BEHAVIOUR OF YELLOWFIN (Thunnus albacares) AND SKIPJACK TUNA (Katsuwonus pelamis) AROUND FADs AS DETERMINED BY SONIC TAGGING

BY

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SUMMARY

The Regional Tuna Project of the Indian Ocean Commission, includes a Sonic Tagging Programme. The results of the sonic tracking of 3 yellowfin tuna and 5 skipjack in Comoros Islands are presented.

The vertical swimming behaviour observed within an area with a deep and slightly marked thermocline, are analyzed in terms of percentage of the time spent at different depths or temperatures during the day and night. The results agree well with previous experiences in other oceans.

The sonic tagging also indicates a short residence time of tunas concentrated by the DCP moored in the area. An important turnover of fish joined to an important migratory flow through that area, appear to characterise the concentrations of tunas exploited around the FAD.

As far as the actual fishing pattern (artisanal fishery) is concerned, it seems that an increase in the number of FADs will be limited by the local market possibilities.

I. INTRODUCTION

The COI (Commission de l'Ocean Indien), with its Regional Tuna Project conducted within the frame of the "Association Thonière", was aware of the necessity for its member countries (Comoros Islands, Reunion Island, Madagascar, Mauritius and Seychelles) to develop simultaneously:

- their own capacity for fishing tunas;
- the knowledge of these species through diverse technical and scientific operations;
- the assessment of existing fisheries.

The artisanal fishery for pelagic fish such as tunas, is of great importance for the food consumption of the Comorian population. The experiments of Fish Aggregating Devices (FADs) were undertaken to try to implement the fishing efficiency of local fishermen for tunas with some apparent success (see Cayŕe *et.al.*, this Symposium). The conclusive results of different tracking experiments of tunas tagged with ultrasonic transmitters (Yuen, 1970; Carey and Olson, 1982; Cayré and Chabanne, 1985; Holland and Brill, 1989) induced the use of this technique to assess the behaviour of tuna in this particular area of Comoros Islands where 9 FADs were anchored around the Anjouan Island (Fig. 1).

It is of particular interest to evaluate the different effects on the localized (horizontal and vertical) movements of yellowfin and skipjack tuna due to:

- the deployment of several FADs in the area;
- the oceanographic conditions;
- the considered period within a 24 hour cycle of one day.

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For this purpose 3 trips at sea were undertaken during 1989 in the vicinity of Anjouan, one of the Comoros Islands, which made it possible to tag and to track 9 fish; the results of these experiments are documented and discussed in this report.

1. METHODS

The sonic tagging experiments. were performed in 1989 during 3 trips at sea aboard the "M'HADANA", a small 13 m long vessel of the National Fishing School of Anjouan.

Sonic Tracking Equipment

All the tracking equipment was built by VEMCO Armdale,* Canada. The transmitters, both pressure and temperature were cylindrical and measured 75 mm in length by 15 mm diameter.

Each tag transmitted a signal with a unique frequency comprised between 50 and 80 KHz; the pulse frequency of a signal was proportional to pressure or temperature, was received through a directional hydropone and decoded aboard the vessel by a VR–60 receiver/decoder unit. The receiver had a storage memory and was equipped with software to store the data and later transfer them to an external computer. During these experiments the data (depth on temperature) were logged every 5 or 20 seconds with a corresponding time reference counted by the decoder. The time between pulses was translated in depth on temperature unit following the calibration data of the transmitter in use. The power supply of the unit was given by an external 12V DC battery without any connection to the ship's electrical system to avoid interference.

The directional hydrophone was attached to the lower end of a pipe fixed on the side of the boat, and was fixed slightly deeper than the keel of the boat.

The whole installation of the tracking material was made in a way similar to the one described by Holland *et. al* (1985). The small size of the ship allowed the directional hydrophone to be fixed pointed to the fore part of the vessel: searching the best orientation of the hydrophone as to get the highest signal level from the sonic tag and the direction of the tracked fish was then established by orientating the boat.

Capture and Tagging

The fish (skipjack or yellowfin tuna) were caught by trolling lines baited with artificial lures equipped with hooks with their barbs removed; this was done so as not to injure the fish and to facilitate the unhooking operation. The fish to be tagged was then placed in a "V" shaped graduated craddle, covered with artificial sponge (kept wet) for softness.

The head of the fish was covered with a wet towel. Fish was measured (fork length) and the sonic tag was attached on to its back, just after the second dorsal fin, with two nylon tie-wraps. The fish was then released at sea and the tracking began. The whole tagging operation (fish out of the sea) lasted between 45 seconds and 1.5 minutes depending upon the fish. Yellowfin were always much more quiet than skipjack.

* Reference to trade names does not imply endorsement by any Service or Organization cited as ORSTOM, COI, Association Thoniere.

Tracking

The receiver/decoder unit was placed in the piloting cabin; one person was piloting the boat to track the fish by keeping the highest signal level given by the receiver; another person was in charge to survey the unit and to note observations such as the detection of other fish with the echosounder and the position of the boat which was determined every 30 minutes using a radar and landmarks. These positions were taken as positions of the fish itself. The information given by the tracking unit (temperature or depth) was stored in the internal memory of the unit every 5 or 20 seconds.

We chose not to track fish longer than 24 hours, giving preference to tracking a larger number of fish instead of tracking a few fish for longer than 24 hours.

Environmental Observations

Aboard the "M'HADANA", the sea temperature, just before or after a tracking operation was taken every 10 meters until a depth between 200 and 300 meters was reached. Two transmitter (one pressure + one temperature) attached together to the end of a line dropped from the bow of the vessel for this operation. Four temperature v.s. depth profiles were obtained (Figs. 2, A to D).

Moreover we obtained through Mr. MARSAC, from ORSTOM Laboratory in Réunion Island, mean temperature profiles calculated for the second (Fig. 3A) and fourth quarter (Fig. 3B) in an area located between 10°S and 15°S/40°E and 45°E. The data used for calculating the mean sea temperature profiles were extracted from the TOGA (Tropical Ocean and Global Atmosphere Centre, ORSTOM–IFREMER, Brest, France) database. The data used for establishing the mean oxygen profile were extracted from the French BNDO (National Bank of Oceanic Data, IFREMER, Brest).

In order to know more about the swimming depth a computer programme was written which permitted the calculation of the percentage of the time spent at different depth layers of 10 meters recorded when a pressure transmitter was used, or at different temperatures counted by 1°C noted by a temperature transmitter. These percentages were calculated for daytime, from sunrise (5.15 am) to sunset (6.15 pm) and at night (6.15 pm to 5.15 am)

2. RESULTS

Nine fish (6 skipjack and 3 yellowfin tuna) were tracked. One skipjack track was not considered because it was too short (55 minutes) and the tagged fish was sinking during the whole track giving evidence that it was dying. The summary results of tracks for the 5 skipjack and 3 yellowfin considered are given in Table 1.

The detections of tunas logged with an echo-sounder (depth and time) when compared with the recorded swimming depths of the fish tagged with depth transmitters (fish no. 1, 3, 4, 6, 8), show tracked fishes were schooling. Thus it can be expected that the observations and behaviour obtained from the sonic tagging operations reflect the behaviour of the "free" skipjack and yellowfin tuna.

Horizontal movements

Figs. 4(a) to 4(f) show the small-scale movements of the tracked fish on a horizontal plain. No figures were drawn for fish no. 1 (skipjack, FL = 41 cm) and no. 6 (yellowfin, FL = 73 cm) because their movements were included in an area of which the surface was less than 2 miles^2. The yellowfin (fish no. 6) was tagged close by the FAD number 2 (Fig. 1) and remained close to that FAD (distance < 300m) during all the time it was tracked (i.e. 13.07 hours); however no signal from this fish could be detected when the boat came back in the following 2 mornings to search for it. The two other fish (fish no. 4 and 8) tagged close to a FAD (less than 1 mile, Fig. 4d and 4f) did not remain near their FAD contrary to what was observed for fish no. 6 described above.

From all these observations and with the exception of fish no. 4 (yellowfin, 105 cm; Fig. 4f it appears Fig. 4a to 4e) that the fish neither remain near the DCP after tagging (fish no. 6, 8, 4) nor return to that DCP or migrate from one DCP to another (fish no. 1, 2, 3, 5, 7) inspite of the presence of several DCP in the area at time of tracking.

This somewhat contradicts the homing behaviour observed in other sonic tracking experiments (Holland *et.al.*, 1985, Cayré et Chabanne, 1986). But this observation is consistent with the fact that during a classic tagging cruise which took place in Comoros Islands area in January 1989, 111 tunas, mainly bigeye and yellowfin were tagged and released within a single operation, near a FAD; none was recaptured though a significant fishing effort was applied in the area (see Cayré *et.al.*, this Symposium) and good publicity plus a substantial reward (16$ by recovered tag) supported this tagging operation.

Thus the Comorian area, which is located in the northern part of the Mozambic Channel, appears to be a place where migrating tunas pass by without stopping for a significant period of time. This observation should be confirmed by some additional tracking experiments and classic tagging conducted during the peak fishing season (January, February).

The mean swimming speed (from 1.2 knots to 4 knots, Table 1) counted as the total distance made during tracks divided by total duration of tracks, is within the range of what was observed from other sonic tracking experiments conducted on the same species in other oceans (Yuen, 1970; Carey and Olson, 1982; Cayre et Chabanne, 1986).

Vertical Movements

Yellowfin tuna:

The depth records obtained for 3 yellowfin tagged with depth transmitters (fish no. 3, 4, 7, Table 1) which appear in Fig. 5, show when superimposed, a remarkable likeness in the swimming behaviour vs. depth and time of the day. This fact together with the observed schooling behaviour of tagged fish just after release at sea, again tends to reinforce the fact that the observations deduced from sonic tracking experiments are not biased.

The raw depth records (Fig. 5) for the 3 yellowfin tuna and the Figure showing the frequency of time spent at different depths during the night (Fig. 6) and during the day-time (Fig. 7) show that swimming depths are greater during the day time (mostly between 70 m and 110 m), than during the night (mostly between 40 m and 70 m). These presence of these 3 yellowfin were very seldom near the surface during the day: from 0 to 3 % of the time (Fig. 7), and more frequently at night though quite variable from one fish (0 %, fish no. 4; Fig. 6) to the other (15 %, fish no. 3).

Actually, local fishermen who use handlines and baited hooks to catch yellowfin, generally remain by the coast, while trolling canoes exploit the DCP area in the morning (from sunrise to 10 am) and in the late afternoon (from 4 pm to sunset). The differences observed above in mean swimming depths during day and night (Fig. 8), could allow the fishermen using handlines to exploit the DCP area and deep water layers (70–100) during the day.

Figs. 9 and 10 represent the frequency of the time spent during the daytime at each class of seawater temperature after an observed temperature (Fig. 2) has been allocated to each 10 meters of the depth layer. The swimming depths observed during most part of the day appear to be located in the upper part of the thermocline (Figs. 2 and 3), while during the night the most frequent swimming depth is situated in the warm mixed layer (temperature) > 26°C, Fig. 9).

Skipjack tuna

Two skipjack were tagged with depth transmitters (fish no. 1 and 8, Table 1); the percentage of the time spent at different depth at night and during the day (fish no. 1 and 8, Figs 11 and 12), show that deeper water layers are visited at night. These incursions into deeper layers were especially undertaken during the first half of the night (Fig. 13). From Figs. 11 and 12, it appears that the percentage of the time spent in the 0–20 m layer is important especially during the daytime (approx. 20% of the time); much more important than was observed for yellowfin tuna.

The skipjack tagged with temperature transmitters (fish no. 2, 5 and 7), and the transformation of depth in temperature unit for fish no. 1 and 8 tracked with depth transmitters, permit the assessment of behaviour vs temperature. Though there is an important variability among individuals, the temperature mostly encountered during the night (Fig. 14) seems slightly inferior to that encountered during the day (Fig. 15). This reflects the nightly deep dives observed.

3. DISCUSSION

Horizontal movements

The observed absence of homing to FADs or apparent absence of movements from one FAD to another, seems to contradict previous studies which noted a kind of homing behaviour of tunas around FADs (Holland *et.al.*, 1985; Cayré et Chabanne, 1986) or natural banks (Yuen, 1970; Carey and Robinson, 1981; Carey and Olson, 1982; Levenez, 1982). An important turnover of fishes in the concentrations harvested around FADs by local fishermen and the fairly improved catches due to FAD attractive effect (Cayré *et.al.,* this Symposium), could be both possible if there is an important migratory flow through the Comoros Islands area. This has to be confirmed by additional tracking experiments and classic tagging conducted within the peak fishing season (January–February). Moreover, the short time of residence near FADs could be due to the fact that the available food within the FAD area is overexploited by so many concentrated tunas; even if some taxonomic groups (such as mysidacae) could become a prey for tunas only in the area of FADs (Brock, 1985).

Vertical Movements

As in previous studies (Yuen, 1970; Cayré et Chabanne, 1986), an increase in the activity of fishes occuring just before sunset was noted. This activity and the observed swimming habits in the upper layer (i.e. the mixed layer) can be explained as an active foraging activity.

The difference between the swimming depths mostly encountered by yellowfin during the day (70–110m) and at night (40–70m) is quite consistent with similar observations made in the Pacific Ocean (Carey and Olson, 1982; Holland *et.al.*, 1985; Cayre et Chanbanne, 1986). As Yuen (1970), it is important to note that the percentage of time spent by tunas near the surface was small. This leads to the question of evaluation of abundance by aerial survey and visual observation of schools on the surface.

Anyway, the percentage of time spent by skipjack near the surface, appears to be more important than for yellowfin. Without making any hypothesis on the relative abundance of both species, this fact could lead to a higher vulnerability of skipjack to the surface gears, as shown by the higher catches of skipjack than of yellowfin.

The relation between swimming depths and thermal structure observed in these experiments is similar to the observations made by Carey and Olson, 1982; according to which the yellowfin tuna "may spend a major portion of the day in the sharp temperature gradient of the thermocline" and move to the top of the thermocline after sunset.

In the area where our experiments took place oxygen concentration did not seem to be a limiting factor in the swimming depth of either yellowfin or skipjack. The minimum value of oxygen concentration (3.2 to 3.4 ml/1) which occurred at 200m (Fig. 2) was well over the lethal limit for both species.

Yellowfin tuna are able to maintain arterial oxygen delivery until oxygen concentration as low as 2.1 mg/1, although they are sensitive (decreasing of heart rate) to reduce ambient oxygen value as high as 4.0 mg O_2/l (Bill and Bushnell, 1989). Skipjack appears to be as sensitive as yellowfin tuna but reduced arterial oxygen delivery was observed from oxygen concentration of 3.8 mg/l (Brill and Bushnell, 1989). Thus skipjack tuna "will not be able to survive long even at modest reductions in ambient oxygen (3.6 mg O_2/l); in fact we observed the time spent by skipjack at depths over 150m (3.5 ml/1) during our tracking, was very short and rare (Figs. 11 and 12).

4. CONCLUSION

The results obtained with sonic tracking method in Comoros Islands, generally appears to agree well with what was observed elsewhere. They tend to indicate that the Comoros Islands area is a place where an important migratory flow of tunas passes by. Except for this important and characteristic feature of the area, it could be expected that the results obtained on vertical swimming behaviours could be extrapolated to other areas of the Indian Ocean and could be used to evaluate the tuna resources.

The substantial turnover of fish around FADs and an important migratory flow lead to the hypothesis that the recruitment rate to Comoros FADs depends on an important part of the whole yellowfin and skipjack population. Following this hypothesis and taking into account the absence of industrial fishing of tunas in Comoros waters, there is little chance to see the number of fish by FADs decreasing as the number of FADs increases, following the results of Hilborn and Medley (1989). It seems that the maximum number of FADs which can be moored around Comoros Islands will be limited much more by the strong currents in some places which make it impossible to settle any FADs and the cost of the FADs relative to the local market possibilities to absorb the landings.

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Table 1 : Summary of tracking: species (SJ = Skipjack, YF = Yellowfin), date, time, location and duration. (*) the distance travelled (or the speed) was too short to be calculated.

No.	1	2	3	4	5	6	7	8
Type of transmitter	Depth	Temp.	Depth	Depth	Temp.	Depth	Temp.	Depth
Species	SJ	SJ	YF	YF	SJ	YF	SJ	SJ
Length (FL)	41 cm	48 cm	80 cm	105 cm	52 cm	73 cm	52 cm	51 cm
Tagging: Date	04/16/89	04/16/89	04/18/89	05/14/89	05/16/89	05/17/89	11/11/89	11/04/89
Time (TU+3)	09.23	17.45	13.05	06.06	07.28	06.18	16.47	16.15
Position	12°01,4S 44°14,5E	12°15,6S 44°10,4E	12°07,8S 44°25,6E	12°06,2S 44°20,6E	11°59,0S 44°17,2E	12°06,8S 44°20,9E	11°58,6S 44°18,0E	12°56,7S 44°17,1E
Duration of the track	02h37	14h00	22h00	24h04	09h32	13h07	24h08	17h00
Distance travelled	04 miles	34 miles	89 miles	38 miles	13 miles	*	28 miles	27 miles
Mean speed (knots)	*	2.4	4.	1.6	1.4	*	1.2	1.6

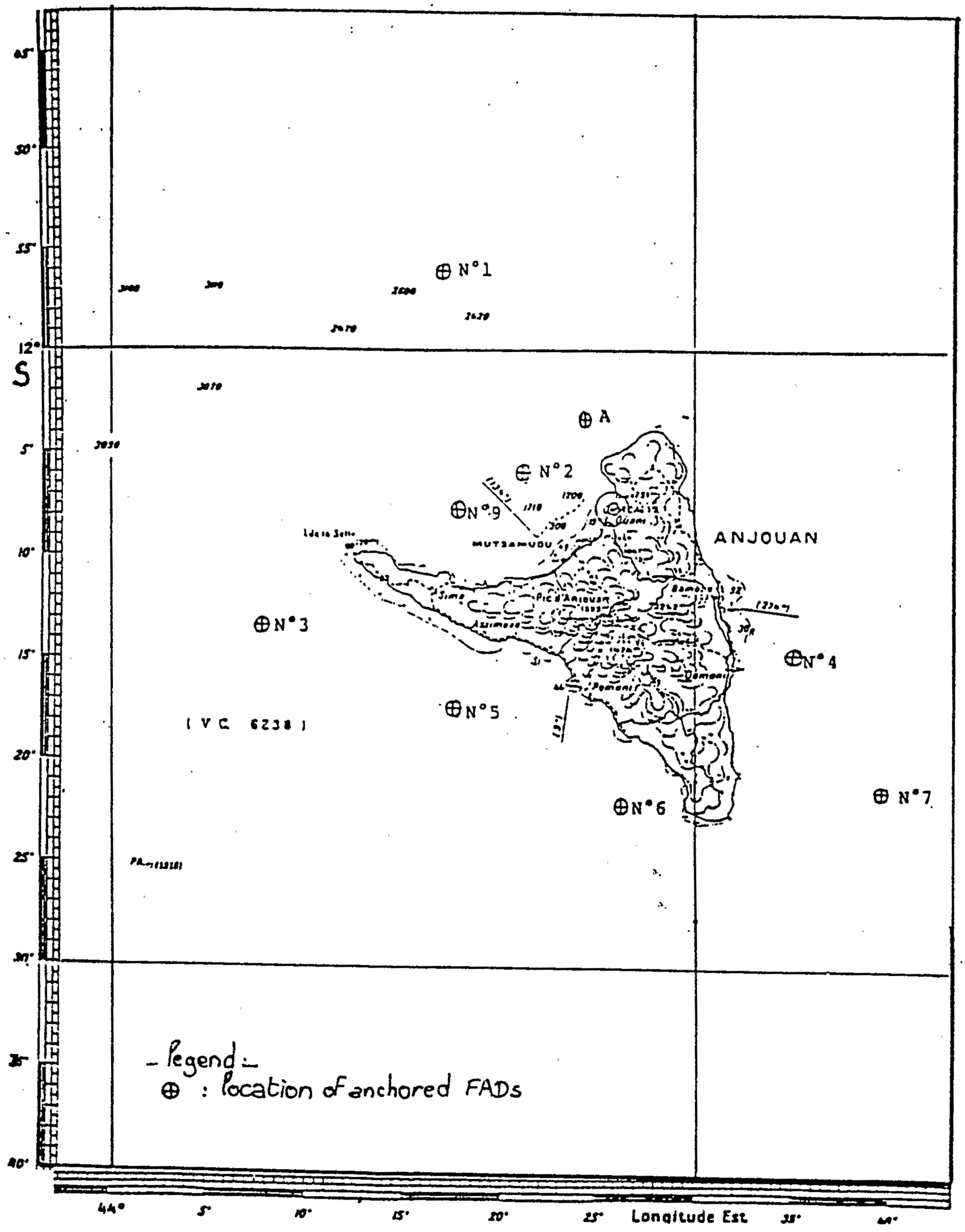

Figure 1. Location of Anjouan Island (Comoros), where the sonic tagging experiments took place; locations of the 9 moored FADs are also indicated.

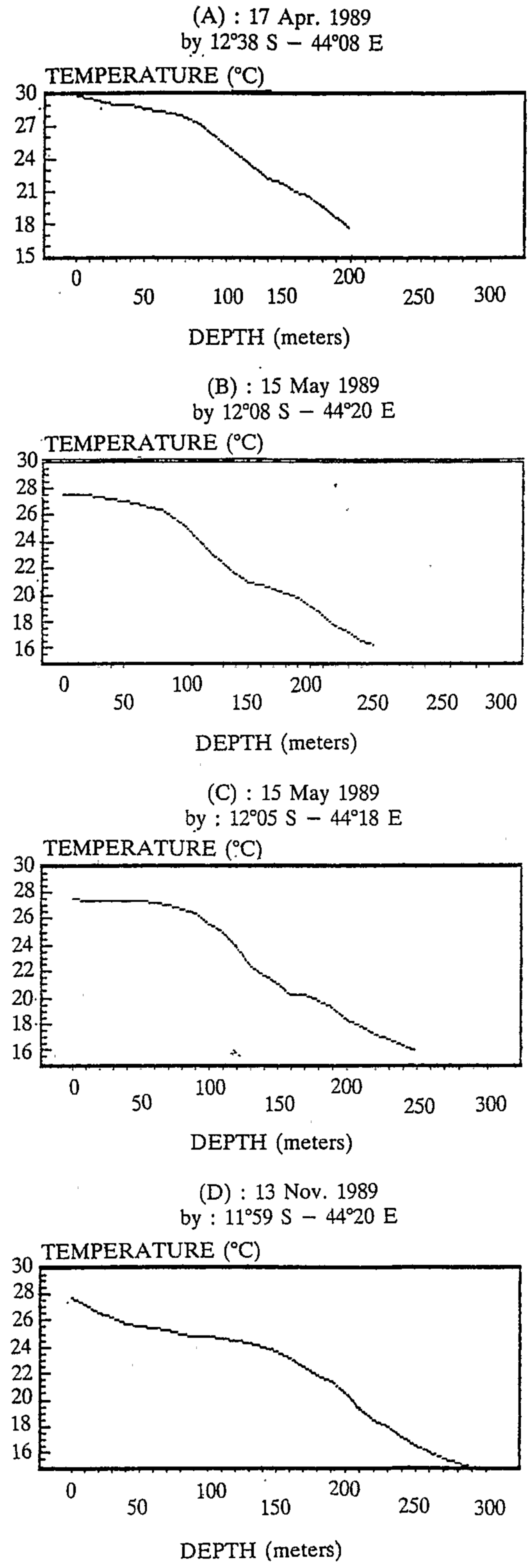

Figure 2. Diagram of sea water temperature from observations made.

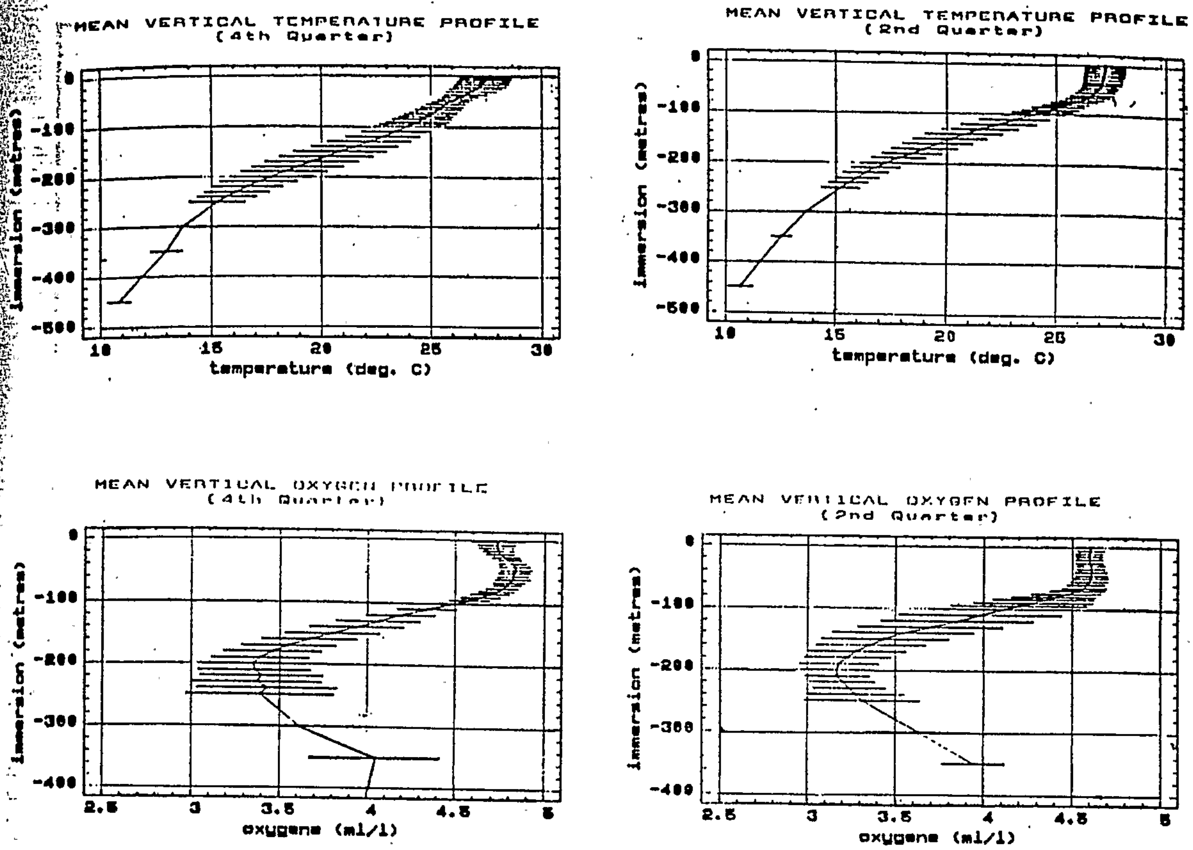

Figure 3. **Mean temperature and oxygen profiles for the 2nd and 4th Quarter in the area located between 10° South and 15° South, and between 40° East and 45° East. Data extracted from TOGA and BNDO data bases (ORSTOM-IFREMER, Brest).**

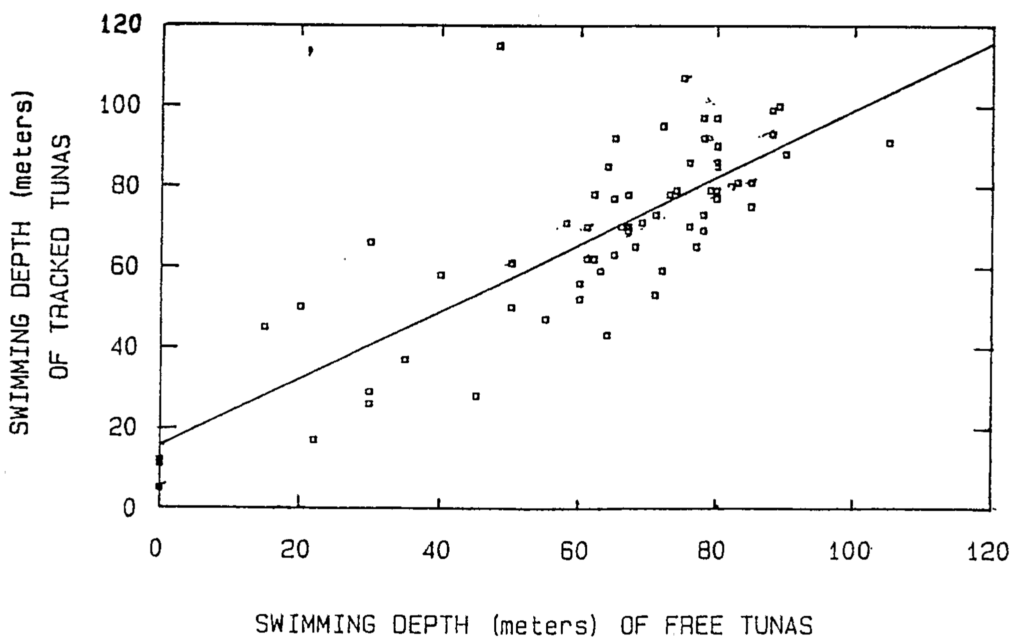

Figure 4. **Relationship (regression) between the simultaneously recorded swimming depths of tracked tunas and free tunas schools (as measured by echo sounder).**

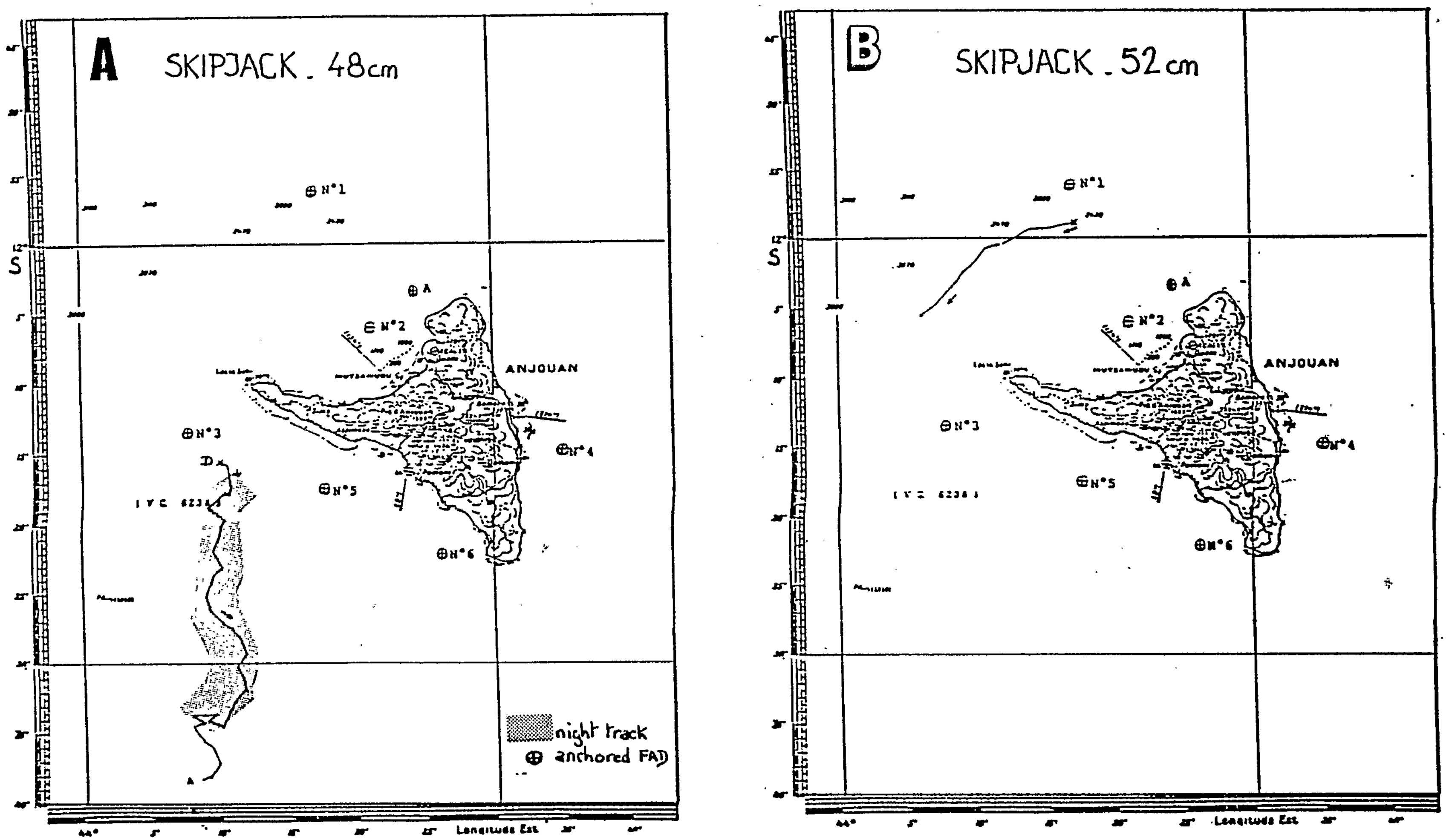

Figure 4. Tracks of tagged skipjacks (A to D) and Yellowfin tunas (E and F). Date and duration of the tracks:
(A) April 16th – 14 hours, (B) May 16 – 9.30 hours.
(see table 1 for detailed iinformation on the tracks)

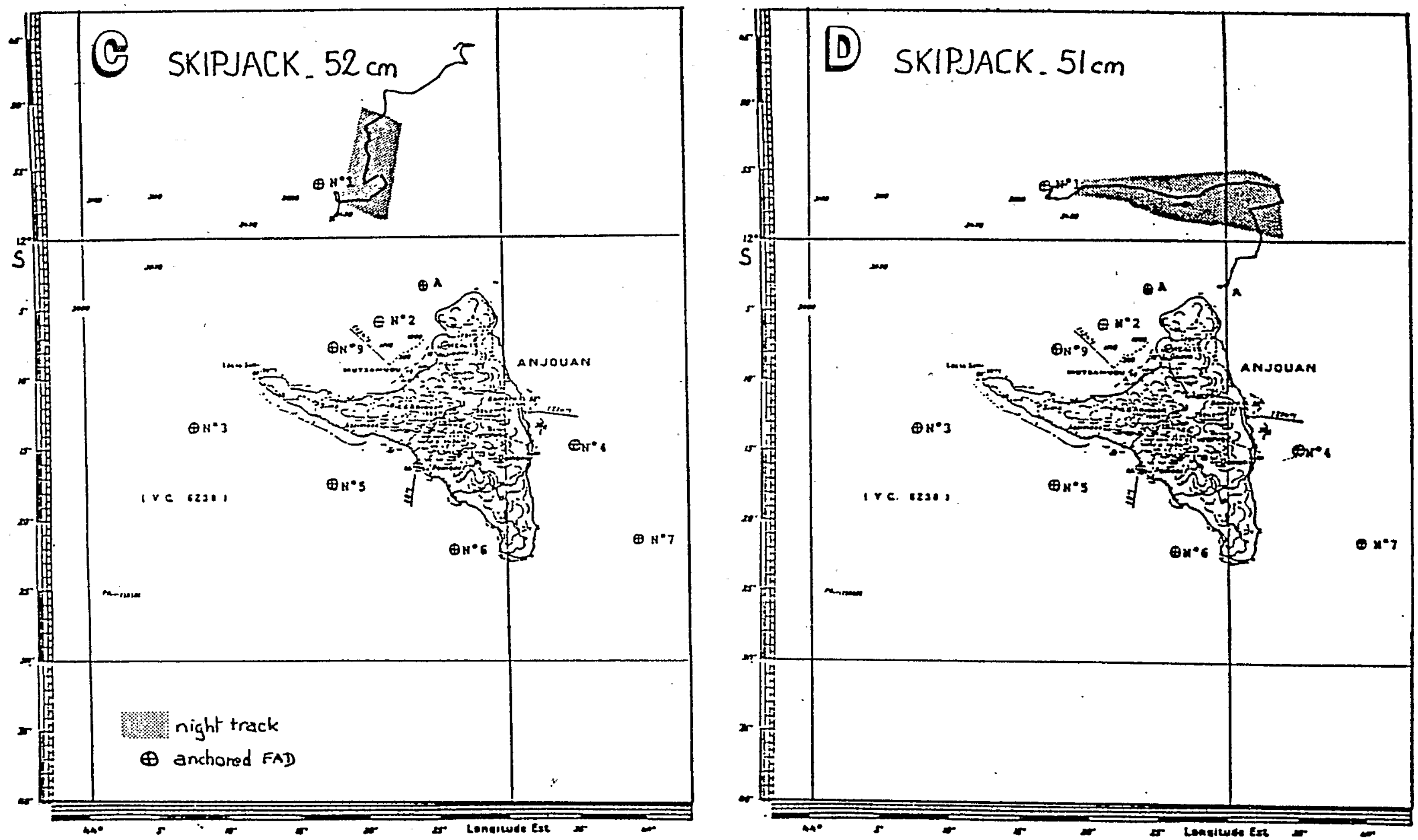

Figure 4. Continued
Date and duration of the tracks:
(C) November 16th −24.10 hours, (D) November 13th − 17 hours.
(see table 1 for detailed information on the tracks)

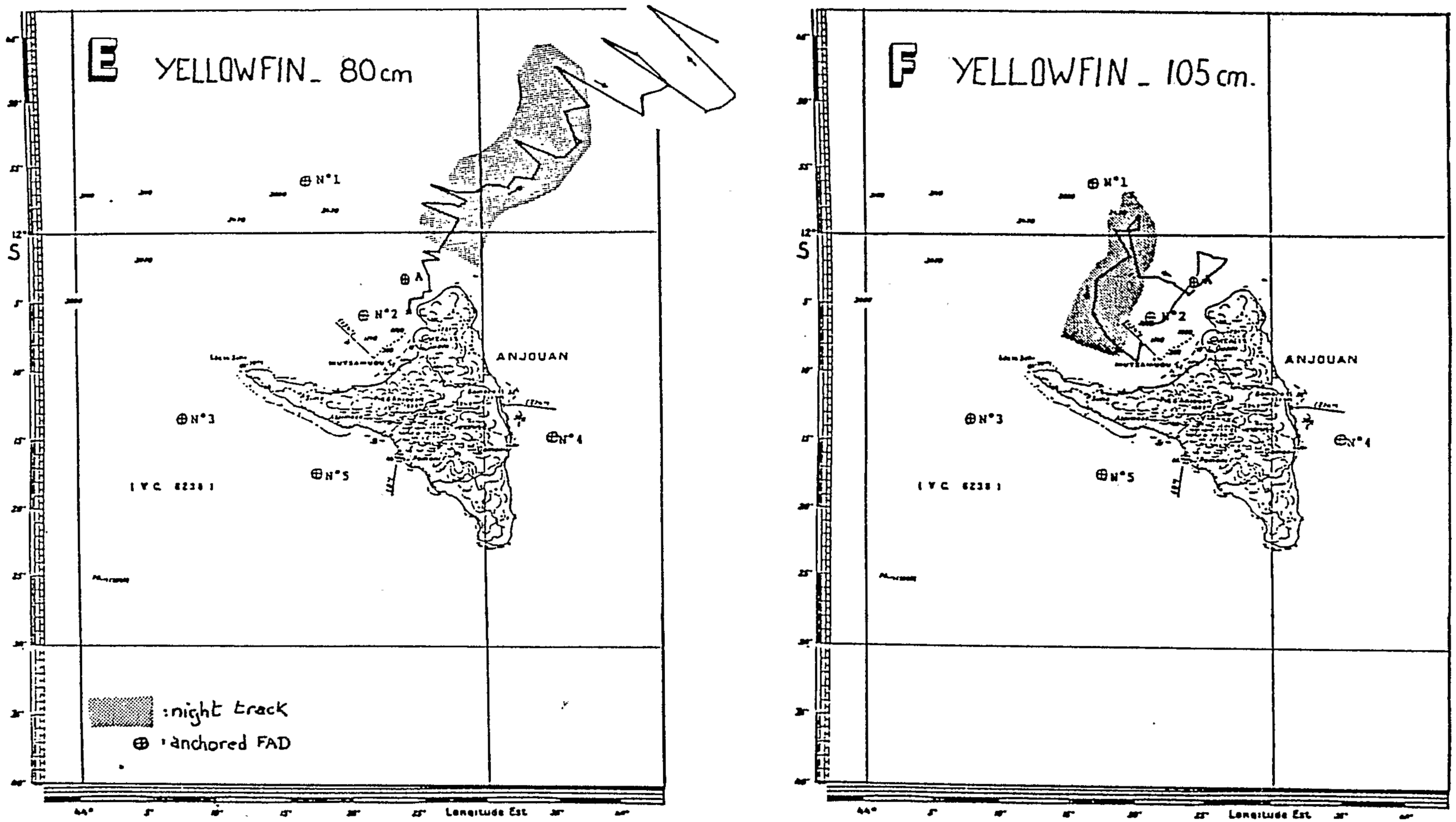

Figure 4. Continued
Date and duration of the tracks:
(E) April 18th – 22 hours, (F) May 14th – 24 hours.
(see table 1 for detailed information on the tracks)

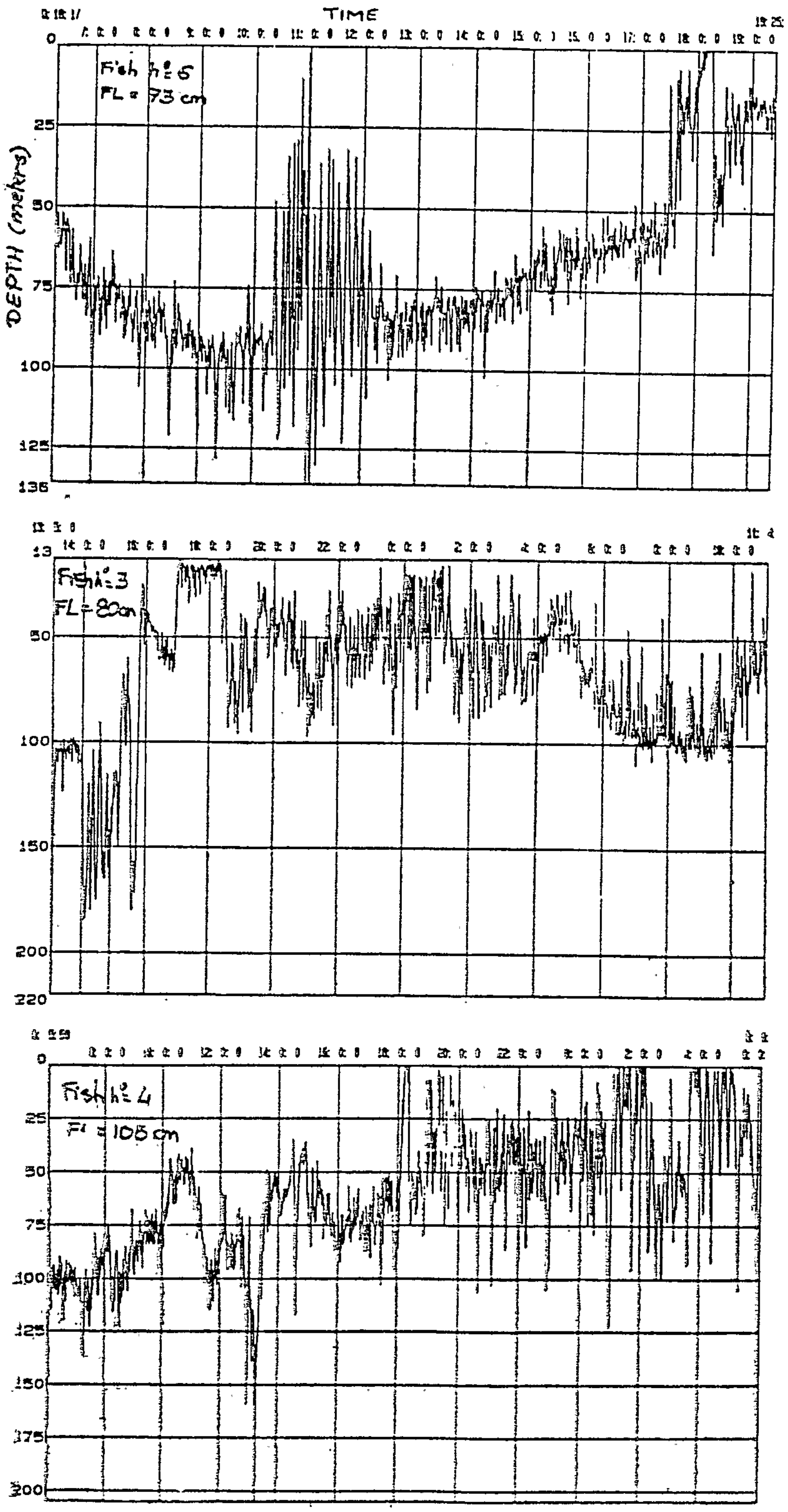

Figure 5. Depth record for yellowfin tunas No. 3, 4 and 6.

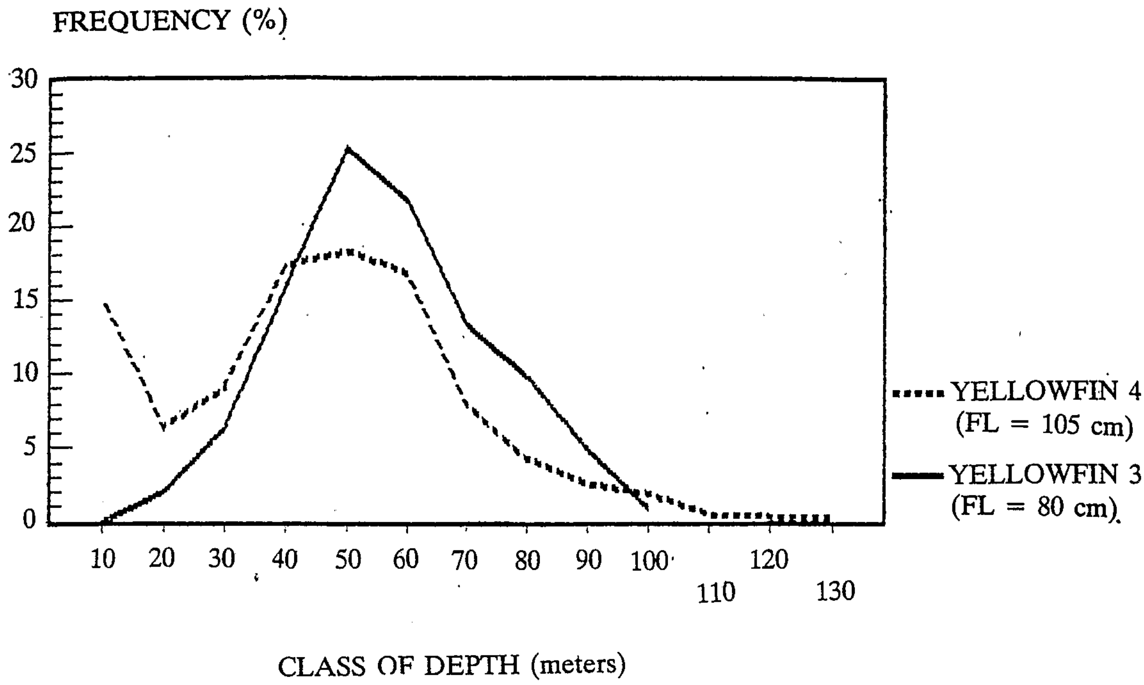

Figure 6. Frequency of the time spent by yellowfin tuna at different depths during the night (6.15 pm to 5.15 am).

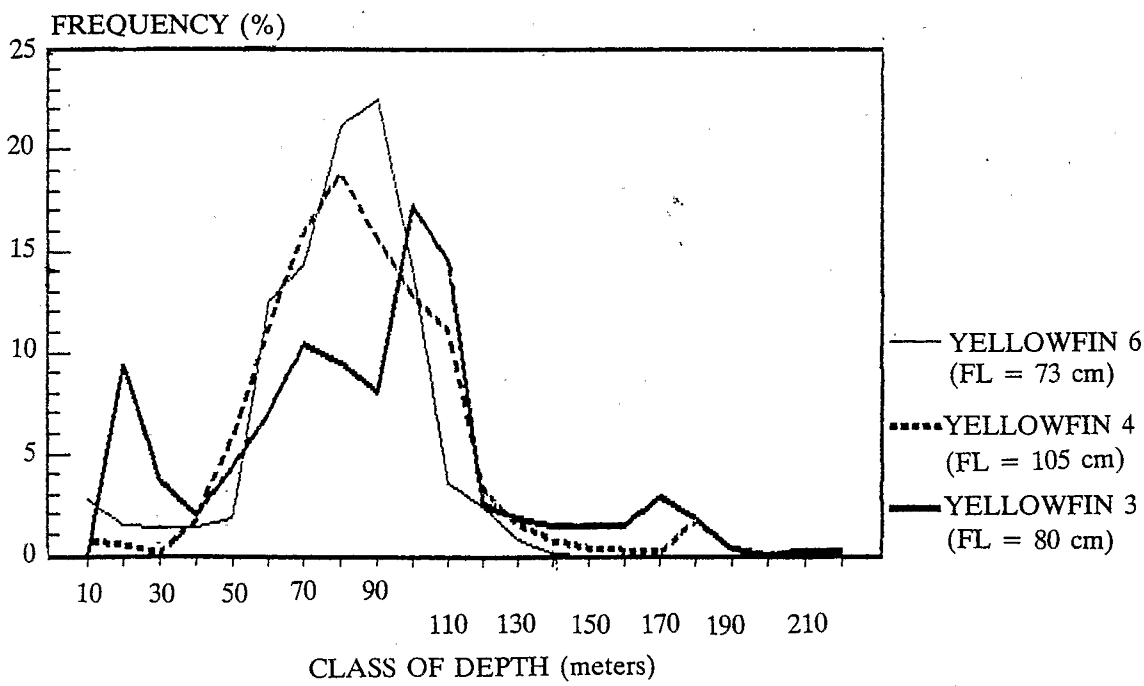

Figure 7. Frequency of the time spent by tracked yellowfin tuna during the daytime (from 5.15 am to 18.15 pm).

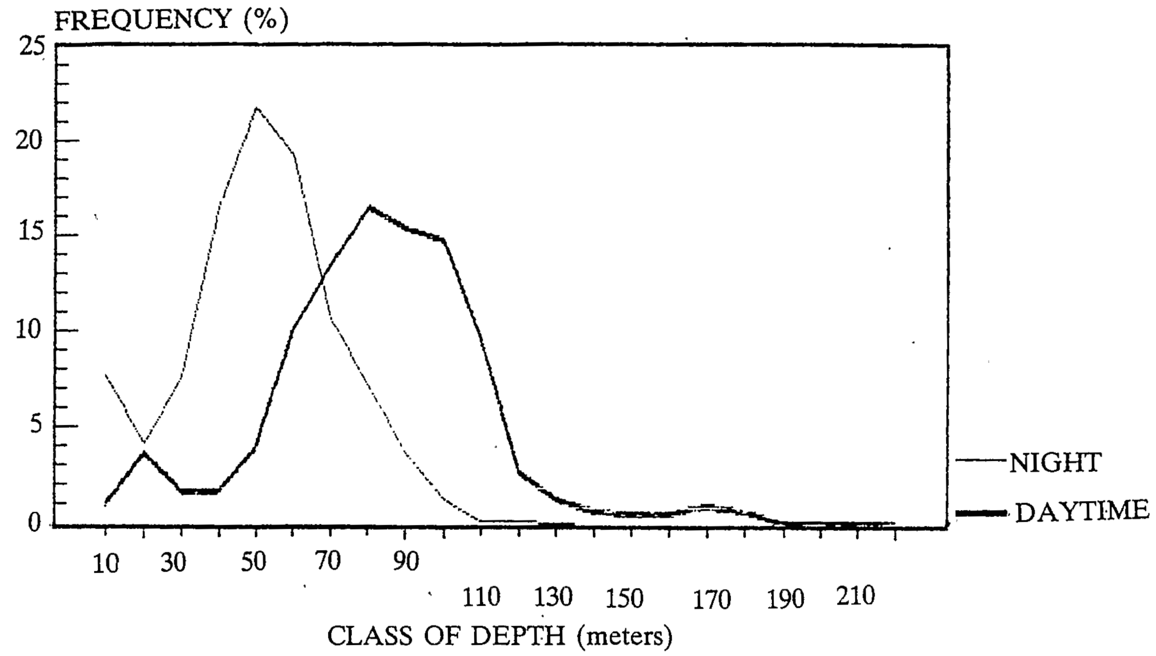

Figure 8. Mean frequency of the time spent by yellowfin tuna at different depths in the daytime (5.15 a.m – 6.15 pm) and at night (6.15 pm – 5.15 am).

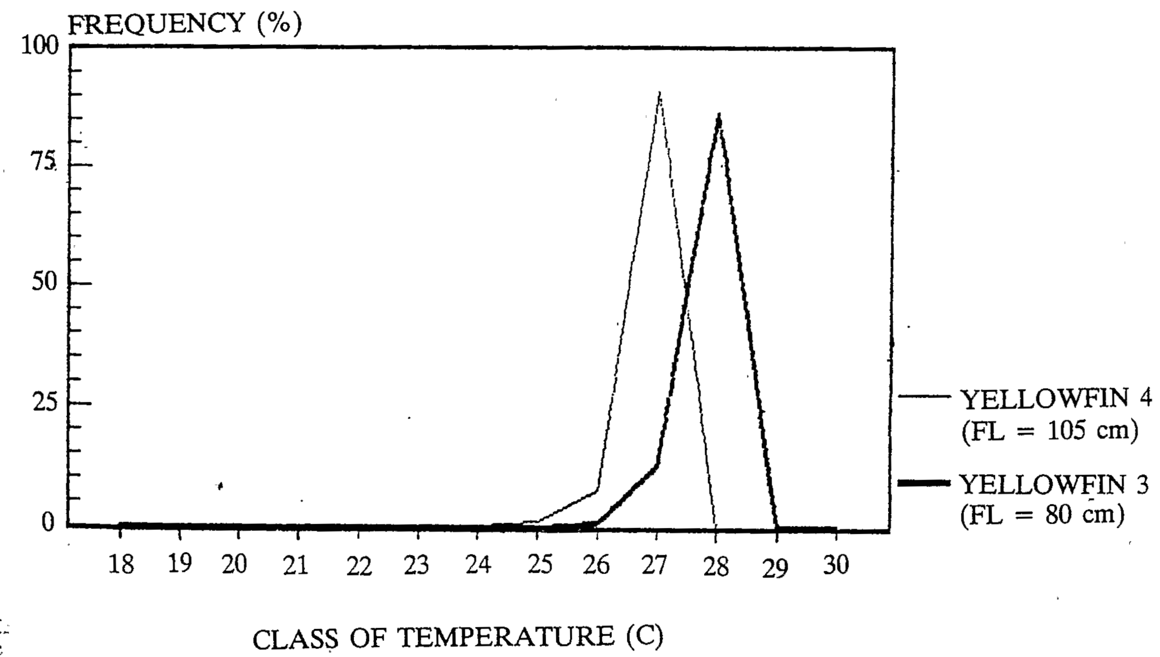

Figure 9. Frequency of the time spent at different temperatures, converted from depth data, by yellowfin tuna at night (from 6.15 pm. to 5.15 am.)

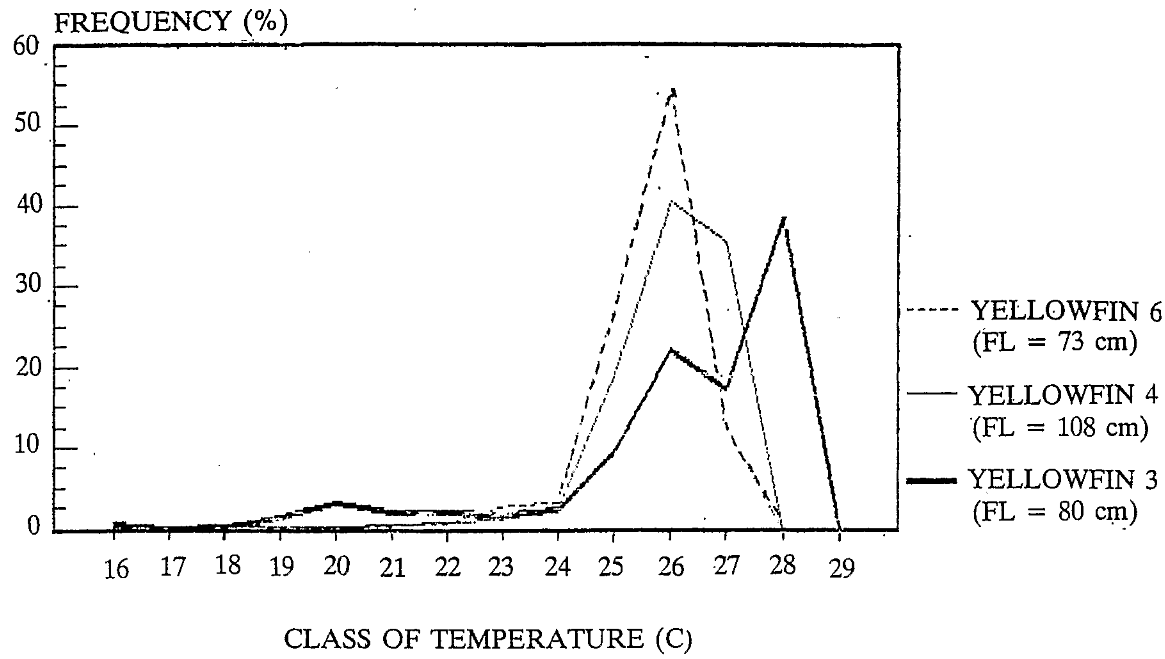

Figure 10. Frequency of the time spent at different temperatures (converted from depth data) during the day time (from 5.15 am to 6.15 pm) by 3 yellowfin.

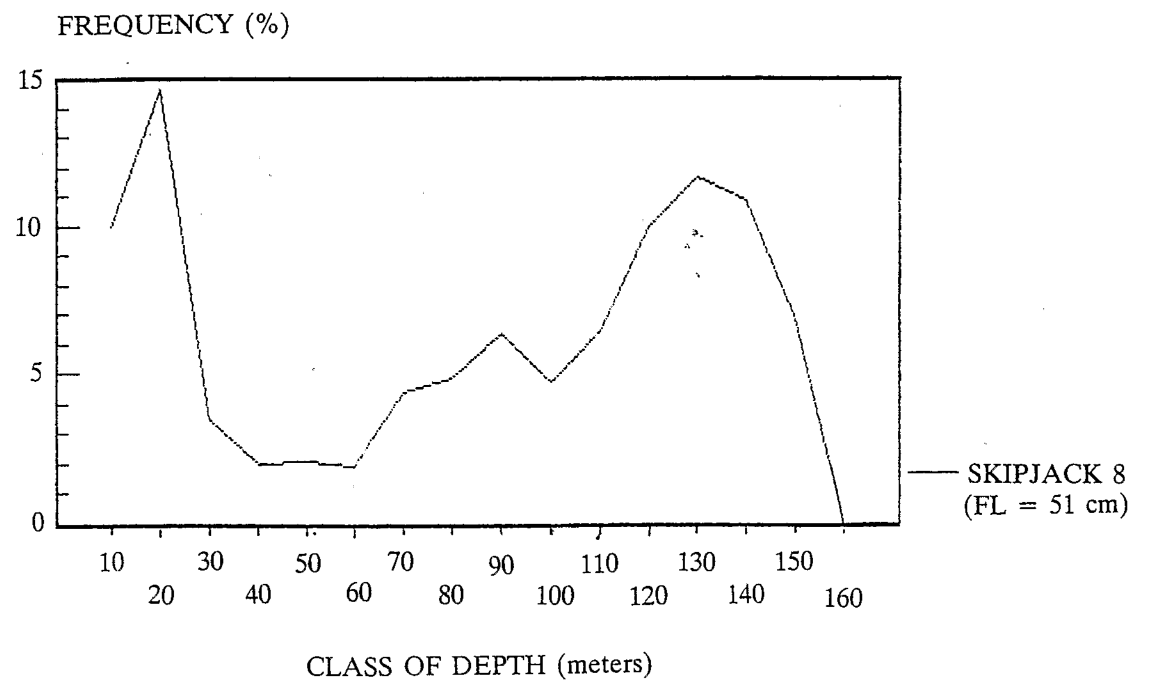

Figure 11. Frequency of the time spent by a skipjack tuna at different depths in the night (6.15 pm to 5.15 am).

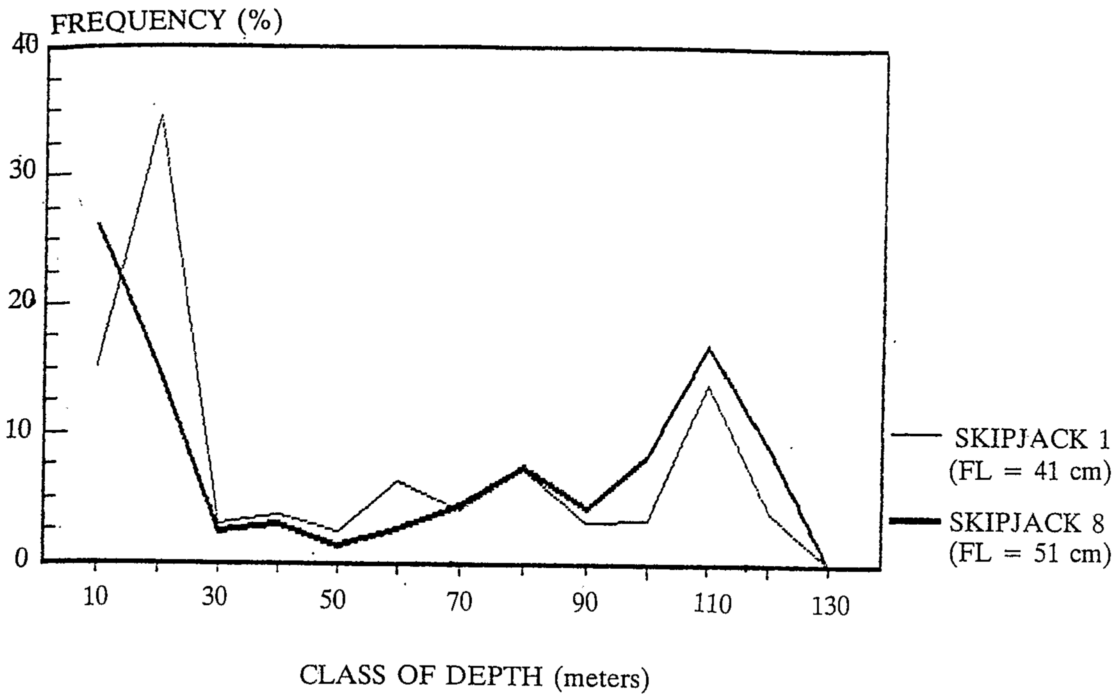

Figure 12. Frequency of the time spent at different depths in the daytime (from 6.15 am to 18.15 pm) by skipjack.

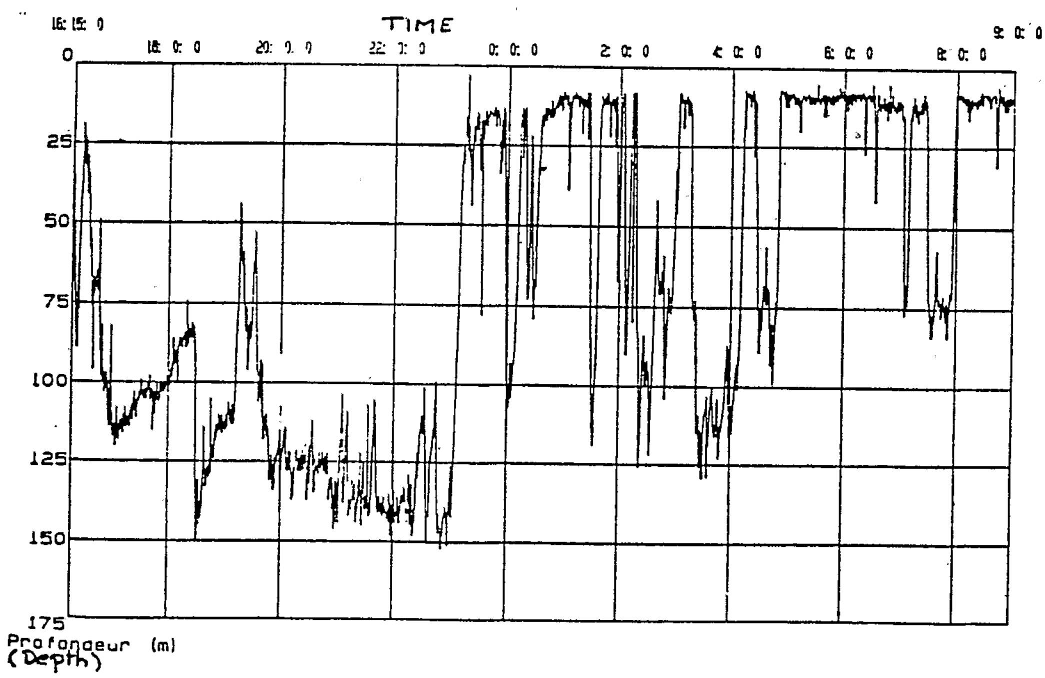

Figure 13. Depth record for skipjack No.8 (Fork lenght = 51 cm).

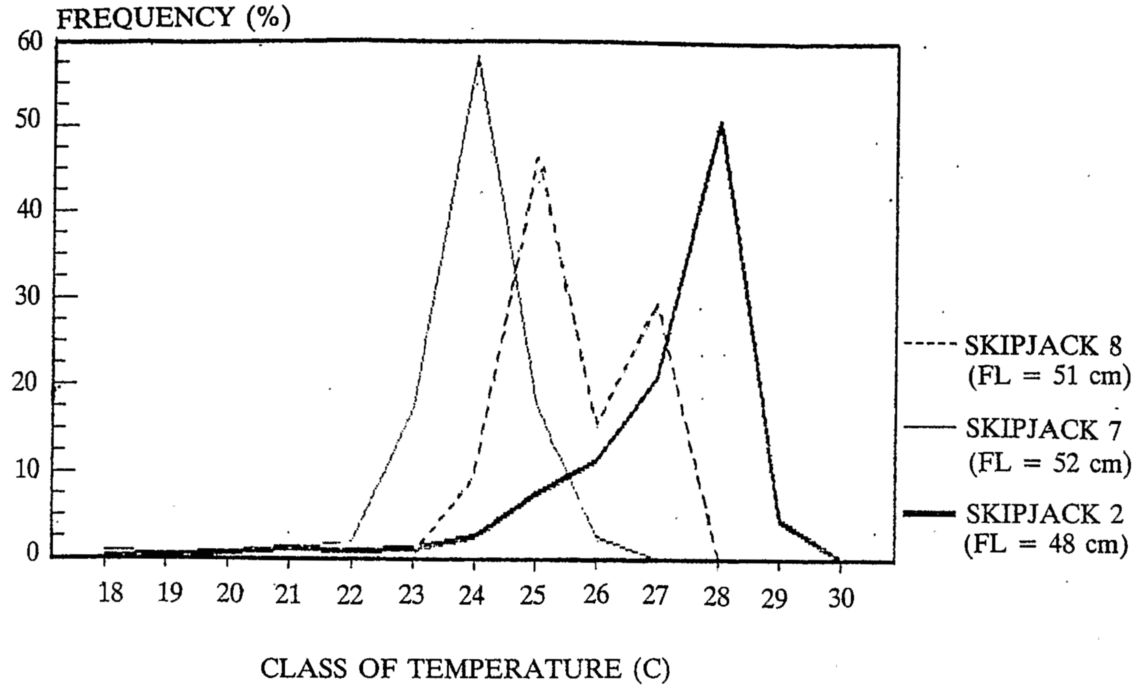

Figure 14. Frequency of the time spent by skipjacks at different temperatures during the night (6.15 pm. – 5.15 am).

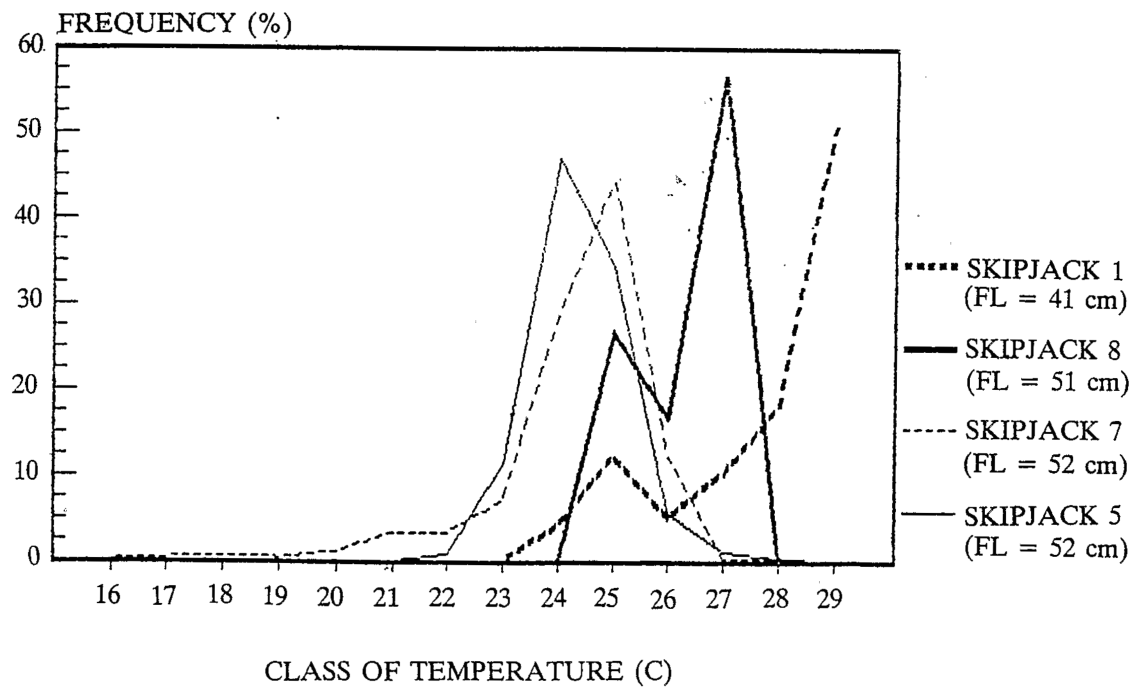

Figure 15. Frequency of the time spent by skipjacks at different temperatures during the day time (5.15 am. – 6.15 pm).

RAPA REPORT: 1991/11

INDO-PACIFIC FISHERY COMMISSION (IPFC)

Papers presented at the

SYMPOSIUM ON ARTIFICIAL REEFS AND FISH AGGREGATING DEVICES AS TOOLS FOR THE MANAGEMENT AND ENHANCEMENT OF MARINE FISHERY RESOURCES

Colombo, Sri Lanka, 14–17 May 1990

REGIONAL OFFICE FOR ASIA AND THE PACIFIC (RAPA)
FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
BANGKOK
1991

PREPARATION OF THIS DOCUMENT

This publication contains the papers contributed to the IPFC Symposium on Artificial Reefs and Fish Aggregating Devices as Tools for the Management and Enhancement of Marine Fishery Resources. The papers have been edited by Mr. V.L.C. Pietersz, Regional Fishery Officer, RAPA, Bangkok, Thailand.

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For bibliographic purposes this document should be cited as follows:

Indo-Pacific Fishery Commission, Papers presented at the Symposium on Artificial Reefs and Fish Aggregating Devices as Tools for the Management and Enhancement of Marine Fishery Resources, Colombo, Sri Lanka, 14–17 May 1990. RAPA REPORT: 1991/11, 435 pp.

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