Capture depths of longline targeted species (yellowfin, bigeye, swordfish): preliminary results obtained from experimental longline fishing carried out in Seychelles' oceanic waters.

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Abstract

The vertical habitat of pelagic species in longline fisheries is a major question in terms of gear selectivity and stock assessment and so is essential to be understood for the sustainable use of the marine resources. In the longline fishery, knowledge of the habitat gives fishermen the opportunity to set their line at a specific depth depending on the time of the day and environmental conditions. It maximizes their chance to catch targeted species and limit as much as possible bycatch.

For that purpose, longline fishing experiments were conducted as part of the CAPPES (Capturabilité des grands pélagiques à la palangre dans les eaux des Seychelles) project using a instrumented longline, equipped with hook timers and temperature-depth-recorders (TDR) from December 2004 to May 2006. Conductivity, temperature and depth profiles were also recorded. These experiments collected data on the vertical habitat of pelagic fishes during daytime and night.

The lines were set in two different ways: shallow at night (setting after sunset and hauling before sunrise) to target swordfish as traditionally done by local fishermen; deep during the day (setting before sunrise, hauling at noon) to target tuna. For each fish caught (target or bycatch) the basket number, hook number where recorded. The depth of captured where later determined.

Results show capture depths for the target species : yellowfin, bigeye and swordfish during both daytime and night-time sets. While yellowfin tuna and swordfish were mainly caught in the first 150m (both for day and night sets), bigeye tuna were captured close to the surface during night and below 150m during daytime.

Introduction

The vertical habitat of pelagic species in the longline fisheries is a major question in terms of gear selectivity and stock assessment (CPUE standardization). It is essential to understand it for the sustainable use of the marine resources (Boggs, 1992; Brill and Lutcavage, 2001; Bigelow et al., 2002; Bach et al., 2003;). Longline is considered as a non selective gear (Bjordal and Løkkeborg, 1996; Marin et al., 1998; Kelleher, 2005). It is a passive gear drifting in the open ocean with baited hooks hanging at various depths according to the target species. Fishermen principally use it to catch tuna species and in the Seychelles, swordfish (*Xiphias gladius*), yellowfin tuna (*Thunnus albacares*) and bigeye tuna (*Thunnus obesus*)) are the target species. Generally, longliners that target swordfish deploy their hooks close to the surface (25 to 100m) at dusk and retrieve them at dawn (Ward *et al.*, 2000). The opposite cycle is used to target tuna (setting a few hours before dawn and hauling at the beginning of the afternoon) and the line is generally set deeper (Ward and Hindmarsh, in press).

The depth at which species are caught is important for understanding the impacts of longline fisheries on target and bycatch species (Bigelow *et al.*, 2006) since composition of pelagic species in longline catches is significantly influenced by the fishing depth. The activity of many pelagic animals and their prey vary with the time of the day (Ward *et al.*, 2004). Swordfish and bigeye tuna feed near the surface at night and move to depths of 500m during the day (Carey, 1990). Bigeye tuna presumably mirror the vertical migration of the SSL (sea surface layer) forage between day and night (Childress and Nyggard, 1974; Josse et al. 1998; Dagorn *et al.*, 2000). Yellowfin tuna spends the majority of its time above the thermocline (Block *et al.*, 1997). Overall, the temperature of the water column and the forage influences the vertical distribution of these pelagic fishes.

This study is a preliminary analysis of data collected during monitored longline fishing experiments carried out in Seychelles waters from December 2004 to May 2006. Our objectives are to compare the vertical distribution of the various captured species, and determine the time of capture. Each species caught was measured and each time and the depth of capture estimated. Results show differences in depth of capture (for the 3 targeted species) between night and day sets, and in relation to the size of the fish.

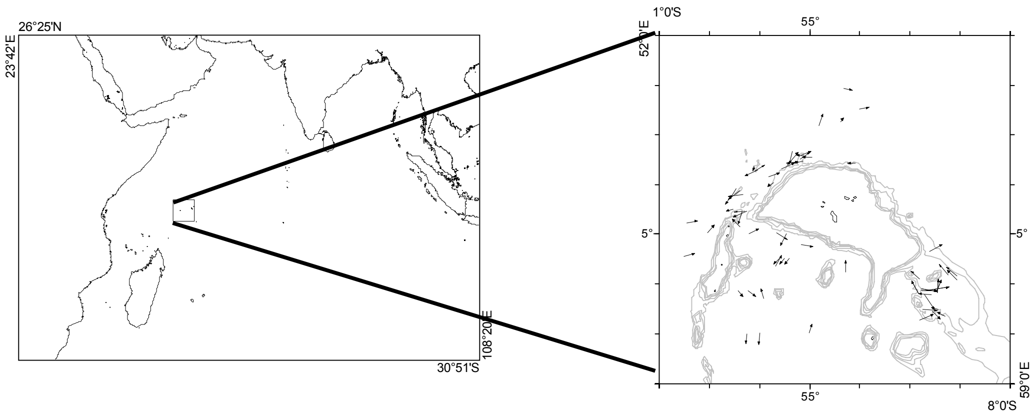
Materials and method

Data analysed in this study were collected as part of the CAPPES project (Gamblin *et al.*, 2006). The prospected fishing area is commonly exploited by small scale Seychellois longliners targeting swordfish, the principal species landed by the domestic longline fishermen (Lucas *et al.*, 2006) and more recently tuna species (yellowfin (*Thunnus albacares*) and bigeye (*Thunnus obesus*).

Description of the instrumented longline

11 trips, totaling 69 sets were conducted in the Seychelles waters around the Mahe Plateau (Figure 1) from December 2004 to May 2006 using an instrumented monofilament longline. Trips were conducted with small scale longliners (the R/V L'Amitie of the Seychelles Fishing Authority (SFA) and two commercial boats (M/V Pisces and Albacore). On average of 400 hooks were deployed per set. Due to the size limit and storage capacity of the vessels (25m max length) trips didn't exceed 10 days and took place within a 150 miles radius around Mahe Island (Wendling and Lucas, 2003).

Figure 1: Spatial distribution of the 69 sets conducted during the CAPPES Project



To monitor the behaviour of the line and to determine its depths and the corresponding time and temperature of capture, two instruments were deployed. Most branchlines were equipped with a hook timer (model produced by Lindgren Pitman Ltd.) placed above the hook (Somerton et al., 1988, Boggs, 1992). It gives the time elapsed in between the attack of the bait and its recovery on board. Temperature-Depth-Recorders (TDR, minilog 12-TX from Vemco) were used to record the depth of the line and the corresponding temperature. They were placed in the middle of the basket, which generally corresponds to the point that will reach the maximum depth (Mizuno et al. 1997).

Fishing strategy and experimental design

For day sets, a line shooter was used to deploy the line, with the aim of targeting deeper layers. Otherwise the line was set taut, as it is traditionally done by the local fishermen to target swordfish in the surface layer during the night..

Table 1 summarizes the main characteristics of the two type of sets. For day sets, setting began on average two hours before sunrise, whereas hauling started at the beginning of the afternoon. The line was generally constituted of two parts: one with shallow baskets and one with deep baskets, with an average of 15 hooks per basket (minimum number of hooks 8 and maximum 30). Night

setting began around 8pm and hauling in the early morning. In this case only shallow baskets were deployed with an average of 9 hooks per basket.
The effort deployed for each type of sets can be considered as similar.

Table 1: Characteristics of the sets carried out during the fishing experiments

	Day set	Night Set
Set start time	4:49	20:24
Set duration	2:06	2:21
Soaking time	6:05	8:29
Hauling start time	13:02	7:57
Hauling duration	3:51	3:39
Number total of hooks	14657	14792
Shooter speed	7.14	6.81
Vessel speed	6.57	6.26
DB	800	553
LLBF	923	852
Average number of hooks/basket	14	9

Each species caught was identified and measured. Time of capture was calculated when it was possible. Regarding bycatch, which were mainly made up of lancetfish (*Alepisaurus ferox*), we considered that they are underestimated, given that the crew did not always inform the scientist on board when they found one (Gamblin *et al.*, working party on Ecosystem and Bycatch, IOTC-2007-WPEB-16).

Estimation of the depth of capture

The depths of capture of each species were calculated using both TDR data and the catenary geometry formulae (Yoshihara, 1951, 1954; Suzuki et al., 1977):

$$D_j = LF + LB + (LLBF/2) * \left\{ (1+\cot^2\varphi)^2 - \left[(1-(2j/N))^2 + \cot^2\varphi \right]^{1/2} \right\} \quad (2)$$

where D_j is the depth of the j^{th} hook, LF the length of the floatline, LB the length of the branchline, LLBF the length of the mainline between two consecutive floats (basket), N the number of hooks per basket + 1, j the j^{th} hook from the mainline, φ the angle between the horizontal and the tangential line of the mainline.
In this case the shape of the line is estimated using the sagging rate (SR) defined as the ratio between the horizontal distance between floats (DBF) and LLBF. Yoshihara (1954) proposed a formula to calculate SR:

$$SR = DBF / LLBF = (\cot\varphi) * \ln\left[(\tan(45^o + \varphi/20) \right] \quad (3)$$

Regarding TDR data, the maximum depth of a line when there was no TDR, is estimated as the average of the value obtained with the TDRs placed before and after.

The theoretical maximum fishing depth were calculated by the Yoshira's formulae and compared to the average of depth values recorded at the middle of the basket. The deformation of the mainline measured by the difference between the theoretical fishing depth (Dtheo) and the observed maximum fishing depth (Dobs) is known as shoaling. The ratio between Dobs and Dtheo corresponds to the cosinus of the deformation angle of the mainline shape. This ratio is used as correction factor to estimate the depth of a hook j (D_j est) :

D_j est = (Dobs/Dtheo) * D_j

where D_j is the theoretical depth of a hook calculated with the catenary equation (2).

Time of capture

When hook timer data were available, capture time were calculated and correlated to the depth of the corresponding capture.

Relationship between depth and length of captured individuals

Each capture was measured (Fork length (LF) and an analysis was carried out to establish whether a correlation existed between the depth of capture and the size of the fish.
Environmental condition

For CAPPES 2, set 4 (night time set) and set 5 (daytime set), the TDR temperature profiles (accuracy of +/- 0.1 °C) were compared with the depths of capture obtained.

Results

Nominal CPUE (Figure 2)

During our fishing experiment, the nominal catch rate of swordfish was highest. Yield was better at night than during daytime (20 fish/1000 hooks). Bigeye tuna had the lowest catch rate which was homogenous for the two types of sets. For yellowfin tuna, the nominal CPUE was higher during daytime fishing operations (7 fish/1000 hooks).

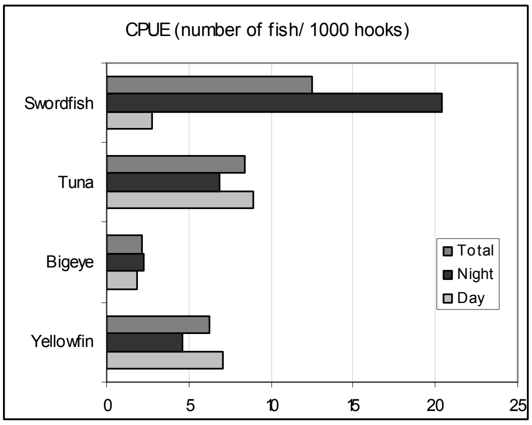
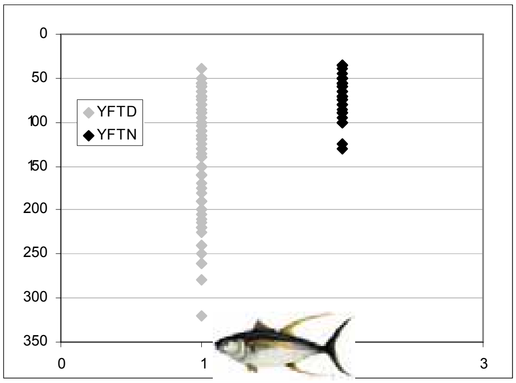


Figure 2: Nominal catch rate (number of fish caught/ 1000 hooks) for targeted species

Depth of capture

Yellowfin tuna (**Error! Reference source not found.**, A, B) were caught during the night in the first 100 m layer (64% of the fish between 50 and 100m). During the day they were captured between 40 and 350m with a majority between 50 and 150m.
Bigeye tuna (**Error! Reference source not found.**, C, D) were captured at night in the first 150 m with a majority of fish caught between 50 and 100m (63%). Day sets present a reverse distribution with the majority of bigeye found below 150m (63%).
Similar to yellowfin and bigeye tuna, swordfish (**Error! Reference source not found.**, E, F) were caught during the night in the first 150m. During daytime, swordfish were captured at or below 150m (24%).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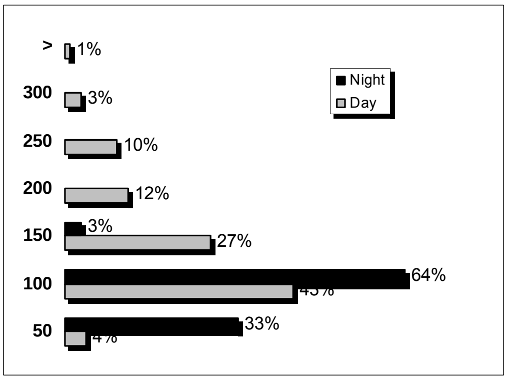
3

A


Night
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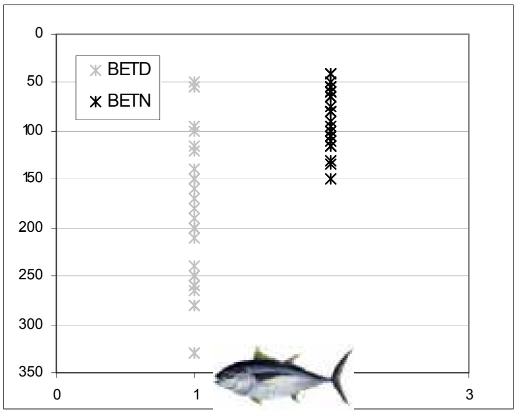
64%
33%

B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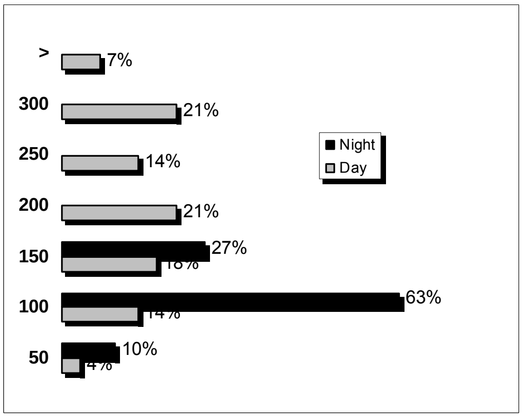
C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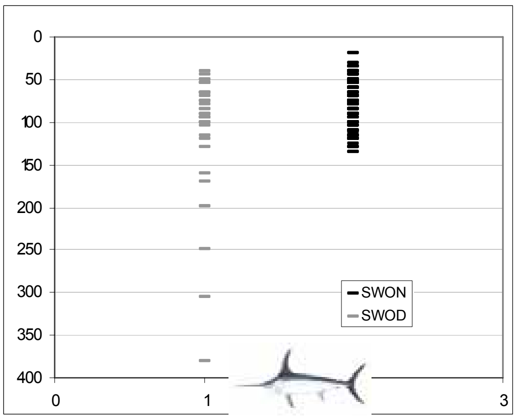
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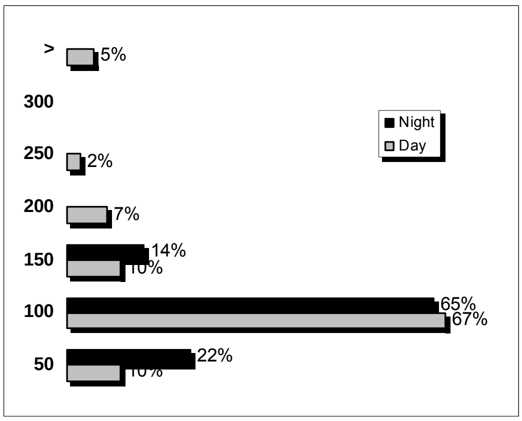
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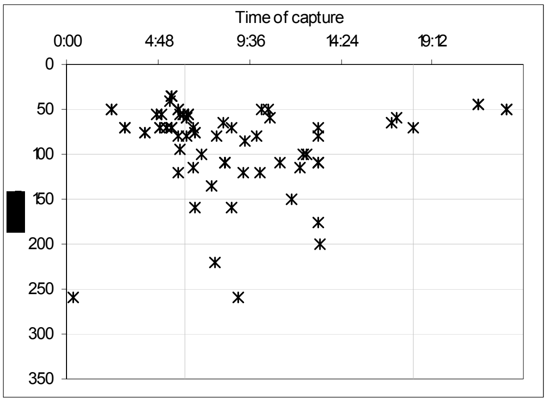
7%
14%
65%
67%
22%

E F

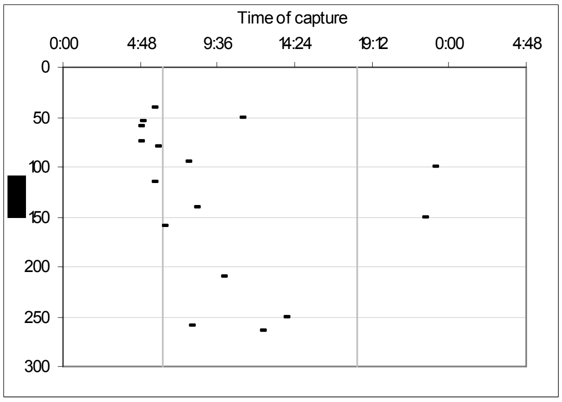
Figure 3: Vertical distribution of capture for the 3 target species : yellowfin tuna (A, B), bigeye tuna (C, D) and swordfish (E, F)

Time of capture

Capture in deep layers (>150m) were only recorded during daytime, except for one yellowfin, supposed to be caught at midnight at 250m (**Error! Reference source not found.**, A). This result was due to a deficient hook timer. One bigeye (**Error! Reference source not found.**, B) was found close to the surface at 11:00 in the morning. The two deep swimming swordfish (300 and 200m) (**Error! Reference source not found.**, C) were caught at 8:15 and at 12:53.



A



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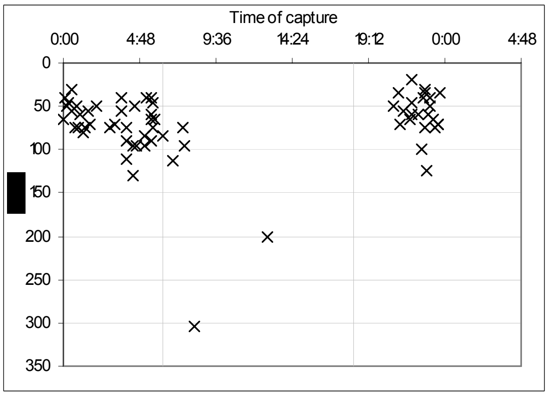

C

Figure 4: Distribution of the depth of capture and estimated capture time for yellowfin tuna (A), bigeye tuna (B) and swordfish (C).

Depth and size

The Fork Length (FL) for yellowfin tuna (Depth and temperature

During night-time fishing operations the three species were captured in the mixed layer which was the sampled habitat. Capture occurred between the surface and 120 m (17° C), ((**Error! Reference source not found.**, B). During daytime, the three species were caught in the mixed layer and below the thermocline. The lowest temperatures were captured occurred were 12° C, 11° C and 10° C respectively for yellowfin tuna, bigeye tuna and the swordfish, (**Error! Reference source not found.**, A).

, A), ranged between 80 cm to 170 cm. Small and large fish were found both in shallow or deep water. The majority of bigeye (Depth and temperature

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, B) (70%) caught both during the day or at night had length superior to 110 cm. Two intermediate individuals (70 and 80 cm fork length) were estimated to have been fished at 350m. Swordfish found below 200m all had FL > 110m (Depth and temperature

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, C).

<u>Depth and temperature</u>

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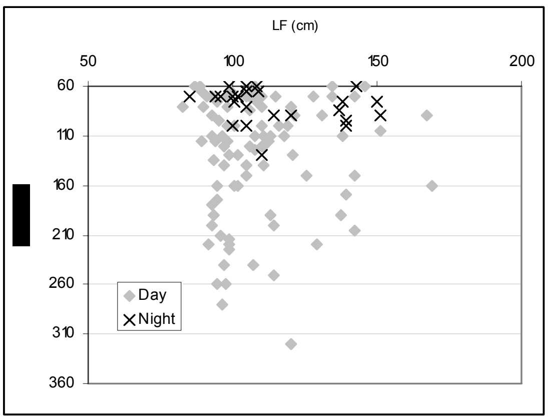
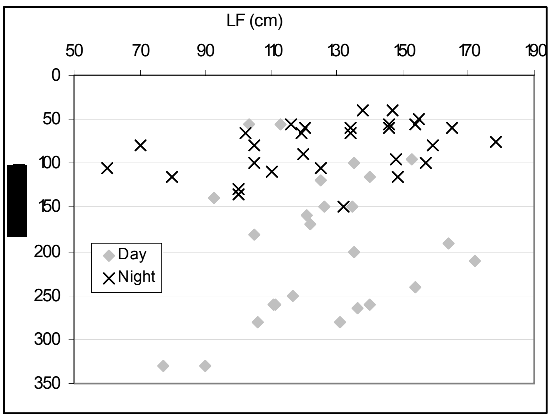


A



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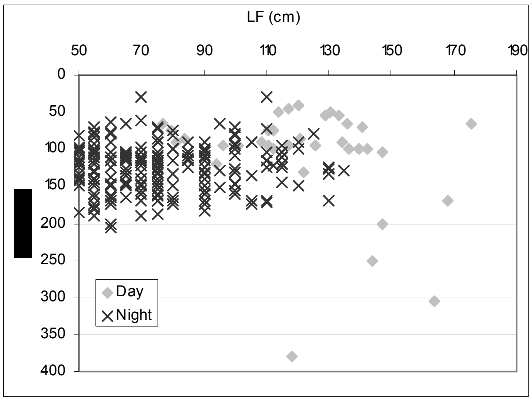
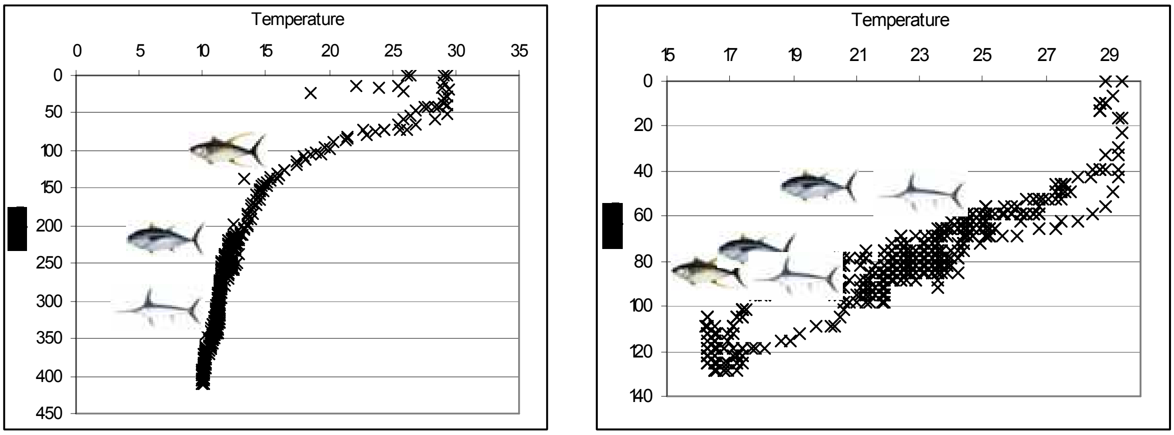


C

Figure 5: Relation between size (Fork Length =FL)and captured depths for yellowfin tuna (A), bigeye tuna (B) and swordfish (C).



A B

Figure 6: Vertical habitat (temperature and depth of targeted fish) during day set (A) and night set (B).

Discussion

Vertical habitat of longline target species is important to understand their catchability and to enhance the estimation of abundance indices. In this context, the habitat based model approach has been considered as a relevant approach if frequency distributions of both hook depths and depth of fish are available. Monitored longline fishing experiments appears as a relevant methodology to achieve this goal (Bach *et al.*, 2003). Our preliminary results are in line with such goel.

Considering vertical distribution, swordfish and tuna species are found close to the surface at night (more than 70% in the first 100m layer). Swordfish, bigeye tuna and yellowfin are known to be able to explore deeper layers during the day. While the majority of bigeye is caught below 200m, yellowfin tuna and swordfish seems to preferentially stay in the 150m layer. These results are in accordance with what is commonly found in the literature. These differences of habitat can be explained by the physiology and capacity of the fish to deal with environmental conditions (temperature and oxygen).

Yellowfin and bigeye tuna are known to have different vertical distribution due to different physiological abilities (Brill, 1994). On one hand, yellowfin tuna prefer to spend most of the time above the thermocline (Block et al., 1997). On the other hand, bigeye tuna and swordfish are able to feed in the deep scattering layer corresponding to cold waters during daytime (Graham and Dickson, 2001). To increase their body temperature they make vertical forays into the warm mixed layer (Holland et al., 1992; Holland and Sibert, 1994). They usually swim within the mixed layer above the thermocline during the day and below during the night (Holland et al., 1990; Dagorn et al., 2000).

The behaviour of swordfish is in theory similar to that of bigeye tuna (Brill and Lutcavage, 2001). However in these experiments, we observe that they were captured at similar depths to yellowfin tuna.

The temperature (>11°C) of capture reported in CAPPES 2 set 4 and 5 are in accordance with the range of temperature supported by the species reported in the literature.

In terms of the relationship between size of the fish and their captured depths, the vertical distribution of yellowfin tuna does not depend on the size of the fish (Brill and Lutcavage, 2001). In the case of bigeye tuna, the adult reaches a maximum depth of 500m and juveniles less than 300m (Brill and Lutcavage, 2001). In the study, two bigeye tuna with a length inferior to 100cm were caught at a depth greater than 300m. The size distribution of swordfish with depth is supposed to be similar to that of bigeye tuna. In this case only swordfish with a size greater than 110 cm were fished below 200m.

These preliminary results concerning vertical habitat of pelagic fishes are in accordance with those obtained in similar sampling area worldwide.

The daily vertical movement of bigeye tuna tends to influence fishermen in the Pacific Ocean who change their fishing tactics, deploying their line during the day in deep layers (Beverly et al., 2004). Furthermore this strategy is supposed to avoid the majority of bycatch that become scarce below 200m (Chavance, 2005). However, during our experiments deep fishing operation during daytime did not result in sustainable catch rate, viable for commercial operations. In these studies, deep day sets did not obtain a yield sustainable for a commercial operations. Hence at the moment no change in fishing tactics can be to the Seychellois fishermen (deep day deep set) to target tuna species at depth. More experiments are needed to validate these results.

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