***CAPPES** : **CAP**turabilité des grands **PE**lagiques exploités à la Palangre dérivante dans la Zone Economique Exclusive des **S**eychelles*

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Abstract

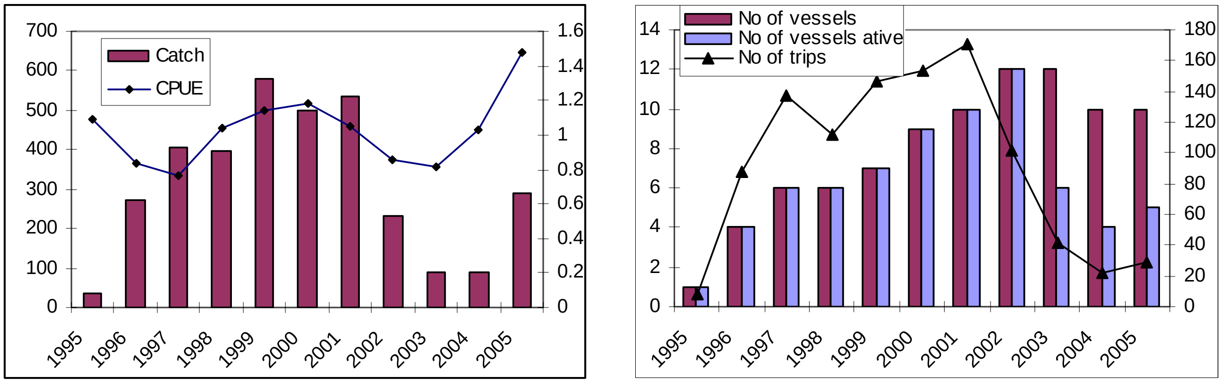
In 2004, the Seychelles Fishing Authority (SFA) in collaboration with IRD (Institut de Recherche pour le Développement) started a research program, called CAPPES, to help the local semi industrial longline fishery, which was encountering some difficulties. For that purpose 69 sets using an instrumented line (Hook timer, Temperature-Depth-Recorder, CTD profiler) were done around the Mahe Plateau. The objectives were to study the behaviour of the gear, the habitat of the target species (tuna and swordfish) and the efficiency of different types of bait. In total 29 449 hooks were deployed and 1478 fishes caught. The 11 research trips allowed the crew to master the use of the gear. A manual showing various gear configurations as a function of the depth targeted will be provided to the skippers. Concerning the bait test, some interesting results were obtained with small bonitos (discard of purse seine) and saury. Habitat results have to be more deeply analysed. The trips also gave the opportunity to observe in situ the predation problem that the industry has to face. Hence a quite important predation rate (1.73) was calculated for the whole program.
In general more trials are needed to make in-depth analysis. These will be possible through the SWIOPF program, which should begin in 2007.

Introduction

Deep-sea tuna fishing plays a major role for foreign and local countries in the Indian Ocean. Historically longline fisheries appeared in the 1950s with the Japanese and Taiwanese fleets (Doumenge 1998). Since then, purse seine and longline catches represent each year about ¼ of the global tuna catches. The tuna longline fishery was first the monopoly of large foreign longliners, which pay for the right to fish of the coastal countries' EEZ. Considering the important resource they own and the increase of fishing pressure on their demersal stocks, these countries developed in the nineties a local longline fishery to benefit directly from their important pelagic resource. Hence in 1991, La Reunion began to build its own fleet and in 1995 Seychelles did the same.

The local Seychelles fleet grew quite rapidly from one vessel in 1995 to 12 in 1999 whilst the landed catch grew from only 35 metric tons to a peak of 580 metric tons in 1999 (Figure 1 A). At that time, the fishery was targeting principally swordfish and tuna for the export markets but other species such as marlins, sailfish and sharks were also landed. However, in 2002, the EU imposed a ban on swordfish exportation to the EU market due high levels of cadmium. This caused a continuous decline in the fishery whereby the number of active vessels, the number of trips, the CPUE and the landed catch have all been on a downward trend (Figure 1 A, B). Since that time, the majority of the vessels switched to sharks finning which is more lucrative thanks to very interesting prices on the Asian market.

This event considerably weakened the fishery, and the swordfish fishery was threatened. In fact despite the lifting of the restriction on export in 2004, most of the vessels are still targeting sharks, which are really more profitable, or do combination of shark and swordfish fishing or are engaged in sea cucumber harvesting which is another lucrative fishery in Seychelles. In 2005, only two boats target swordfish and tuna fulltime. Furthermore, export restriction is not the only problem for the Seychelles fleet. The fishery has to face depredation on the longlines caused by top predators, mainly sharks and marine mammals. Very high levels of depredation can be observed on a regular basis on the longlines.



A B

Figure 1: Total catch, CPUE (A), number of vessels, number of vessels active, number of trips (B) of the semi-industrial fishery for the period 1995-2005

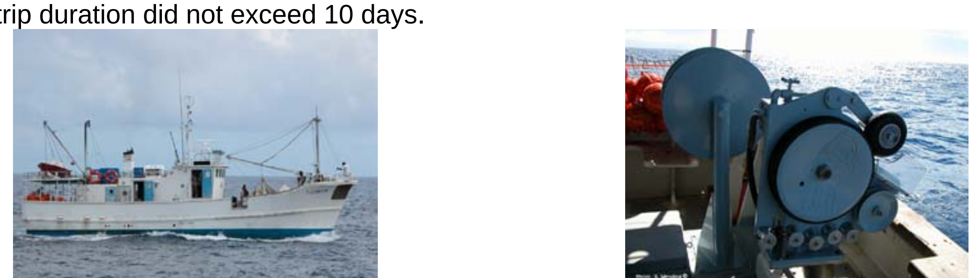
To help the local semi-industrial fishery, the Seychelles Fishing Authority (SFA) launched in November 2004 a research and development programme with the assistance of the Institut de Recherche pour le Développement (IRD). The general outline of the program was discussed and agreed during a regional working party organized by SFA in 2004 (Bach et al. 2004). The main objectives were to study the behaviour of the fishing gear under different setting scenarios, study the habitat of the targeted species (depth, temperature) and evaluate the efficiency of various types of bait, which is one of the important constraints in this kind of fishery. For that purpose, longline trips were conducted with either the SFA research vessel or in collaboration with commercial longliners around the Mahe Plateau. For all sets, an instrumented line was used to provide data on the behaviour of the fishing gear, the vertical distribution of fishes and to collect environmental data.

This paper presents the results obtained, a discussion on this research program and perspectives for the future.

I- Materials and methods

I.1 Boat used, fishing gear and objectives of the trips

In all, eleven longline trips were carried-out from November 2004 to May 2006. They were conducted with SFA's research vessel R/V l'Amitié (Figure 2A) and occasionally with commercial boats (M/V Pisces and Albacore). Because of the small size of these boats and the limited storage space, trip duration did not exceed 10 days.



A B

Figure 2: A- R/V L'Amitié, B- line shooter

The long-line fishing system used consists of a monofilament mainline of approximately 4mm in diameter. The branch lines which are also monofilament (1.8 mm diameter) consist of a hook, leaded swivel and are attached to the mainline by a snap. The main line is wound up on a hydraulic winch. Thanks to a line shooter (Figure 2 B), the long-line can be set at a speed greater than that of the boat. This allows reaching deeper layers than those targeted traditionally by the fishermen. However, to target swordfish, hooks are deployed in the mixed layer at depths ranging from 25 m to 100 m according to fishing grounds. In that case, the mainline is set taut without the need of a mainline shooter.

The objectives differed from one trip to another (Table 1). Five trips were dedicated to target tuna and so lines were set during the day (setting early morning, hauling early afternoon). Both shallow and deep layers were targeted. The others were set at night (setting around 22h, hauling early morning) as usually done by the commercial fishermen when targeting mainly swordfish at the surface. During those night sets, different types of baits were used (Table 1). Squid, small bonitos, muroaji, mackerel and saury were tested during CAPPES. Squid is the bait traditionally used by local fishermen.

Table 1: Features of the trips

Cruise Name	Vessel Name	Start date	Total hks	Bait used	Sets	Objectives
Cappes 1	MV PISCES	12/11/04	1320	Mackerel, Saury	1(Day)	Target tuna
Cappes 1	ALBACORE	12/11/04	2814	Mackerel, Saury	6(Day)	Target tuna
Cappes 1	L'AMITIE	12/11/04	470	Saury	3(Day)	Target tuna
Cappes 2	L'AMITIE	3/22/05	370	Saury	1(Night)	Bait test
Cappes 2	ALBACORE	4/5/05	2229	Mackerel, Saury, Squid	5(2Night, 3 Day)	Target tuna/Bait test
Cappes 3	L'AMITIE	5/10/05	2729	Bonite, Squid Saury	8(Night)	Bait test
Cappes 3 B	MV PISCES	4/21/05	3619	Squid	4(Night)	Bait test
Cappes 4	L'AMITIE	6/10/05	828	Muroaji, Saury, Squid	5(Day)	Target tuna
Cappes 5	L'AMITIE	7/13/05	2623	Bonite, Muroaji, Saury, Squid	7(Night)	Bait test
Cappes 6	L'AMITIE	9/30/05	1778	Bonite, Muroaji, Saury, Squid	6(Night)	Bait test
Cappes 7	L'AMITIE	11/17/05	2972	Saury, Squid	7(Day)	Target tuna
Cappes 8	L'AMITIE	3/23/06	1638	Saury, squid, muroaji	4(Night)	Bait test
Cappes 9	L'AMITIE	4/21/06	2743	Saury, Squid	6(Night)	Bait test
Cappes 10	L'AMITIE	5/10/06	3316	Saury, Squid	7(6Day,1Night)	Target tuna/Bait test

I.2 Location of sets

Sets were done around the Mahe Plateau (Figure 3A). In fact, the operation range of the boat cannot optimally exceed 150 nautical miles (Wendling and Lucas 2003). The location was chosen before the trip using CATSAT maps (SST, altimetry and plankton) purchased by SFA from CLS. Plankton and altimetry charts show front zones supposed to be attractive for tuna, as can be seen in the altimetry map (Figure 3(B)) used during CAPPES 10. In fact, tuna distribution is considered to be influenced by physical and biological characteristic of the environment (temperature, oxygen, forage, depth of the thermocline) (Barkley and al. 1978, Bertignac and al. 1998, Bertrand 1999, Maury and al. 2001, Bertrand and al. 2002).

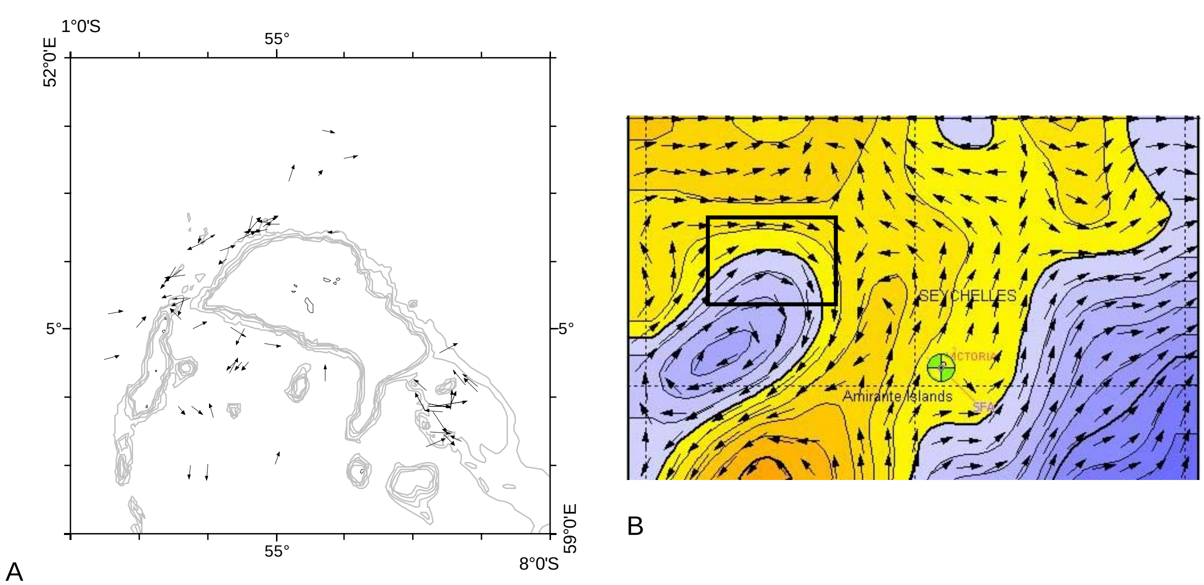


Figure 3: A-Location of the 69 sets conducted during CAPPES. B-Altimetry map of CAPPES 10. The black rectangle represents the area chosen.

<u>I.3 Instrumentation of the line</u>

To tackle the objectives of the programme, the experimental fishing was conducted with an instrumented line as was done in the Pacific Ocean (Boggs 1992, Bach et al. 1999, 2003, Bertrand et al. 2002) and in the Indian Ocean (Poisson and Taquet 2001, Wendling et al. 2003).
Two instruments were deployed (Figure 4 A et B). Most branchlines were equipped with a hook timer (model produced by Pitman) placed above the hook. They give the time elapsed in minutes between the attack of the bait and its recovery on board; that means the time at hooking. Temperature-Depth-Recorders (TDR) (VEMCO model) were used to assess the depth of the line and the temperature. They are put in the middle of a basket, between two floats, so represent the maximum depth of the mainline. Sometimes a CTD profiler was used to collect more accurate environmental data (Figure 4 C).


A

B


C

Figure 4: A-TDR, B-hook timer, C-CTD profiler

For most of fish caught, the following information is available:

- ✓ time fish caught
- ✓ depth at which caught
- ✓ water temperature at time and place of capture.
- ✓ if CTD, temperature and conductivity profile of the environment

<u>I.4 Data collected</u>

Thanks to the instrumented line and dedicated forms, four categories of data were collected during each trip. They concern geographical, technical, biological and environmental features (Table 2).

Table 2: Various kinds of data collected during the program

Geographical	Technical	Biological	Environmental
Date	Speed of boat	Baskets and Hooks	Temperature
Time	Speed of shooter	No. of catch	Depth
Location of setting	Length of branchline	Time of catches	CTD profile
Location of hauling	Length of leader	Bait type fish took	
	N° of hooks	Species	
	Intervals between hooks	Size	
	N° of baskets	Sex and maturity stage	
	Bait type	Status of fish (alive, dead, exhausted, escaped)	
		N° of fish depredated by species and type of predator	

All these data have been included in a database, called DEFIL (Database for Experimental Fishing using Instrumental Longline) that was specifically designed for the project.
They have been analysed and the first results are presented in part II.

II-Results

II.1 Catches

Table 3 presents an evaluation of catches obtained during the project. In total, during the 69 sets conducted, 1478 fishes were caught. In this table, swordfish appears as the main commercial species in the catches (23.3%); tunas are the second one (11.6% for yellowfin tuna (*Thunnus albacares*) and 4.1% for bigeye tuna (*Thunnus obesus*)). Sailfish (*Istiophorus platypterus*) were caught in fairly large quantities (9.3%), often during day sets. Discards seem to be quite important (28.4%). Furthermore, we can consider that they are underestimated, as not all the discards were registered by the technicians. The greatest proportion of discards was recorded during daytime sets and constituted mainly of *Alepisorus ferox* (lancet fish). Sharks are an important bycatch (9.5%) too. They were each time released.

Considering hook timer data, 21% of the catches were on an instrumented hook. This percentage represents the fishes caught on lines equipped with a hook timer for the species considered; we only keep the case where the information of the hooking time was valid. It is quite a small proportion. This can be explained by the fact that at the end of program only about 150 hook timers were still working.

Table 3: Catches by species and realized with hook timer

Species	No Caught	Percentage(%)	No with HT Data	Percentage(%)
Xiphias gladius	344	23.3	73	21.2
Thunnus albacares	171	11.6	56	32.7
Thunnus obesus	61	4.1	18	29.5
Istiophorus platypterus	137	9.3	36	26.3
Makaira indica	7	0.5	1	14.3
Makaira mazara	7	0.5	1	14.3
Coryphanea hippurus	76	5.1	11	14.5
Katsuwonus pelamis	28	1.9	1	3.6
Other Species	57	3.9	19	33.3
Rays	29	2.0	8	27.6
Sharks	141	9.5	27	19.1
Discard	420	28.4	63	15.0
Total	1478	100	314	21.2

The geographical distribution of swordfish, yellowfin tuna, bigeye tuna and sharks has been represented (Figure 5) (number of fishes caught by 0.5 mile side square).
For swordfish, one main area can be seen in the south east of the Mahe plateau with 98 fishes caught in the square centred on 6°15S 57°15'E. For yellowfin tuna, most of the catches were in three areas: the north of the Mahe Plateau with 20 fishes caught in the square centred on 3°45'S 54°45'E, the east of the Amirantes Plateau with 21 fishes caught in the square centred on 6°15'S 53°45'E and finally in the south east of the Mahe plateau with 23 fishes caught in the square centred on 6 °15'S 57 °15'E. For bigeye tuna no trend can be observed (too few individuals caught, n=61).
The majority of sharks were fished in the south east of the Mahe Plateau with 48 fishes caught (and released) in the square centred on 6°30'S 57°30'E.

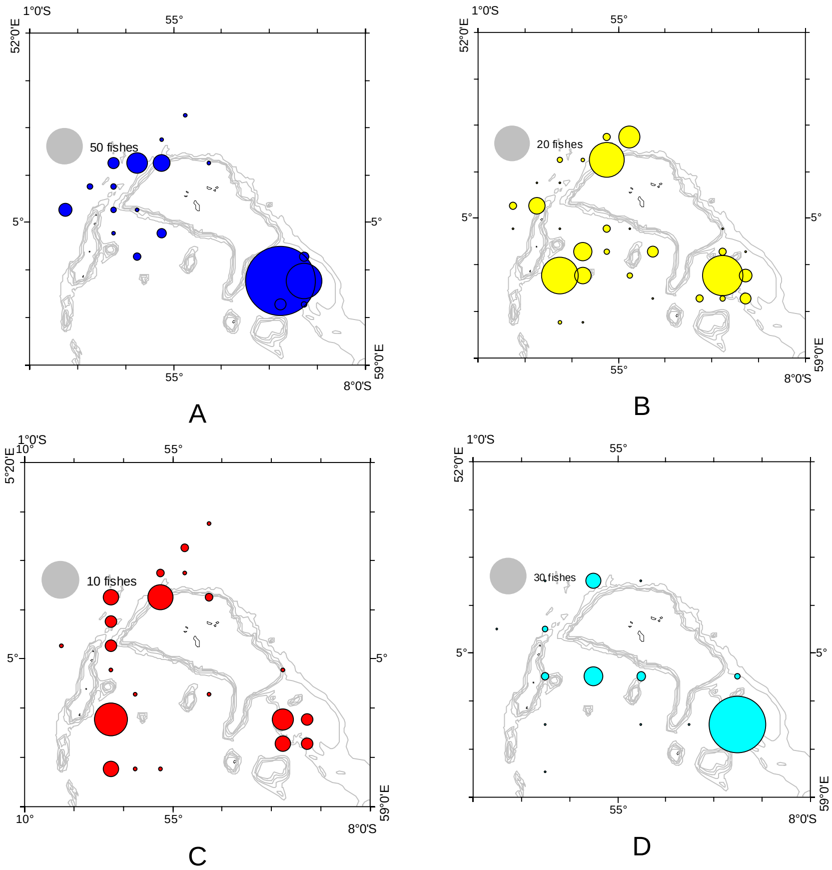


Figure 5: Geographical distribution of the catches (number of fishes in a 0.5 miles side square); A-swordfish (n=344), B-yellowfin tuna (n=171), C-bigeye tuna, D-sharks

<u>II.2 CPUE</u>

The yield or CPUE (number of fishes/1000 hooks) for the three main commercial species (yellowfin and bigeye tuna and swordfish) was calculated and represented in Figure 6 (CPUE by 0.5 mile side square).

For swordfish, two areas with a yield greater than 10 fishes for 1000 hooks stand out; one in the north west in the square centred on 3°45'S 54°45'E and the other in the south east in the square centred in 6°15'S 57°15'E. For yellowfin tuna, maximum yield is found in the west in the square centred on 5°15'S 54°45'E and 3°45'S 54°15'E. For bigeye tuna, the only yield greater than 10 fishes/1000 hooks was observed in the north of the Mahe plateau (square 3°45'S 54°45' E).

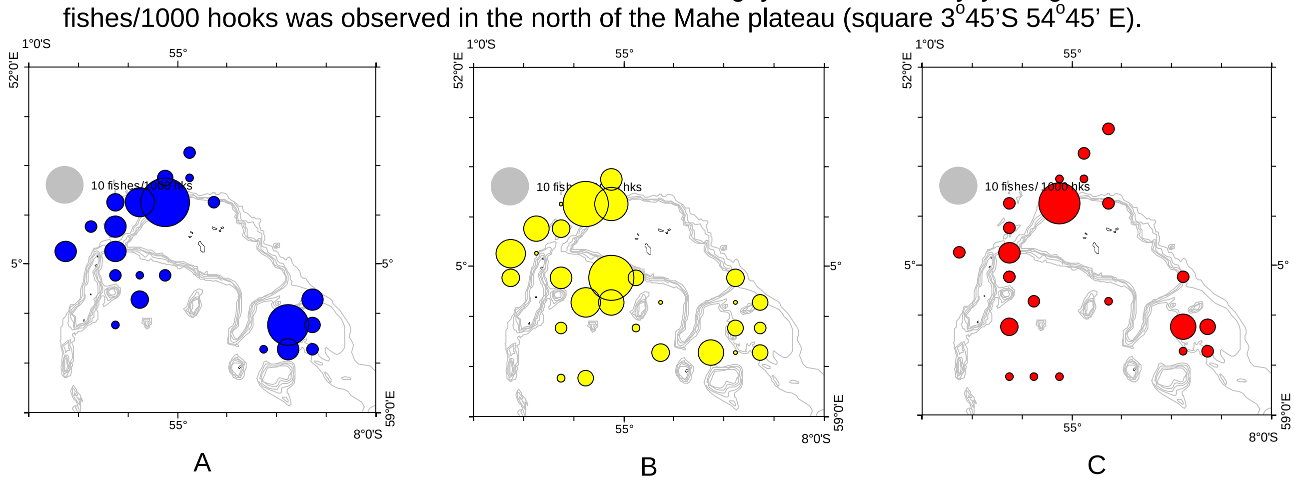


Figure 6: Geographical distribution of the CPUE by 0.5 mile side square for swordfish (A), yellowfin tuna (B) and bigeye tuna (C).

II.3 Gear configuration

One of the objectives of the program was to study the behaviour of the gear and in particular using the line shooter to find the way to target deeper layers than usually done by fishermen. For that purpose, we tested different combination of vessel speed and shooter speed (this means different sagging ratio of the line). We also increased the number of hooks per basket that traditionally is around 8 hooks. Table 4 shows the main range of values obtained for the different parameters, which determine the depth targeted. We managed to target the layers we wanted. The maximum depth (Pmax) recorded by TDR during the program was 500m.

A technical manual will be written for the fishermen in order to give them the gear configuration in particular how to use the shooter to diversify their fishing strategy.

Table 4: Summary of the gear configuration for the shallow and deep sets done during the program.

Gear configuration	Tuna targeting		Swordfish
	Shallow	Deep	Shallow
No hks/basket	5-15	12-30	5-15
Shooter speed	6-8	5-8	5-8
Boat Speed	5-7	4-7	5-7
Sagging ratio	82-100%	56-90%	70-100%
Pmax reached	50-150m	150-500m	50-150m

II.4.Behaviour

For tuna species (yellowfin and bigeye) and swordfish, we represented the fishes caught as function of the time of the day (Figure 7). Swordfish appears to be caught mainly from 22h to 1h and early morning (before sunrise). The trend is quite different for tuna, which are caught from early morning to the beginning of the afternoon.
Tuna were caught during the day preferentially with deep longline whereas swordfish were usually fished at the surface with light stick during the night sets.

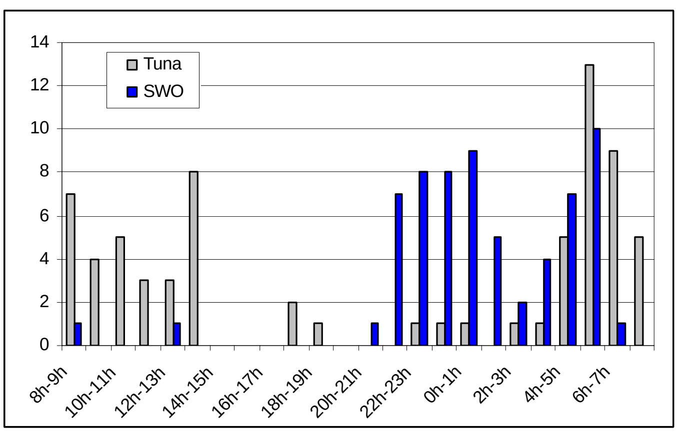


Figure 7: Distribution of tuna and swordfish catches (number) during the day.

II.5.Biometry

Biometry analyses have been conducted only for yellowfin tuna and swordfish.

A Length classes

Length classes' analyses have been conducted on fork length (LF) (lower jaw fork length (LJFL) for swordfish and fork length for tuna) for 159 yellowfin tuna and 129 swordfish (Figure 8, Figure 9). Length classes are expressed in 1 cm intervals.

Concerning yellowfin tuna (Figure 8), the mean size of the fishes is 112.5 cm. The size range is from 68 cm to 170 cm and the median 108cm.

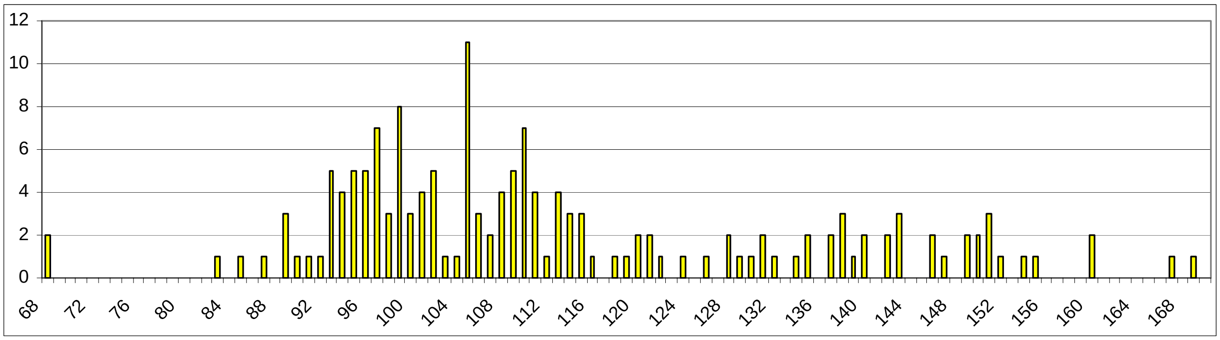


Figure 8: Distribution of the length (LF) of the yellowfin tuna caught during CAPPES.

For swordfish (Figure 9), the mean size of the distribution is 136cm, which is also the median. The size range is from 65 cm to 214cm.

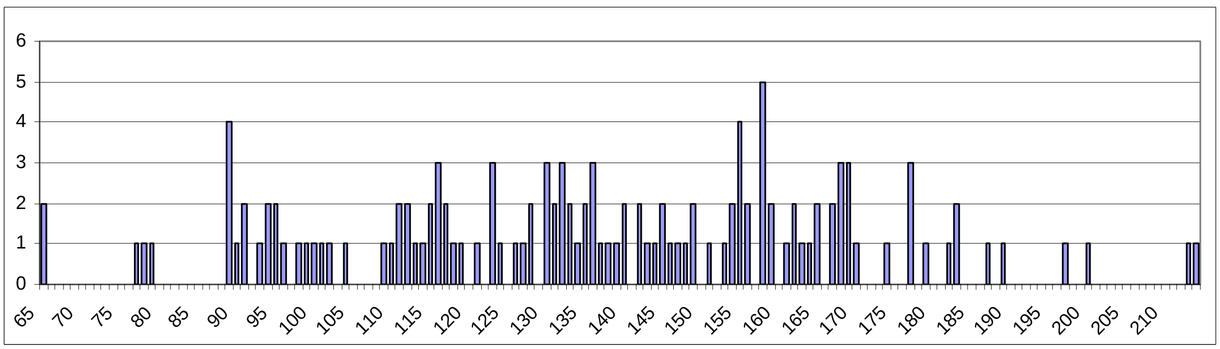


Figure 9: Distribution of the length (LF) of the swordfish caught during CAPPES.

B.Sex ratio

A spatial analysis of the sex ratio has been conducted for swordfish and yellowfin tuna (Figure 10). In order to have a sufficient sample of individuals, data was aggregated in a 2 miles side square.

For swordfish we observe a more important proportion of females in the south from 5°S. It corresponds to the results found during the first program on longline fishery in Seychelles, named PAPPS (Programme d'Action pour la pêche palangrière Seychelloise) (Wendling et al. 2004).

For yellowfin tuna, no specific trends can be noted. The sex ratio is quite homogenous in the different regions where fishes were caught during CAPPES.

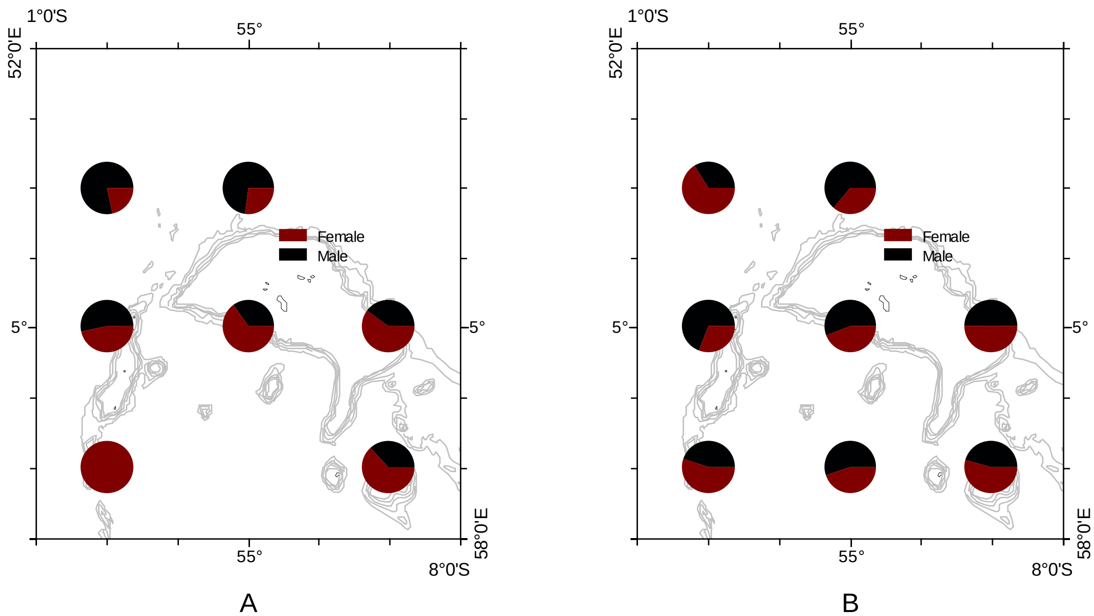


Figure 10: Distribution of the proportion between males and females in 2 miles square (A swordfish, B tuna)

II.6 Bait

Some interesting results were obtained from the bait efficiency tests. Small bonitos (by-catches from the purse seine fishery, called 'ravil') seem to attract bigger swordfish and reduce catches of non-targeted species. This result was obtained during CAPPES 3. Nevertheless more trials have to be done before making further conclusions. In general no new type of bait (saury (SAU), muroaji (MUO), bonito (RAV), or mackerel (MAC)) used during the program provides better results than squid traditionally used by the local operators. Squid proved to be the most efficient to catch swordfish as well as tuna (Table 5). Nevertheless a good percentage of yellowfin tuna was caught with saury. Considering that it has been rarely used, mackerel seems to be good bait for tuna.
Regarding discards, saury appears to give very bad results and attracts a lot of by-catch species. In the program sharks were more attracted by squid.
However more trials are needed as 11 experimental trips do not provide sufficient data for strong conclusion.

Table 5: Distribution of the catches by type of bait

	Total catch	MAC	MUO	RAV	SAU	SQU
Xiphias gladius	344	9	3	31	36	265
Thunnus albacares	171	26	7	4	63	71
Thunnus obesus	61	8		1	16	36
Istiophorus platypterus	137	4		8	55	70
Makaira indica	7				3	4
Makaira mazara	7			4	1	2
Coryphanea hippurus	76	1	2		29	44
Katsuwonus pelamis	28				2	26
Other Species	57	8	0	1	26	9
Rays	29	5	0	0	15	9
Sharks	141	3	1	20	28	89
Discard	420	91	10	0	260	59
Total	1478	155	23	69	534	684
Percentage	100	**10.5**	**1.6**	**4.7**	**36.1**	**46.3**
Total hooks	29449	2465	1296	2248	9877	13563
Percentage	100	8.4	4.4	7.6	33.5	46.1

II.7 Depredation

Depredation by sharks and marine mammals were observed during the program (Figure 11). Most of the sharks involved were pelagic species such as the blue shark (*Prionace glauca*), the oceanic whitetip shark (*Carcharinus longimanus*) and the silky shark (*Carcharinus falciformis)*. The marine mammals predating on the line was most of the time the short finned pilot whale (*Globicephala macrorrhynchus*) or the false killer whale (*Pseudorca crassidens*). They can be easily mistaken.
Predators, if not directly observed from the boat, were identified from the shape of the bite: a clean bite and often in a small area for sharks and large (fin included) bites and muscles torn to shreds for marine mammals.

A

B

Figure 11: Swordfish depredated by a shark (A) and a false killer whale (B)

Only 53 fishes were depredated during CAPPES (Table 6). This represents a specific percentage of 4% (it represents the number of fish depredated in term of the total of the same fishes caught), which is weak in comparison with the percentage usually encountered in the Indian Ocean.
The predation of swordfish represents 60% of the total predation and 9.3% of the specific one. In comparison with the other species (respectively 11% and 3.5% for yellowfin tuna and 6% and 4.9% for bigeye tuna), swordfish are the most attacked species. These results correspond to the percentage of predation calculated for the Seychellois semi industrial fishery for the period 1995-2005, where 56% of the fishes depredated were swordfish and 13% were yellowfin tuna (Wendling et al. 2004). 26.4% of the damages were caused by sharks and 40% by marine mammals. It can be noted that Nishida et al. observed during a program conducted in the Indian Ocean to study the tuna longline fishery, 35% of depredation caused by sharks and 62% by marine mammals (Nishida et al. 2003).

Table 6: Summary of the fishes depredated by species and kind of predator. The specific percentage represents the number of fish depredated in term of total fishes of the same species caught

N	Species	% specific	Shark(%)	MM(%)	Unkown
32	Xiphias gladius	9.3%	21.9%	56.3%	21.9%
6	Thunnus albacares	3.5%	33.3%	16.7%	50%
3	Thunnus obesus	4.9%	33.3%	33%	33%
6	Istiophorus platypterus	4.4%	17.0%	16.7%	66.7%
2	Coryphaena hippurus	2.6%	50%		50%
2	Katsuwonus pelamis	7.1%	100.0%		
1	Lophotus capellei	33.3%			100%
1	Alepisaurus ferox	0.3%			100%
53	All species	4.5%	26.4%	39.6%	34%

A rate of depredation (no. of fishes lost/1000 hooks) has been calculated for the three main commercial species (Table 7). The mean value for all the commercial species is 1.73. It is underestimated because it doesn't take into account the fishes entirely eaten by the predator. It is greater than the rate found during the PAPPS program or for the all the semi industrial fishery for the period 1995-2002 (Wendling et al. 2004).

Table 7: Rate of depredation (number of fishes lost/ 1000 hooks deployed) obtained for the 3 main commercial species during the program.

Species	Rate of depredation (no of fishes lost/1000 hooks)
Xiphias gladius	1.09
Thunnus albacares	0.20
Thunnus obesus	0.10
All commercial species	1.73

III. Conclusion

This paper presents the first analyses conducted since the end of the verification of the database. They already show quite interesting results for the three objectives targeted by the project.

- Concerning the study of the gear behaviour, we can consider that the line shooter can be effectively used. During CAPPES, we tested different setting scenario and are now able to target the depth wanted. To master the fishing depth is fundamental to understand the impacts of longline fisheries on target and by-catch species (Bigelow et al. 2005).
  A manual presenting the configuration of the gear as function of the depth targeted will soon be provided to the skippers of longline vessels.

- For the second objective 'to study fishes habitat', the results have to be more deeply analysed. However first analyses of catches, CPUE and biometry provides some interesting results on fishing location, yield, sex distribution and length classes. They are often in accordance with those found during the previous longline research program PAPPS (Wendling et al. 2004).
  Data should allow drawing a map of the species distribution as function of depth and temperature like those provided in the ZONECO New Caledonia program (Chavance 2005). A database for CTD has yet to be built in order to study all the environmental profiles.

- Concerning bait, more trials are needed before being able to make stronger conclusions. At first sight, small bonitos and saury appear to be a good option, but this has to be confirmed. Pascal Bach will present a paper in Mayotte in November 2006 on the 'ravil experience' (Bach et al. In prep) during the 'Incidental catch of non-targeted marine species: Problems and mitigation measures' workshop.

The predation during CAPPES was quite important particularly during CAPPES 10. It is a concern of the Seychelles Fishing Authority, which is aware of the problems encountered by fishermen and of the important economic loss they have to face. The depredation issue will be further studied through a French expert mission, which will take place at the end of the year. The experts will take part in a commercial trip and then organise a two days workshop. A mitigation plan should be proposed to all stakeholders, based on the findings of the experts.

The CAPPES research program was carried out in collaboration with the Seychellois commercial fishermen. In fact, not only did they take part in research trips (CAPPES 1 and 2) but some are still using TDRs regularly. Furthermore, SFA continues providing them with CATSAT data to help them better choose their fishing location. A final workshop where all the results of CAPPES will be presented is planned for the beginning of 2007. A recovery plan for the longline fishery has been drafted as part of the 5-year Seychelles Fisheries Development Plan and should be applied from the beginning of 2007.

Finally, even if the CAPPES project fieldwork has come to its end, similar research will continue through the SWIOFP (South West Indian Ocean Fisheries Project) project, which is supposed to begin in 2007. In fact, the Seychelles are responsible for the regional coordination of the component named ‘’assessment and sustainable use of pelagic fishes’’. One activity of this component has the same thematic as CAPPES, which is improving fishing strategy for target species, reduce by-catch and mitigate depredation by marine mammals; the SWIOFP project will build on the results obtained during CAPPES. A further research initiative at regional level is the CAPPER soon to be implemented in la Reunion and there will be close collaboration with SFA. Finally the data collected during the CAPPES project will be used by Vincent Lucas for part of his master’s degree thesis in Perpignan (France) in 2006/2008.

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