CHARACTERISTICS OF SWORDFISH (*Xiphias gladius)* CATCHES ACHIEVED BY EXPERIMENTAL FISHING USING INSTRUMENTED LONGLINE IN THE SEYCHELLES EXCLUSIVE ECONOMIC ZONE (EEZ)

Preliminary results of an experimental long line fishing program: « Programme d'Action de la Pêche Palangrière Seychelloise – PAPPS »

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October, 2003

Abstract

The local pelagic longline fishery targeting swordfish started in the Seychelles in 1995. Actually 10 vessels are active. In June 2000 a two year research program was set up through partnership of SFA, IFREMER and the French cooperation in Seychelles. Between 2000 and 2001, 18 longline trips corresponding to 136 sets were conducted on the SFA's research vessel "L'Amitié". The longlines were equipped with hook timers and temperature/depth recorders which permitted estimates of the time, the depth and the survival rate of the catch to be made. Most of the longlines were set after sunset and hauled after sunrise. A total of 730 swordfish were caught (64.4% of commercial species). Yellowfin and bigeye tuna represents 18.8% and 12.0% of the commercial catches respectively. The number of swordfish caught on hook timer is half the total swordfish caught (345 fish). Catch by unit of effort (CPUE) for swordfish for the program is equal to 12.2 fish for 1000 hooks. Data collected by hook timers, show similar trends as observed in Reunion island (France), 52% of swordfish are caught during the first 3 hours following the hooks setting. CPUE balance by hour are maximum between 8:00 PM and 9:00 PM (5.76 fish.1000-1 hooks.hour^{-1}). Average survival rate calculated was 20%. More than 50% of the swordfish were dead after six hour on hook. Sex ratio (female vs. male) was 0.696, and a significant difference between the ratio female - male is observed for the majority of month of the year. The distribution of sex ratio of sexed fish show that female proportion is higher than male for swordfish up to 180 cm (MFL).

Résumé

La pêcherie palangrière seychelloise ciblant l'espadon a démarré aux Seychelles en 1995. Actuellement, 10 navires sont actifs. En juin 2000, un programme de recherche de 2 ans fut créé au travers d'un partenariat entre la SFA, l'IFREMER et la Coopération française aux Seychelles. Entre 2000 et 2001, 18 campagnes à la mer correspondant à 136 poses de palangres furent effectuées à l'aide du navire de recherche de la SFA « L'Amitié ». Les palangres étaient équipées d'horloges à hameçons et d'enregistreurs de pression/température afin d'estimer le temps, la profondeur et le taux de survie des prises. La plupart des palangres furent filées après le couché du soleil et virées après l'aube. Un total de 730 espadons a été capturé (64,4% des espèces commerciales). Les captures de thons albacore et patudo représentent respectivement 18,8% et 12% des prises commerciales. Le nombre d'espadons capturés sur les horloges à hameçons (345 poissons) représente la moitié des captures totales de la même espèce. Les captures par unité d'effort (CPUE) d'espadon dans le cadre de ce programme sont de 12.2 poissons pour 1000 hameçons. Les données collectées par les horloges à hameçons présentent des tendances identiques à celles observées à l'île de la Réunion (France), 52% des espadons sont capturés après les 3 premières heures de mise à l'eau des hameçons. Les CPUE pondérées par heure sont maximales entre 20h et 21h (5,76 poissons.1000 hameçons^{-1}.heure^{-1}). Le taux moyen de survie est de 20% et la durée maximale est de 13h53. Moins de 50% des espadons sont vivants après 6 heures de capture. Le sex-ratio (femelles/mâles) est de 0.696 et *une différence significative est observée entre le ratio femelle – mâle sur la majorité des mois de l'année. La distribution des sex-ratios présente permet d'observer une proportion de femelles supérieure pour les espadons de plus de 180 cm (LMF).*

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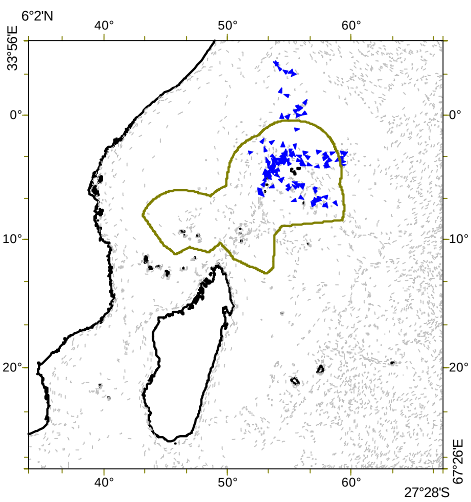
1. Introduction

The local pelagic longline fishery started in the Seychelles in 1995 with 2 vessels (Bargain *et al.,* 2000 and 2001). More vessels entered the fishery from 1998, and by 2001, 11 were operating. The main target species is swordfish *(Xyphias gladius*), which are iced or frozen and sold locally or exported. Catches also includes non targeted species like tuna *(Thunnus albacares, Thunnus obesus*) or other billfish (*Istiophorus platypterus, Makaira mazara, Makaira indica*) and others (skates, rays) which are generally discarded. In June 2000 a scientific program was drawn up in the Seychelles, aimed at supporting the development of the longline fishery, in the Western Indian Ocean. This program was set up through the partnership of three institutions: the Seychelles Fishing Authority (Seychelles), the French Institute for the exploitation of the sea (IFREMER, Reunion Island) and the French cooperation based in Seychelles (French Embassy, Seychelles).

This program was achieved through experimental fishing campaigns on board of SFA's Research Vessel "L'Amitié". A total of 18 scientific campaigns using instrumented longline were carried out in the Seychelles exclusive economic zone (EEZ). A total of 136 sets were made between October 2000 and July 2002, corresponding to a fishing effort of 60,434 hooks. The location of all the fishing operations are shown on figure 1.



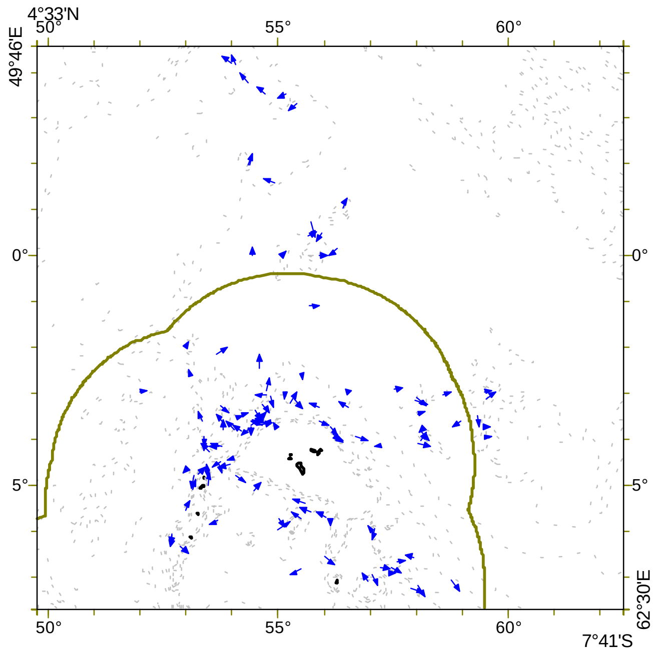


Figure 1. *Location of the Seychelles EEZ and the 136 longline (blue arrows) sets for the program used in the analysis.*

The fishing gear, a traditional longline (Berkeley et al.,1983) was made of a 20 km long Polyamide monofilament (3 mm diameter) main line. It was equipped with 100 to 500 hooks (8/0, Tuna hook or "J" hook) snapped on the main line (branch line was polyamide monofilament 0.18 – 0.20 mm diameter). Each segment (or basket) included between 8 to 15 hooks (mean 9) 50 meters apart. Each segment was attached to the main line by 2 ropes (27 or 45 m) and maintained on the surface with buoys.

The targeted species was Swordfish *(Xyphias gladius*) and in order to maximise its catch (Kume and Joseph, 1969 ; Carey F.G. and Robinson, 1981 ; Carey F.G., 1990) the sets were generally done after the sunset and hauled after the sunrise. Some longlines were set during the day for specific tuna fishing experiments. All hooks were baited with defrosted squid (200 – 300 g). Every 3 to 5 hooks a fluorescent green light stick (Berkeley et al.,1983) was attached 3 m above the hook to increase the attraction to the bait.

Based on previous experimental longline programs (Boggs C.H., 1992 ; Bach et al., 1999 ; Poisson et Taquet, 2001) each main line was equipped with 100 to 300 hook timers (HT) and between 2 to 4 temperature/depth recorders to collect or estimate: the time of the catch, the survival rate, the depth of the catch and the relationships with environmental parameters. The total fishing effort is 60,434 hooks including 24,409 equipped with hook timers (40%). The fishing effort for the hooks equipped with a timer is presented on figure 2.

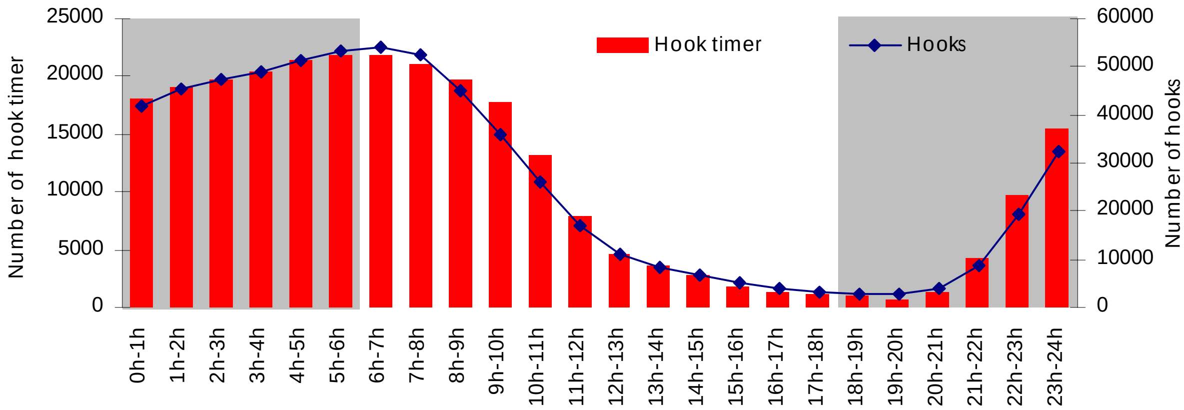


Figure 2. *Fishing effort in hooks and hook timer according to the time of the day used on the 136 experimental longlines sets between October 2001 and July 2002 in Seychelles' EEZ. Dark areas represent night period.*

2. Catches

2.1. Specific diversity

Swordfish was the main species caught (table 1) with 730 fish (64.4% of commercial species and 60.3% of total catch). Yellowfin and big eye tuna represents 18.8 % and 12.0% of the total commercial catches respectively. Sharks represent 6% of all species captured (commercial and non-commercial species).

These results are different to the ones obtained in La Reunion (France) with 46.5% for swordfish, 7.8% for yellowfin and 10.3 % for big eye tuna (Poisson F. and Taquet M., 2001). The number of swordfish caught on hook timers is about half of the total swordfish caught, or 345 fish (47%).

Tableau 1. *Commercial catches for the 136 long lines and relative proportion for each species.*

Species	Number of catch	Number of catches on hook timer	Percentage (%)	Catch rate (fish.1000 hooks^{-1})
Xiphias gladius	730	345	64.4	12.1
Thunnus albacares	213	92	18.8	3.6
Thunnus obesus	136	75	12.0	2.2
Istiophorus hippurus	34	17	3.0	0.3
Makaira mazara	5	1	0.4	<0.1
Makaira indica	3	1	0.3	<0.1
Other commercial species	12	6	1.0	0.2

2.2. Geographical distribution

From data collected during the program, geographic distribution of the 3 main species caught are represented in figure 3 by 0.5 square miles. Most of the catches were obtained around the Mahe continental shelf. Some sets were made around the "Coco de mer" sea mount.

The geographical distribution of CPUE by 0.5 square miles for the three main species have been done and is represented in figure 4. The CPUE for swordfish recorded during the program is equal to 12.2 fish for 1000 hooks, that is slightly superior to the CPUE obtained by the professional longline fishery (Wendling B. *et al*., 2003) during the same period (11.8 fish for 1000 hooks).

For yellowfin and bigeye tuna, CPUE are 3.6 and 2.2 fish for 1000 hooks respectively compared to the 4.6 and 1.5 obtained by the professional longline fishery. The evolution of CPUE for swordfish by quarter is represented in figures 5 and 6.

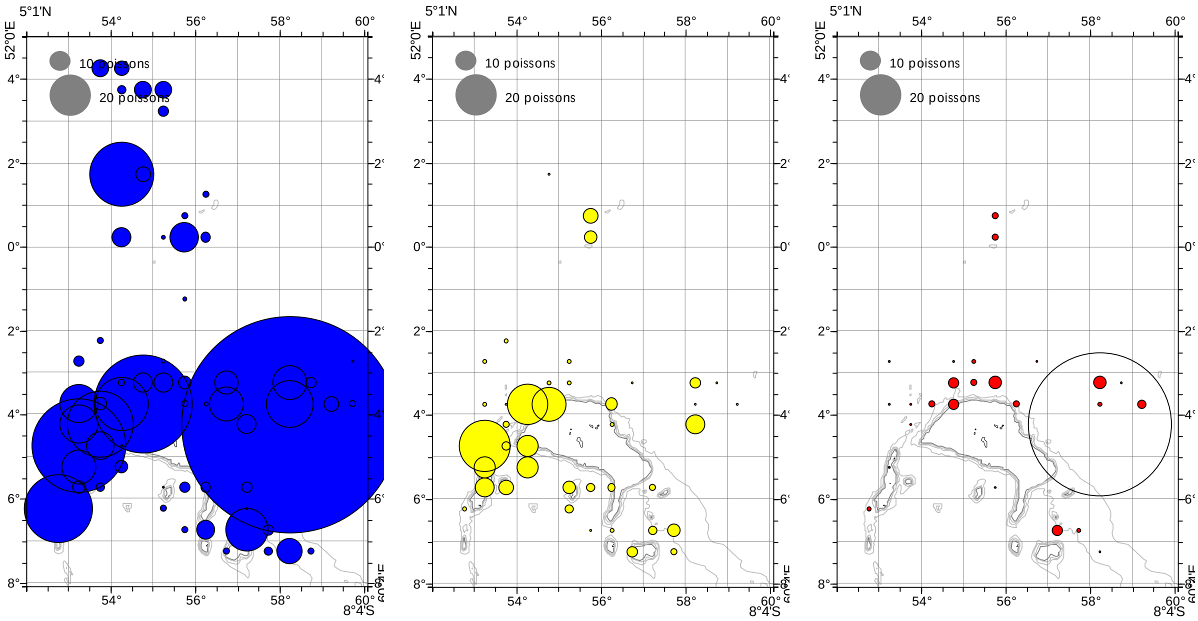


Figure 3. *Spatial distribution of catches for swordfish (blue at left), yellowfin (yellow at the middle) and big eye tuna (red at right), number of fish. For bigeye tuna empty circle represent exceptional catches obtained on 4'15S 58°15'E.*

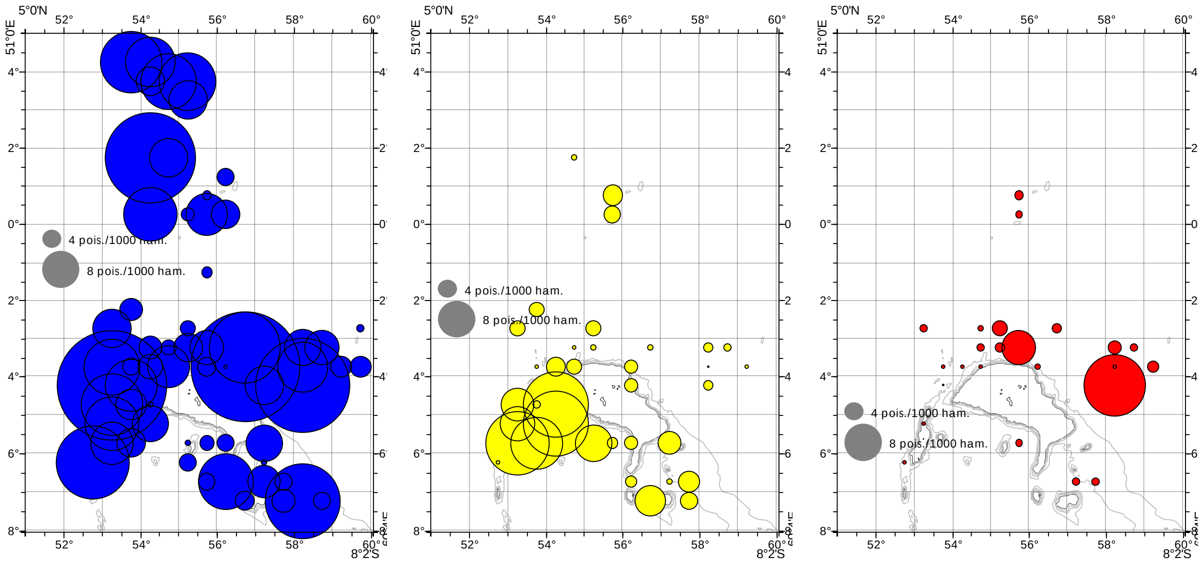


Figure 4. *Spatial distribution of CPUE(number of fish for 1000 hooks) for swordfish (blue at left), yellowfin (yellow at the middle) and big eye tuna (red at right).*

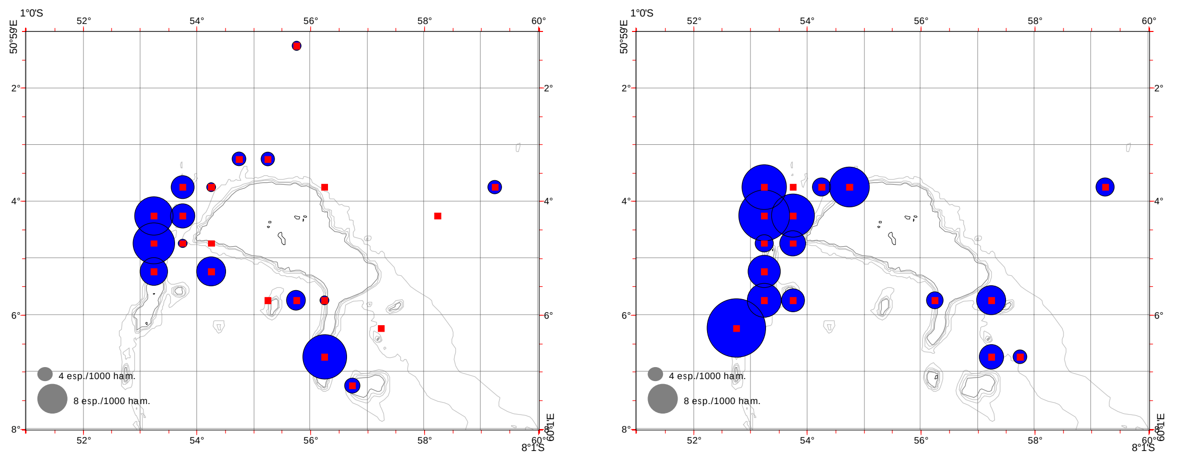


Figure 5. Spatial distribution of CPUE (number fish/1000 hooks) for the first (left) and the second quarter (right) by 0.5 square mille (n = 184 and 209). The red points represent the geographic areas sampled during the program.

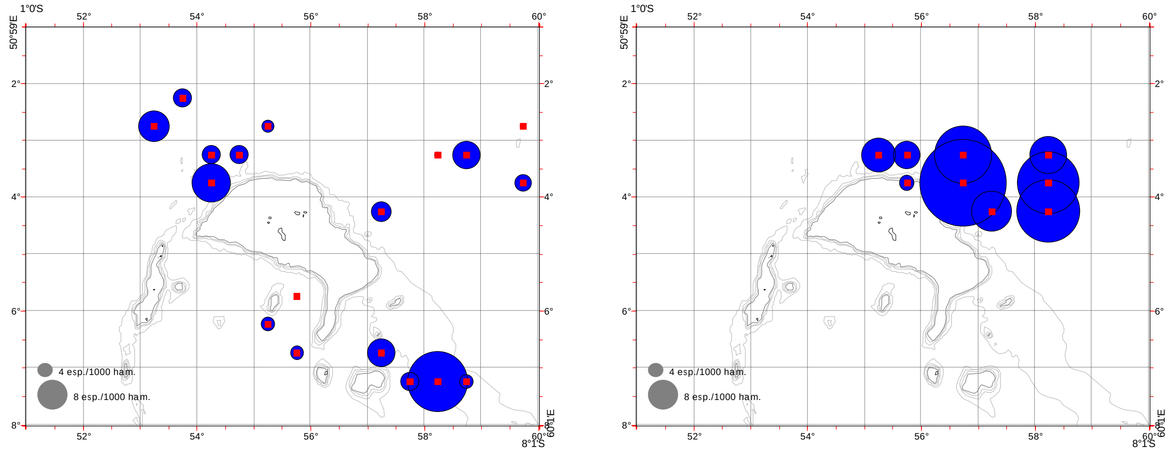


Figure 6. *Spatial distribution of CPUE (number fish/1000 hooks) for the third (left) and the fourth quarter (right) by 0.5 square mille (n = 122 and 182). The red points represent the geographic areas sampled during the program.*

Monthly evolution of CPUE is represented in figure 7. A non-parametric Analyse of variance (ANOVA) has been applied on the data (Kruskal and Wallis test) confirmed (H = 15,3 et p = 0,08) that CPUE show significant difference during the year. From July to September, CPUE are less than 10 fish.1000 hooks^{-1} (no significant difference p>0.05). On the contrary, higher CPUE are observed at the end and beginning of the year (October and January) and in May.

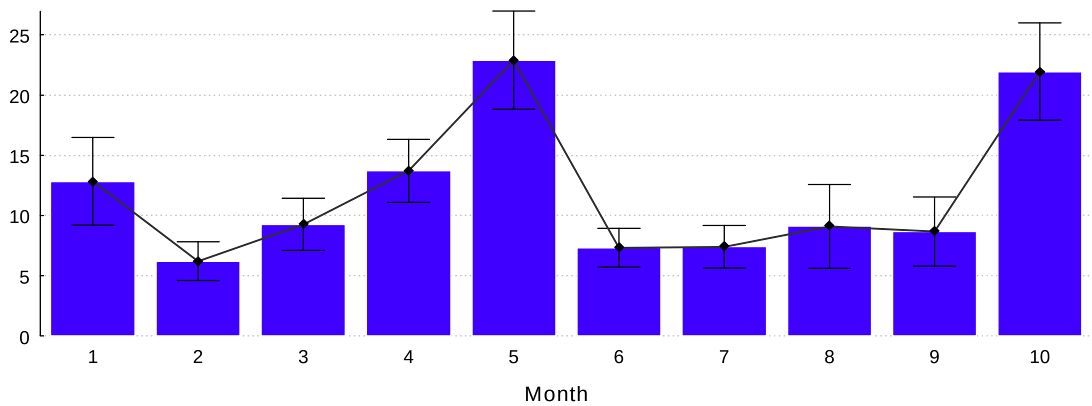


Figure 7. *Evolution of swordfish CPUE (+1SE) by month (swordfish.1000^{-1} hooks) observed on the 136 fishing operation from October 2000 to July 2004 (n=694). Data are no available for the months November and December.*

3. Behaviour of the target species

Two analyses were realised from data collected by hook timer. In one hand the repartition of swordfish catches from the time the longline was set and on the other hand the CPUE balance by the fishing effort deployed by hour (swordfish.1000^{-1} hooks.hour^{-1}). The total number of swordfish caught according to setting time of instrumented hooks is represented in figure 8. A total of 52% of swordfish were caught during the first 3 hours after the hook was set and 21% within the first hour. After the sixth hours, the frequencies are inferior to 5%. These results are similar to what Poisson *et al.* (2001) described for Reunion Island. The two main hypotheses are the decrease of the bait's appetence (coloration, chemical flavour) and the lost of brightness of light stick.

The CPUE balance by the fishing effort deployed by hour (swordfish.1000^{-1} hooks.hour^{-1}) are presented in figure 9. The CPUE increase significantly after 7:00 PM to reach a maximal value (between 8:00 PM and 9:00 PM) of 5.76 fish.1000^{-1} hooks.hour^{-1} and decrease progressively after 11:00 PM to a minimum at 7:00 and 8:00 in the morning. During the day CPUE are low and no catches were recorded between 3:00 and 7:00 PM. This is probably linked to the fishing effort deployed at this period. The distribution of the CPUE during the day is identical to what was observed by F. Poisson and M. Taquet (2001) for the Reunion longline fishery using the same technologies and materials. Only catch obtain between 10am and 7:00 PM seems to be lower. This could be partially explained by a lower fishing effort during this period of the day recorded in Reunion island.

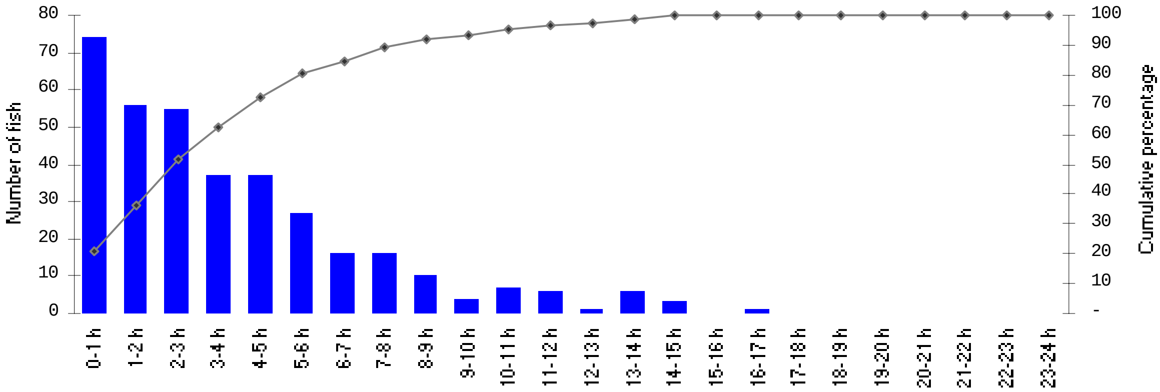


Figure 8. *Cumulative percentage of swordfish catch according to the setting time of hook timer.*

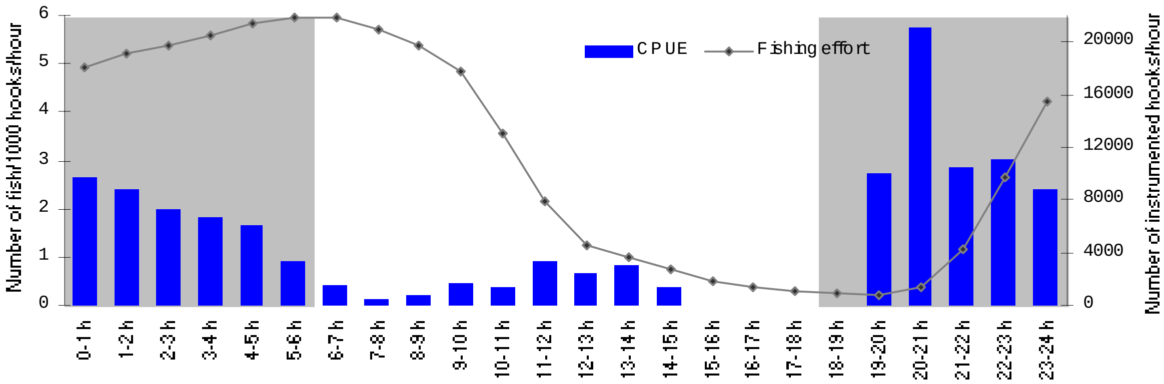


Figure 9. *Swordfish CPUE (swordfish.1000^{-1} hooks.hour^{-1}) obtained during the program on hook timer (n = 345). Dark areas represent night period.*

The survival time was collected for 317 fish, taking into account the time of capture and fish status (alive or dead) when the fish were brought on board (figure 10). Time after capture spreads from 0h06 to 15h37. The maximum survival time observed for a swordfish is 13:53, however less than 50% of the swordfish were dead after six hour on the hook.

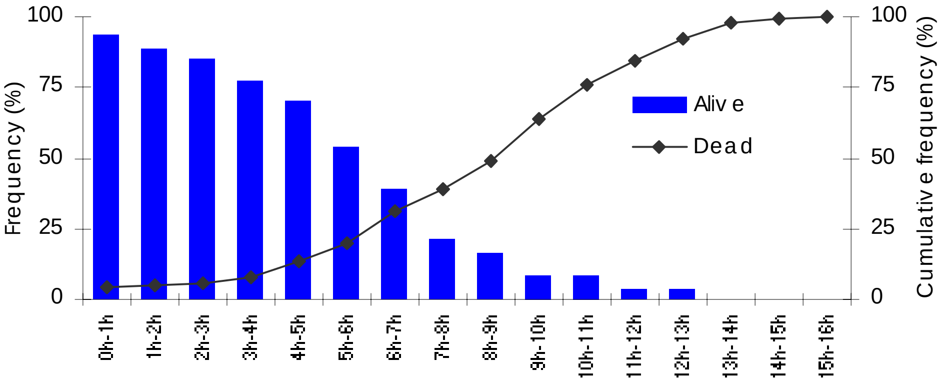


Figure 10. *Swordfish survival time after been hooked (n = 317). Red line represent 50% limit.*

3. Biological data

3.1. Biometric measures

During every campaign all swordfish caught were sexed and measured for biometric study. Three measurements were recorded, Pectoral Anal Length (PAL), Eye Fork Length (EFL) and Maxillary Fork Length (MFL). The data are linked to geographical position hence allow spatial-temporal analyses of size frequency distribution. Relationships between different measures are presented on table 2 and figure 10. Linear function is under the form y = ax + b + ε defined by STATISTICA 5.1, Statsoft ©. A total of 644 swordfish were measured, 635 for MFL, 585 for PAL, 484 for EFL (table 2 and figure 11).

Table 2. *Characteristics of the different conversion equations.*

x (cm)	y (cm)	a	b	n	R²
MFL	PAL	0.381	-5.271	575	0.9134
MFL	EFL	0.932	-8.475	483	0.9798
EFL	MFL	1.052	11.626	483	0.9798
EFL	PAL	0.403	-1.188	435	0.9131
PAL	MFL	2.396	24.135	575	0.9134
PAL	EFL	2.263	12.860	435	0.9131

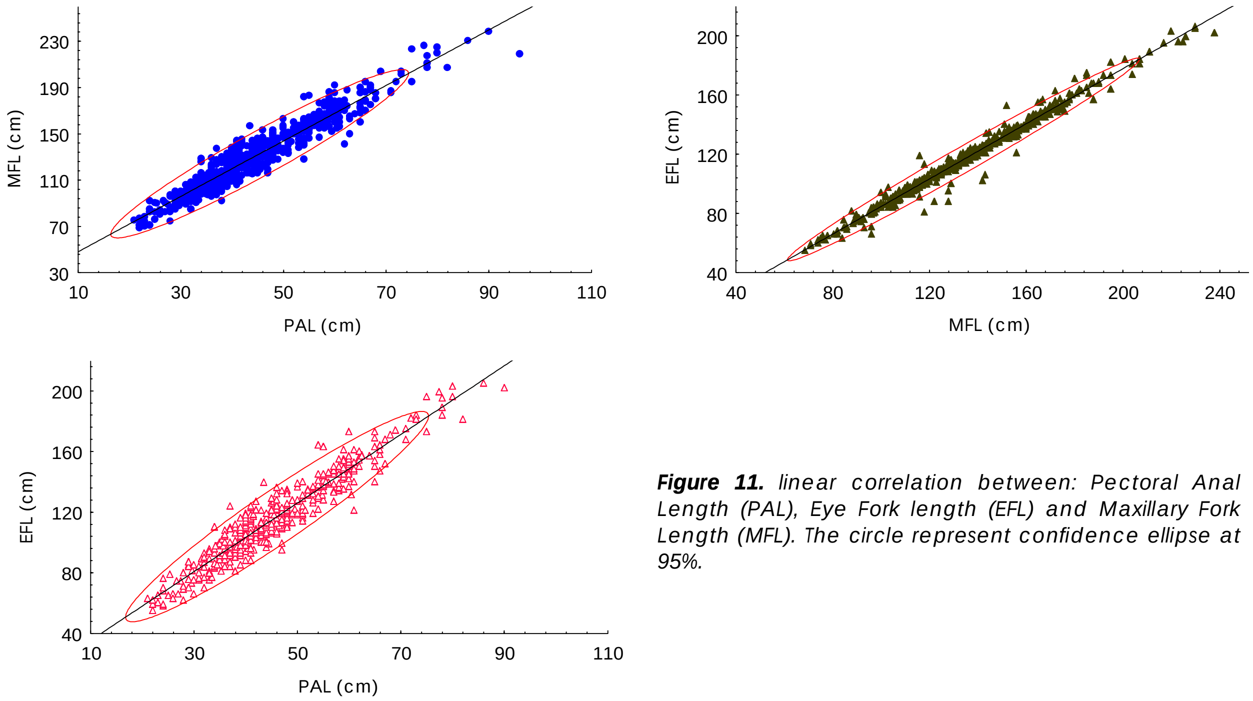


Figure 11. *linear correlation between: Pectoral Anal Length (PAL), Eye Fork length (EFL) and Maxillary Fork Length (MFL). The circle represent confidence ellipse at 95%.*

3.2. Size frequency

Analysis of size frequency data were realised from maxillary fork Length (MFL) and pectoral anal length (LPA) from a sample of 635 fish for MFL, and 585 for PAL (figures 12). Size class are in centimetres. For MFL, distributions are spread between 36 and 238 cm and for PAL between 21 and 96 cm. (median MFL: 130 cm – PAL: 44 cm; mean MFL: 132.3 cm and PAL: 45.3 cm).

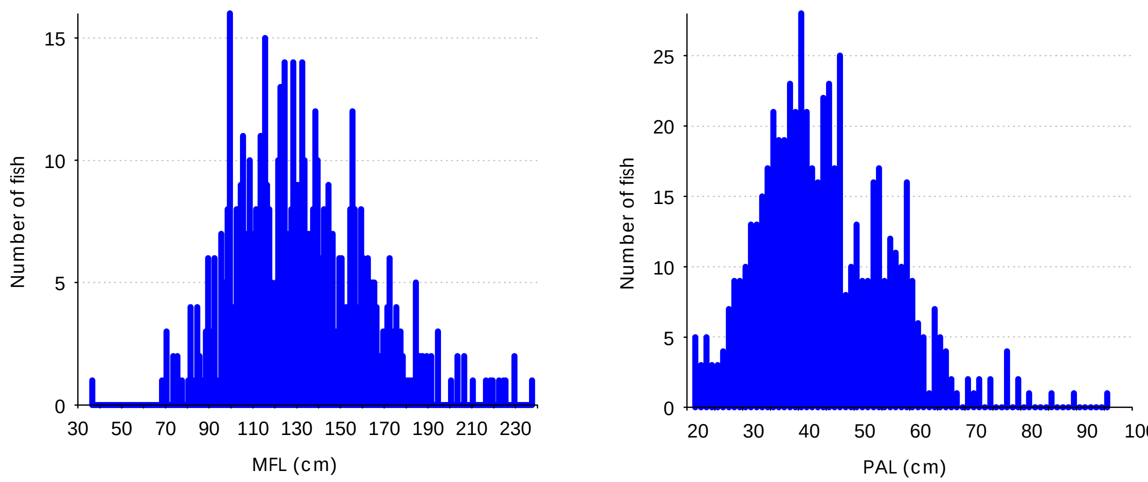


Figure 12. *Size frequency distribution MFL (Maxillary Fork Length) and PAL (Pectoral Anal Length) for swordfish caught and measured during the program (n = 635).*

3.2. Sex ratio

Sex ratio (number of female vs. number of male) observed on the 616 swordfish sexed during the program was 0.696. This sex ratio is opposite of what have been observed in La Reunion (SR: 1.8) by Poisson *et al.* (2001). The annual evolution of sex ratios is presented in table 3 data were aggregated by month. All fish were sexed by visual observation of gonads.

In the way to evaluate data observed vs. theoretical arbitrary frequency, a Chi² test (Kendall et Stuart, 1979) was applied on monthly length frequencies (female ^{observed} and male ^{theoretic}). The Chi² values show a significant difference between the ratios female / male for the majority of the months, with the exception of September, where the proportion of male is significantly higher. The annual sex ratio is very significant (Chi² 0.05 ; 1 = 99.96).

Histological study of gonads realised by Poisson *et al.* (2001) on the Reunion longline fishery identified from indices define by Hinton *et al.* (1997), showed the laying period and size of first maturity. On the geographical area located between 15 et 25° south and 52 et 57° east, laying take place in October and April and size of sexual maturity (MFL_{50}) were 170.4 ± 2.1 cm (95 % CI) for females and 119.8 ± 1.9 cm (95 % CI) for males (Poisson *et al.,* 2001 ; Vampouille *et al*., 2001). This laying period is associated with sex-ratio close to 1 in the area of concern. Taking into account the smallest size of our sample, monthly evolution of sex ratios in the Seychelles region do not follow the same trend as what was observed in the south. Only histological analyses of gonads will allow provide concrete results on the area.

Table 3. *Monthly evolution of sex ratio (female VS male) of swordfish sexed during the program. No experimental fishing trips during November and December*

Month	Sex-ratio	Number of fish (F+M)	Chi²	
Janvier	0.33	4	1.33	M>F
Février	0.91	42	0.18	
Mars	0.59	119	12.81	M>F
Avril	1.08	81	0.23	
Mai	0.37	89	25.86	M>F
Juin	0.62	21	1.92	M>F
Juillet	0.64	46	3.57	M>F
Août	1.33	21	1.00	
Septembre	3.29	30	36.57	F>M
Octobre	0.60	163	16.48	M>F
Novembre	-	-		
Décembre	-	-		
Total	**0.696**	**616**	**99.96**	**M>>F**

Spatial analyses of sex ratio are presented in figure 13. To obtain a significant number of data, values were aggregated by 2 nautical miles square. Data on the north of the equator do not cover a whole year (only February, July and October). The general trend is a higher proportion of female to the south of 5° south. A second distribution by semester has been presented taking into account the lack of data on laying period in the region.

The distribution of sex ratio (female vs. male) by 10 cm size class of sexed fish show 2 modes (figure 14): where female proportion is higher than male. These modes concern juvenile from size range between 80 and 110 cm and larger fish when maxillary fork length is higher than the class size 170 – 180 cm.

A polynomial equation could be obtained to model the sex ration in function of MFL. It is equal to $y = -1{,}07)^{-7} x^4 + (6{,}759)^{-5} x^3 - (0{,}015) x^2 + (1{,}371) x - 42{,}993 + \boldsymbol{\varepsilon}$ ($R^2 = 0{,}881$; y = sex ratio ; x = MFL size class by 10 cm range). These results are identical to the observations realised on the Reunion fishery (Poisson *et al.*, 2001) for the mature swordfish where proportion of female became dominant for MFL higher than 165 cm.

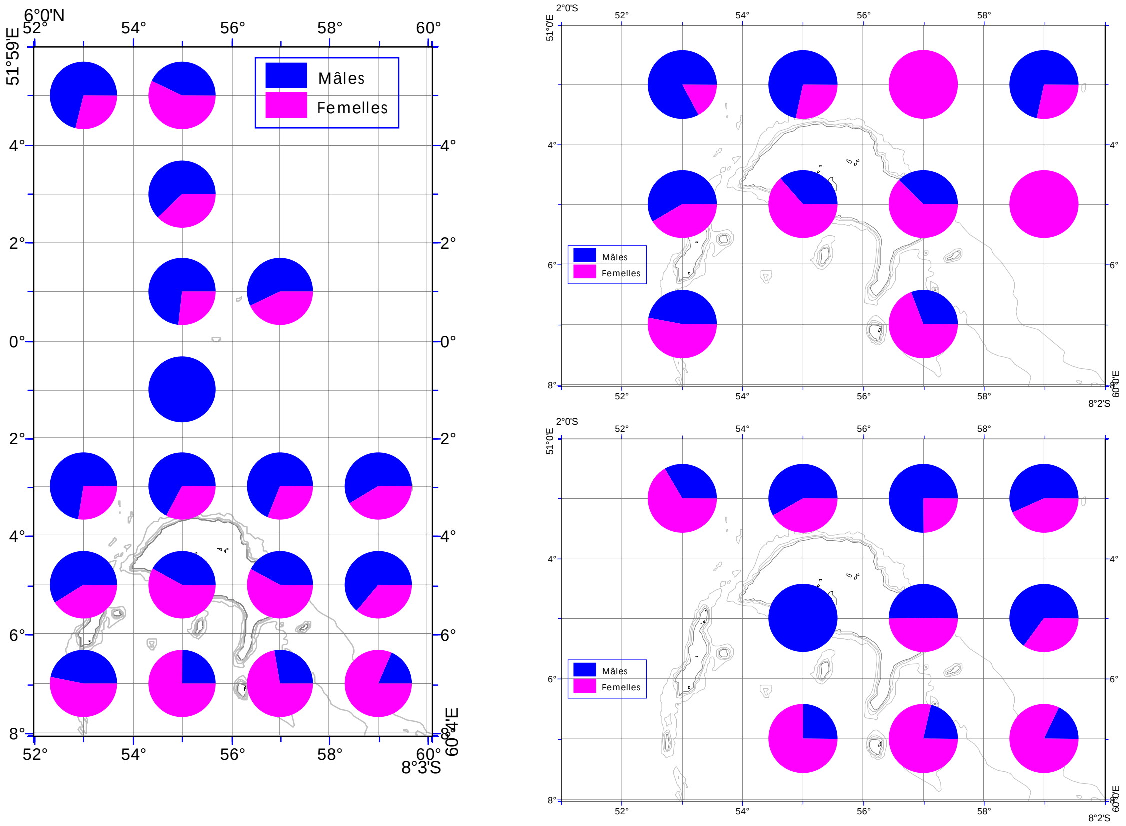


Figure 13. *Geographical location of observed sex ratio by 2 nautical miles square – on the left global results obtain for the entire program (n: 612) – (top right) sex ratio observed for the first semester (n: 139 males and 213 females, SR: 1.53) – (below right) sex ratio observed for the second semester s (n: 146 males and 114 females, SR: 0.78).*

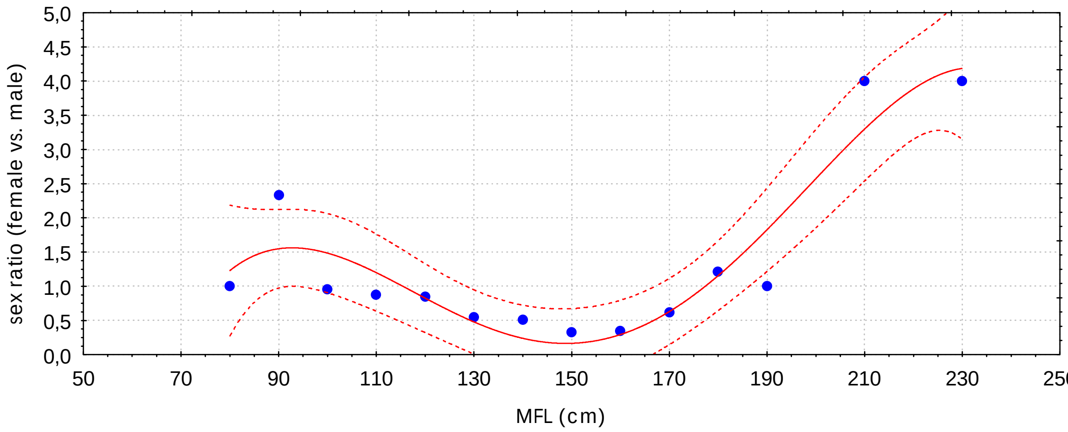


Figure 14. *Repartition of swordfish sex ratio (female vs. males) sexed during the program and aggregated by 10 cm class size. The curves represent the polynomial model, and the model interval of confidence at 95%.*

Acknowledgments

We thank Mr. R. Payet and Mr. P. Michaud for their administrative support during this program. Thanks also goes out to Mr. P. Woodcock and Mr.G. Ernesta for their logistic support and to the crew of R/V L'Amitié's for their continual support throughout this program.

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