fish's daily path through the column of water.

Nycthemeral migration is clearly shown here, as the fish spent nighttimes near the surface, at depths of between 0 and 100 m whereas during the daytime it was located at greater depths of between 350 and 400 m (the maximum depth recorded by the tag for this fish was 985 meters). Vertical migrations took place at daybreak toward the bottom and at end of the day towards the surface. The following figure gives the example of a 'regular' day for a bigeye tuna.

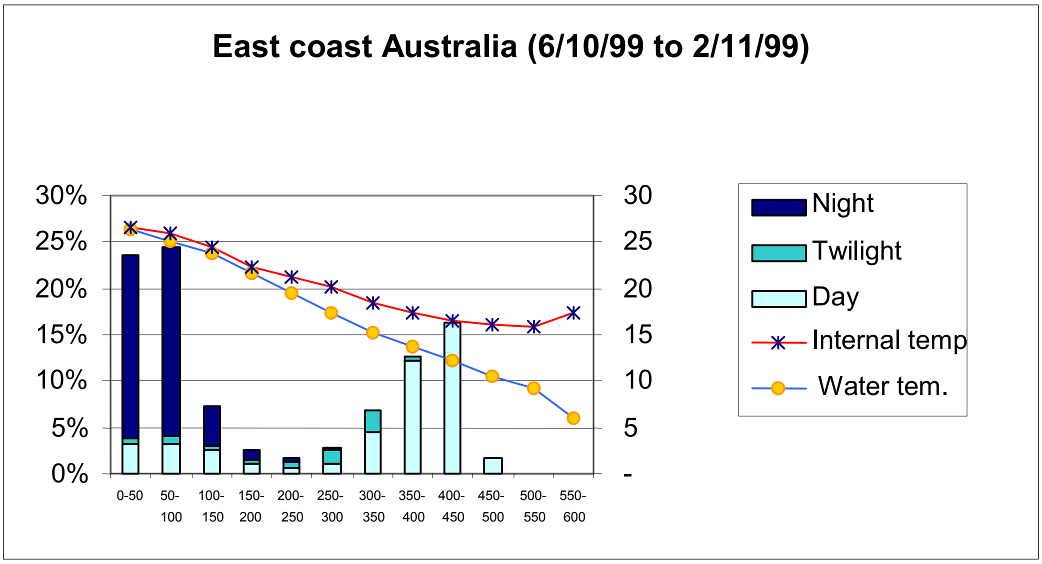


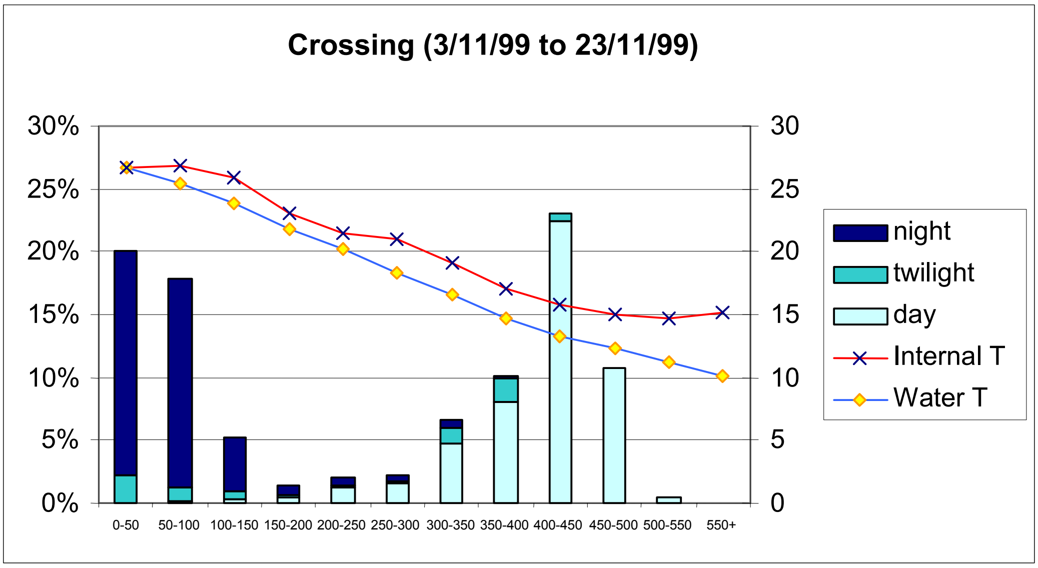
The following graphs (one per zone) show the percentage of time the tuna spent in each 50 meter band of the water column by day and by night. The 'twilight" periods are comprised by time intervals of one hour before sunrise and a half hour after plus a half-hour before sunset and one hour after.

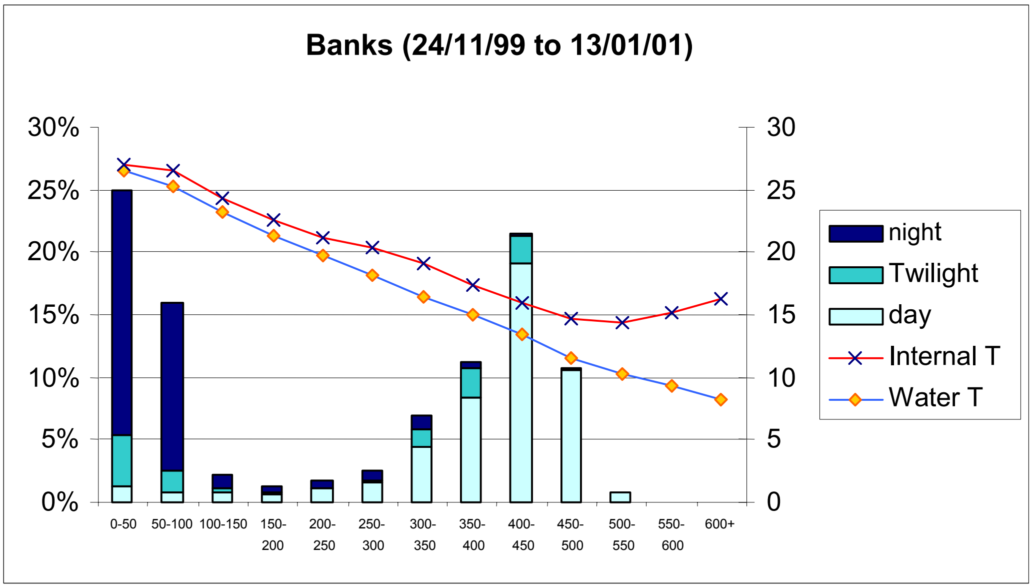
The graphs also show the mean temperatures of both ocean water and the fish for each depth range (temperature figures are given on the vertical axis on the right). This highlighted the process of thermoregulation which exists in tuna. It is clearly seen that for this specimen, its internal temperature paralleled the surrounding water temperature, but never went below about 14 degrees even when the fish was in water of 5 or 6 degrees.

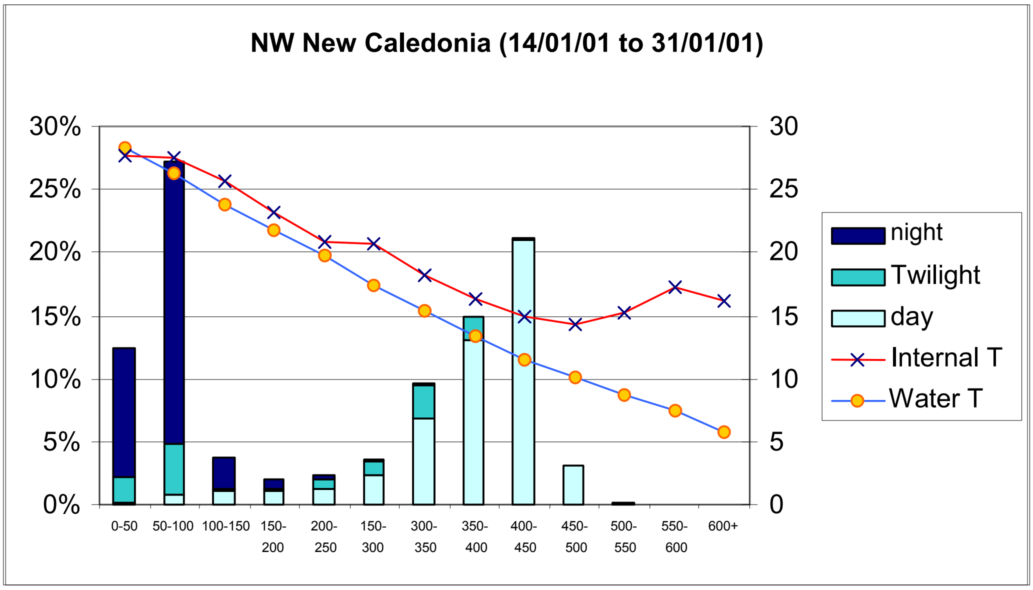
When we look at each graph more closely, some differences appear, which make it possible to suppose that the fish's behaviour varied depending on the zone where it was.

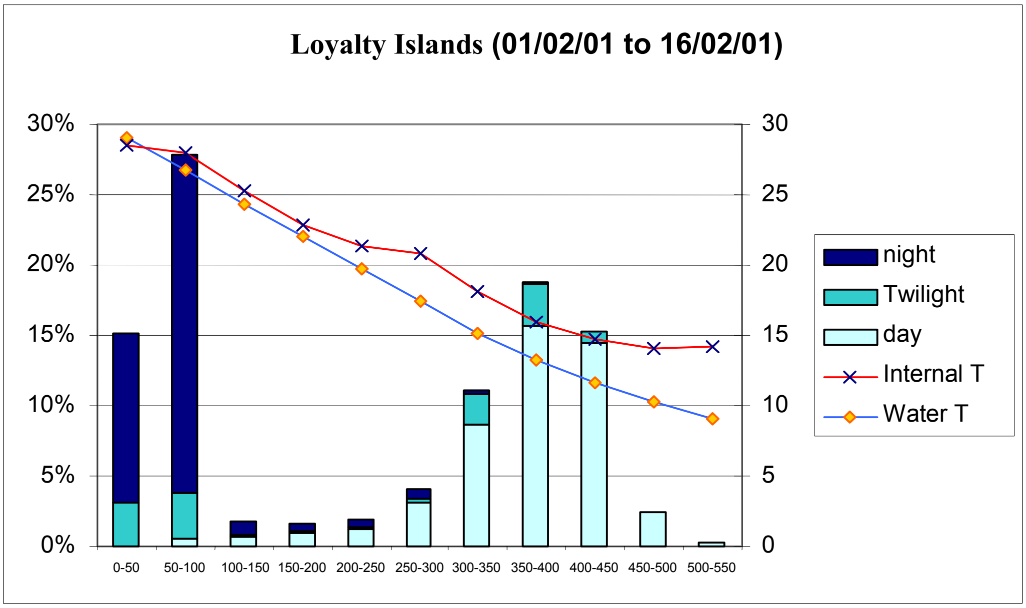
- On the Australian coast, the tuna spent more than half the time between 0 and 150 m, especially at night, but also during the day (9% of the day as compared to 2.6 to 4% in the other zones).
- In the most southerly zones (Crossing, Banks, Southern New Caledonia), the 0-50 m zone was preponderant in comparison to the 50-100 m zone, while the opposite was true in the most northerly zones (NW New Caledonia, Loyalty Islands, Northern New Caledonia-Vanuatu).
- In these same southern zones, the tuna was at greater depths during the daytime (between 11.2 and 6.3% at more than 450 m as compared to 3% in the northern zones).






Banks (24/11/99 to 13/01/01)
30%
25%
20%
15%
10%
5%
0%
30
25
20
15
10
5
0
0-50
50-100
100-150
150-200
200-250
250-300
300-350
350-400
400-450
450-500
500-550
550-600
600+
night
Twilight
day
Internal T
Water T


NW New Caledonia (14/01/01 to 31/01/01)
30%
25%
20%
15%
10%
5%
0%
30
25
20
15
10
5
0
0-50
50-100
100-150
150-200
200-250
150-300
300-350
350-400
400-450
450-500
500-550
550-600
600+
night
Twilight
day
Internal T
Water T


Loyalty Islands (01/02/01 to 16/02/01)
30%
25%
20%
15%
10%
5%
0%
30
25
20
15
10
5
0
0-50
50-100
100-150
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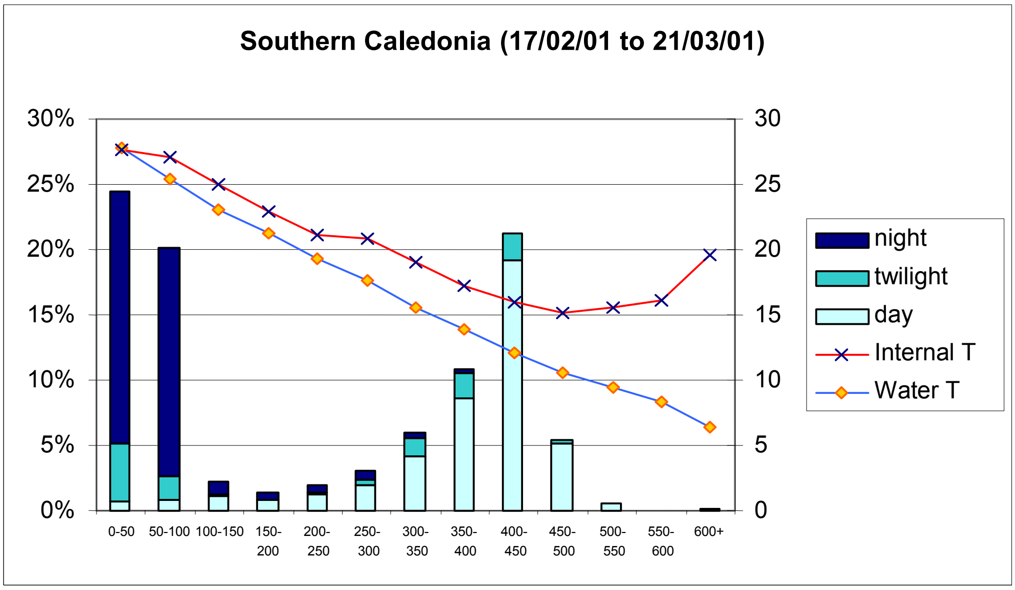
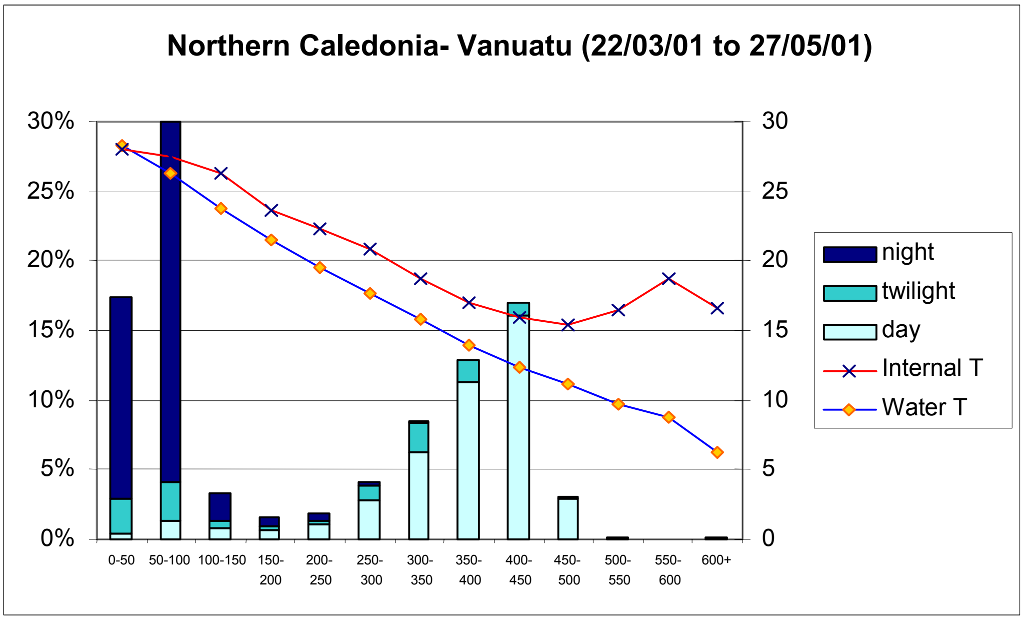
Twilight
day
Internal T
Water T

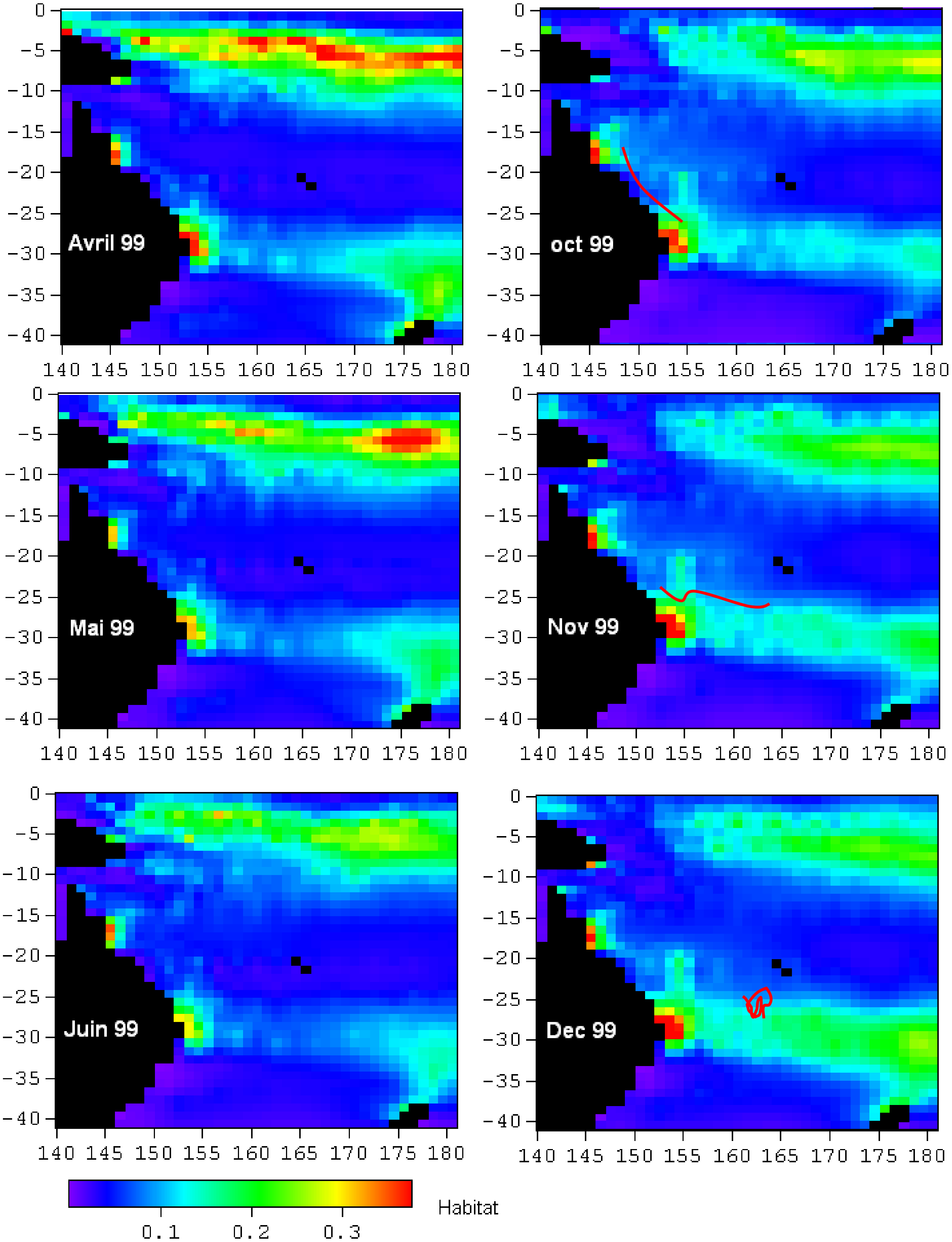




Reasons for migration

The main reason that tuna travel is to find food. The existence of environmental databases (water temperature, currents, weather, phytoplankton concentrations, etc.) made it possible to develop secondary production prediction models (as the animals that eat the phytoplankton are themselves the primary production). As they form the first link in the food chain on which these tuna feed, models can predict a scale of probably for the fish's presence.

The following example shows habitat distributions favourable to tuna calculated from temperature and prey biomass concentrations (predicted by the SEPODYM model developed by SPC). It is interesting to note that during the final quarter of the year, a seasonal increase in prey combines with warming of the water to provide a favourable habitat route between Australia and southern New Caledonia. The route does in fact seem to correspond to the path taken by the tuna which disappeared in the cold season (2nd and 3rd quarters).



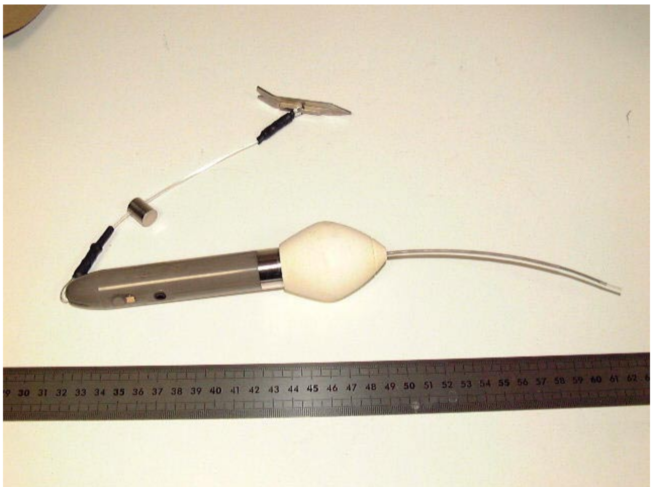
Mean monthly distributions of the tuna habitats predicted by the SEPODYM model developed by the SPC's Oceanic Fisheries Programme (resolution of one square degree) during 2nd and 4th quarters 1999. The tagged tuna's approximate trajectory is shown by a red line.

Conclusion

These archival tags provide a lot of new information on tuna behaviour. This knowledge should allow us to better grasp their distribution and migrations. These data are vital for improving the mathematical models developed to describe the of tuna population dynamics in relationship to their environment. Such models make it possible to predict changes in these populations and so better manage tuna resources.

Future projects

Tagging campaigns are planned in the region beginning in March 2003. Internal archival tags and satellite archival tags will be placed on bigeye and yellow-finned tuna. The satellite tags record the same information as the internal tags but the fish does not have to be caught again in order to collect the stored information. In fact, the satellite tag has a mechanism which allows it to detach itself from the fish after an adjustable lapse of time (between one day and one year). Once it has detached, the tag floats to the surface and transmits the stored data to a satellite (Argos system) which then retransmits them to a land-based processing centre. The information can then be sent by e-mail to the person who placed the tag. This marvellous technology is limited by the tags' cost and their relatively large size which only allows them to be placed on tuna that are big enough to support them (>40 kg).



Satellite tag

Reward/what to do if you catch a tagged fish

1. Internal archival tag

Fish that have tags in their abdominal cavities normally also have conventional yellow or orange ‘spaghetti’ type tags clipped to the second dorsal fin. The tag’s external antenna can, in any case, be easily spotted as it sticks out the fish’s ventral wall. Be extremely careful not to pull on it and take a few precautions when you gut the fish so as not to accidentally stab the tag with your knife. Wash and dry it and then keep it dry. It is important to record the fish’s size (even approximate) and, if possible, its sex (eggs or milt?) As it would be interesting to know how well the fish supported the tag, put a piece of rope around its tail to identify it so that it can be photographed at landing.
Finally note down the date and position of capture.
The addresses and phone number of the people to be contacted are marked on the tag.

2. Satellite archival tag

A tagged tuna may be caught before the date the satellite beacon was to be released. In that case, recover the beacon with its anchor. This is normally inserted through the base of the second dorsal fin and you will probably have to remove that fin.
Do not worry about the damage done to the fish as top price will be paid for it by those who tagged it.
Note down the same information as for the internal tags and contact those responsible as soon as possible to inform them that you have recovered the beacon.

Contact: Bruno Leroy, SPC, BP D5, 98848 Noumea Cedex, New Caledonia
Telephone: +687 262000 Fax +687 263818

There is a large reward: US$ 250

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[i] SPC: Secretariat of the Pacific Community, Noumea, New Caledonia
[ii] Commonwealth Scientific & Industrial Research Organisation, Marine Research Division, Hobart, Tasmania
[iii] Pacific Regional Oceanic and Coastal Fisheries Project funded by the European Union