SWIOFP – ASCLME Project

Mesoscale eddies and large pelagic fish in the Mozambique Channel

Grands prédateurs en relation avec les tourbillons méso-échelles dans le Canal du Mozambique.

Report of monitored longline fishing experiments carried out on board the fishing vessel "Brahma" from 1st to 20th April 2010

Rapport de la campagne de pêches expérimentales à la palangre réalisées à bord du palangrier « Brahma » du 1er au 20 Avril 2010

BACH P., FILIPPI T., BERKE G. & SHARP A.

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CONTENTS

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1 Context : SWIOFP/ASCLME project

Up to now, only tuna and some large pelagic fishes associated with tuna fisheries in the South Western Indian Ocean are under monitoring and management by the regional fisheries management organization (RFMO): Indian Ocean Tuna Commission (IOTC). However many other marine living resources in the region are exploited by commercial fisheries and require a regional approach in order to improve their respective management in an "ecosystem approach to fisheries" perspective. These resources are mostly spread along Exclusive Economic Zones (EEZs) of coastal countries representing shared stocks of crustaceans, demersal fishes and small pelagic fishes. Because of the weakness of financial supports in marine fisheries research in the region compared to the diversity of stocks to manage, both scientists and policy managers have to share information and knowledge to improve marine resource management at local, regional and basin-wide scales. Moreover, the south-western part of the Indian Ocean is known to be home of several endangered species of the marine megafauna (sea turtles, marine mammals) and the improvement of biological knowledge regarding these species is essential in order to reduce interactions with fishing activities. The South West Indian Ocean Fishery Commission became operational relatively recently. The aim of this Commission is to promote a regional management of local fisheries complementary to marine fisheries management activities of the Indian Ocean Tuna Commission. This management will be structured around the three core functions of fisheries management: monitoring/survey, control (decisions on the appropriate exploitation levels) and surveillance (strict monitoring of compliance). Activities regarding the survey/monitoring are classically carried out by the Scientific and Technical Committee (SCT) Major objectives for the first five years of the SWIOF Project are to develop operational framework to implement an efficient MCS. This initiative does not necessarily depend on the emergence of the SWIOFC but it represents a driver of its survey/monitoring function.

Indeed, the principal components are:

☞ Integration of local fishery database at a regional level,

☞ Audit of knowledge in general (scientific, technical) of major exploited stocks (crustaceans, demersal stocks and small and large pelagic fishes) with the aim of respective estimations of exploitation levels,

☞ The collect of data for non-commercial species due to theirs interactions with commercial fisheries (for instance some marine mammals interacted with gillnet fisheries, sea turtles interacted with longline fishery and purse seine fishery on FAD).

Countries involved in the project are countries of the South West Indian Ocean having coast along the ocean : Kenya, Tanzania, Mozambique, Republic of South Africa, Seychelles, Comoros, Madagascar, Mauritius and France (Eparses Islands, Mayotte, Tromelin, Reunion). Somalia could be soon integrated in the project as observer country.

The global cost of these five years project is 21 millions $ US (~ 16 millions €).

The French Fund for the Environment (FFEM = Fonds Français pour l'Environnement Mondial) participates in this project as co-financial support at a level of 800 K€ (1 millions of US $). Essentially, these funds are mobilized to support 3 components of the project :

- Component 1 "Data and Information": Gap analysis and supply of an integrator database software named « StatBase »,
- Component 4 "Pelagic Fishes": Electronic tagging programme for swordfish and bigeye tuna, deployment of anchored Fish Aggregating Devices (FADs) allowing managing actions to increase the number of fishing activities for a given fishing pressure, improvement of fishing gear (develop methods to mitigate adverse impact of some fishing practices, application of the ecosystem based approach to fisheries),
- Component 5 "Non-commercial species": research studies of some marine mammals populations interacting with longline fisheries in the region, research programme of sea turtles movement behaviour to identify area and period for which the risk of accidental mortality due to fishing activities is high.

This project is carried out at a regional scale simultaneously with the ASCLME project (Agulhas Somalia Current Large Marine Ecosystem). One of the objectives of the ASCLME project is to develop indicators (simple or composite) to characterize ecosystems. As corollary of this objective, ASCLME investigates physical and biological characteristics of the ocean in this region and then the habitat of marine living resources targeted in the SWIOF project. These two regional projects ASCLME and SWIOFP are parts of a set of project included in the Marge Marine Ecosystem international project. These two projects share some tools or operational framework such as oceanographic cruises.

2 Introduction : SWIOFP/ASCLME cruise in the Mozambique Channel

Mesoscale eddies in the Mozambique Channel are known to enhance the biological productivity of oceanic regional waters from several oceanographic events: upwelling of deep waters in the core of cyclonic eddies, advection phenomena of the coastal biological productivity towards oceanic waters, concentration of nutrients to the border of eddies (high physical gradients structure). Recent studies have shown the propagation of the biological enrichment through different components of the ecosystem, from the primary production (phytoplancton) to top pelagic predators such as seabirds, tuna, sharks, billfish, sea turtles, marine mammals). These top predators patrol in foraging areas related to mesoscale eddies in this region.

This ASCLME/SWIOFP oceanographic cruise is characterized by the interdisciplinary collaborative approach planned to analyze the role of eddies in the increase of the biological production of the pelagic ecosystem and on the catchability of large pelagic fishes intensively exploited by both purse seiner and longliner fleets. The high probability of incidental catches (bycatch) by longliners in this fishing zone that could be « hotspots of pelagic biodiversity » will be analyzed. This impact of eddies on the ecosystem will be studied at different levels of the food chain from the first component of the chain (phytoplankton) to top predators.

In order to achieve an ecosystem based research taking into account all its components simultaneously, two working and sampling platfoms were combined (1) the oceanographic research vessel of IRD «Antea » operating in the ASCLME project framework and (2) a fishing vessel equipped with a drifting longline operating in the SWIOF project, particularly the component 4 (Pelagic component) of this project. The objectives of the cruise of the R/V «Antea» were :

❶ To describe physical, chemical, biogeochemical environments including sampling of the phytoplankton and zooplankton and estimations of the primary production,

❷ To quantify the biomass of the micronekton obtained with acoustic transect (echosounder), to describe micronekton patches observed with an echosounder, and to study the fauna composition of these micronekton patches sampled with a pelagic trawl.

The commercial longliner, the F/V « Brahma » based in La Reunion undertook a sampling of large pelagic fishes in the mesoscale eddies by using a monitored longline. An effort was done to deploy the fishing gear in eddies previously sampled by the R/V « Antea ». Large pelagic fishes were sampled in their open ocean habitat by using a drifting longline equipped with temperature depth recorders and hook timers. The species identification and the biological sampling (biometry, stomach contents, muscles and liver for genetic, isotopic and contaminants analysis, hard parts: otoliths and vertebra) were done for all individuals caught (except individuals of protected species immediately released alive if this type of events occurs). Finally, interactions between the longline and the marine megafauna were addressed by considering data on the longline behaviour during the fishing time and the trigger action of hook timers.

The objectives of this second report of operations carried out in the frame of the component 4 of the SWIOF project are similar to those described previously in the first cruise report (Bach et al., 2009) [1] :

❶ To describe the operational methodology (hydrological stations, fishing trials) used during the cruise ,

❷ To present the timetable of operations realized,

❸ To list biological and fishing samples collected on board as preliminary results,

❹ To briefly conclude regarding the sampling strategy adapted to consider simultaneously environment and living resources of the ecosystem.

1 - Bach P., E. Romanov, T. Filippi, 2009. SWIOFP/ASCLME Project: Mesoscale eddies and large pelagic fish in the Mozambique Channel – Report of monitored longline fishing experiments carried out on board the fishing vessel “Manohal” from 27th of November to 18th of December 2008. IRD/SWIOFP Report, 74 p.

Moreover, we took advantage of these longline fishing operations in the Mozambique Channel to deploy electronic tags on 3 species of sharks (the blue shark, *Prionace glauca*, the silky shark, *Carcharhinus falciformis*, the oceanic white tip shark, *Carcharhinus longimanus*) on interest in the frame of the European research project MADE "Mitigation of Adverse Ecological Impact of Open Ocean Fisheries", (http://www.made-project.eu/).

It must be noted that the deployment of electronic tags (PSAT tag) on swordfish which is one of the target species involved in the SWIOFP Component 4 was one of the major objectives of this cruise as well. Unfortunately, this objective could not be reached as individuals with a suitable size were dead or too exhausted to be tagged.

3 Time schedule of operations

This second cruise of the SWIOFP Component 4 « Pelagic Fishes » started on Thursday 1st of April from Le Port (La Reunion) at 6:00 pm.
The route of the cruise (date, time, latitude, longitude every 5 minutes) was obtained from the vessel monitoring system (VMS) and this data will be stored in the SEALOR [2] database.

At the beginning of the cruise, the major part of oceanographic operations and sampling would have been achieved in a spatial window located between latitudes 18°S et 24°S. In order to join this area as fast as possible we decided to travel towards the south of Madagascar crossing the Sainte Marie Cap.

Synthetic representations of operations at sea (hydrology, instrumented longline fishing=ILL) are displayed on Figures 1 and 2 and on the Table 1.
The geographic positions of ILLs superposed on the oceanographic environment described by the sea level anomaly (SLA) parameters are displayed on the figure 2.

Table 1 – Date, time and geographical positions of the setting and the hauling of instrumented longline (ILL) sets for the SWIOFP Longline cruise n°2.

Date	Set number	Setting time	Setting duration (hrs)	Lat (°S)	Long (°E)
03/04/2010	1	19:05	2.49	24.68	49.73
06/04/2010	2	20:58	1.42	24,46	42,74
07/04/2010	3	20:29	1.40	23,65	41,46
08/04/2010	4	20:50	1.40	23,06	39,98
09/04/2010	5	20:40	1.46	21,82	39,89
10/04/2010	6	20:38	1.44	20,14	39,6
11/04/2010	7	21:05	1.47	19,79	40,54
12/04/2010	8	20:53	1.52	20,03	40,77
14/04/2010	9	20:45	1.52	18,84	39,36
15/04/2010	10	20:28	2.07	18,72	40,6
16/04/2010	11	20:33	2.23	19,57	41,51

2 - Bach P., N. Rabearisoa, T. Filippi & S. Hubas, 2008 - The first year of **SEALOR** : Database of **SEA**-going observer surveys monitoring the local pelagic **LO**ngline fishery based in La **R**eunion. IOTC/WPEB/WP13, 26 p

Figure 1 – Chronogram (A) and time proportions (B) of operations carried out on board the F/V “Brahma” during the SWIOFP instrumented longline cruise n°2.

4 Material and methods

4.1 Oceanographic observations

Hydrological observations were carried out using CTD probe SEABIRD Seacat SBE19plus (equipped with depth, temperature, salinity, oxygen and fluorescence sensors). Probe casts were carried out to the depth ~ 450 m with assistance of vessel' anchor winch. With this equipment we obtained vertical profiles of the temperature (°C), salinity (PSU), dissolved oxygen (ml/l) and chlorophyll (Figure 2).

Station duration was approximately 1 hour, therefore to minimize time losses, most of the stations were coupled with fishing operations: generally after the setting of longline. Some stations were done both before and after the setting. Some hydrological stations were not associated with fishing operation.

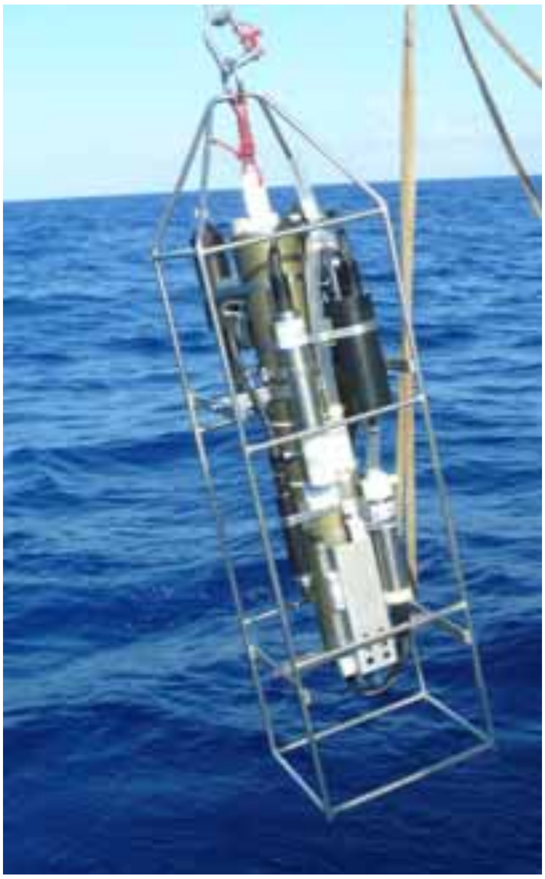


Figure 2 – Deployment of the CTD probe SEABIRD Seacat SBE19plus

4.2 Biological observations

All biological sampling were performed during hauling of the longline. Sampling matrix and planned sampling volumes are presented in the Table 2.

All fish were measured with a calliper (for straight length measurements) and measuring tape (curved length measurements) with precision to 1 cm. Several types of morphometric measurements were taken to develop relationships for further conversion of size to size or size to weight. The following measurements were taken:

Tuna: straight fork length (FL); curved fork length (CFL); straight predorsal length (PDL), and straight pectoral-anal length (PAL), (Figure 3 A).

Billfish: curved total length (TL); straight lower jaw-fork length (LJFL), curved lower jaw-fork length (CLJFL), curved eye-fork length (EFL), curved pectoral-anal length (PAL), (Figure 3 B).

Sharks: curved total length (TL); curved fork length (FL); curved standard length (SL); curved inter-dorsal length (IDL); straight length of the rear margin of the left and the right pectoral fin P1P (L) and P1P (R) respectively, (Figure 3 C).

Skates: straight total length (TL), straight disk width (DW) and straight disk length (DL).

Other species: straight fork length (FL).

Total weight was measured with spring balances or electronic balances:

100 kg max weight spring balances for fish > 20 kg, accuracy = 1 kg,

50 kg max weight electronic balances for fish 1-20 kg, accuracy = 50 g,

and 1 kg max weight spring balances for fish < 1 kg, and for gonads and liver, accuracy = 5 g.

Sex and maturity stage: of fish were recorded, gonad were weighed. Liver was weighed in tuna.

Stomach fullness: were recorded using (using semi-quantitative scale from 0 to 4): 0 – empty stomach, 1 – traces of food, 2 – less than ½ of stomach, 3 – more than ½ of stomach, 4 – full stomach, its walls stretched. Non-empty stomachs were sampled totally for every species till reaching cumulative number of 30 stomachs. After this limit, non-empty stomachs were randomly sampled.

Samples of white muscles: (~20 g) from the dorsal part of fish close to the head were taken for further analysis of **stable isotopes, lipids, genetics** – for sharks (by request of Nicolas Hubert, ECOMAR) and for swordfish (by request of IFREMER, project IOSSS). Same amount of liver were taken for stable isotopes and lipids analysis. Species sampled and sampling volumes are presented in the Table 2. White muscles and liver samples for stable isotope and lipids studies were placed in the NALGENE® Cryotubes, which stored in the DEWAR container with liquid nitrogen.

Contaminants: It was planned to sample white muscles (preferably 100 g of muscle tissues from dorsal part of fish) and liver (same volume of sample) of tuna, swordfish and two shark species (Table 2) for analysis of contaminant level (PCB) in the fish tissues. However contaminant sampling methodology is non-compatible with fish processing for further marketing. In particular, sampling of relatively big part of white muscles from the dorsal part makes the fish unmarketable. Fish processing by the crew makes impossible also removal of non-contaminated liver from the fish body. Therefore we focused on the contaminant sampling of non-marketable species: blue shark and silky shark. Sampling of tuna was opportunistic. We have also very limited supply of nitrile gloves (less than 10 pairs), which is necessary for clean sampling of tissues for contaminants. When our reserves of clean gloves are finished we developed a technique of tissue sampling using aluminium foil ('RB AluGlove'™, pat. pending) to avoid direct hand contacts with sampled tissue and to protect tissue from hand contamination.

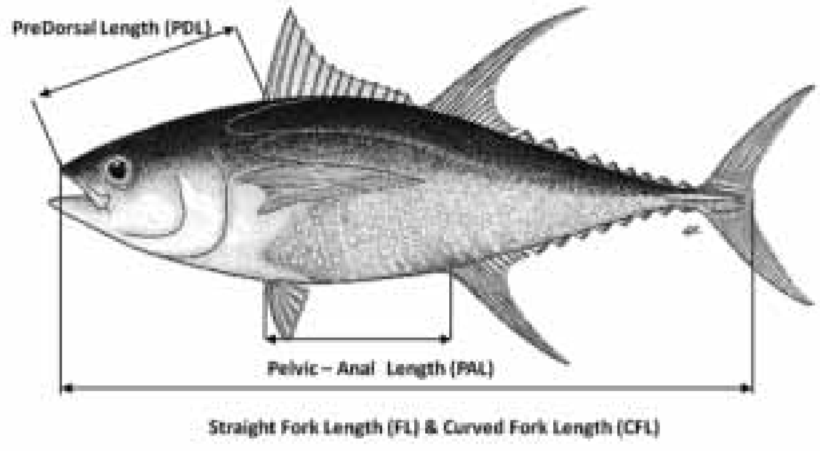
Hard parts: vertebrae (mostly for blue shark and silky shark), first dorsal fin spine (tuna only), otoliths (tuna only) were taken for development of calibration technique on stable isotope composition between white muscles and hard parts and for fish ageing applications.

Table 2. Sampling matrix by species or species groups

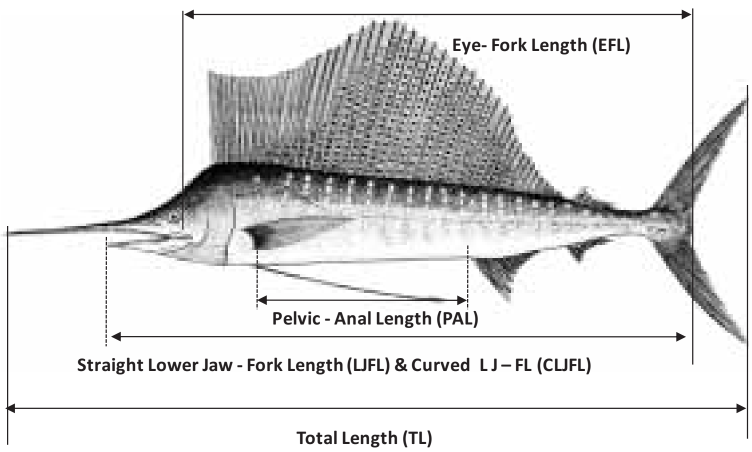
Species		Hook, basket, time recording,	Identification	Measurement	Weighing	Analysis	Contaminants (5)		Lipids (20)		Isotopes (30)		Vertebrae	Otoliths	Spines	Stomachs (30)	Genetics
							Muscles	Liver	Muscles	Liver	Muscles	Liver					
Tuna	YFT	✓	✓	✓	✓	✓	✓ σ	✓ σ	✓	✓	✓	✓	✓	✓	✓	✓	
	BET	✓	✓	✓	✓	✓	✓ σ	✓ σ	✓	✓	✓	✓	✓	✓	✓	✓	
	ALB	✓	✓	✓	✓	✓	✓ σ	✓ σ	✓	✓	✓	✓	✓	✓(**)	✓	✓	
	Other TUN	✓	✓	✓	✓	✓					✓		✓			✓	
Billfish	SWO	✓	✓	✓	✓	✓	✓ σ	✓ σ	✓	✓	✓	✓	✓	✓		✓	✓
	Other BIL	✓	✓	✓	✓	✓					✓		✓			✓	
Sharks	BSH	✓	✓	✓	✓	✓	✓ σ	✓ σ	✓	✓	✓	✓	✓			✓	✓
	FAL	✓	✓	✓	✓	✓	✓ σ	✓ σ	✓	✓	✓	✓	✓			✓	✓
	PSK	✓	✓	✓	✓	✓					✓		✓			✓	✓
	Other sharks	✓	✓	✓	✓	✓					✓		✓ (*)			✓	✓
Other species	ALT	✓	✓	✓	✓	✓					✓	✓		✓ (**)		✓	
	OIL	✓	✓	✓	✓	✓					✓		✓			✓	
	LEC	✓	✓	✓	✓	✓					✓		✓			✓	
	Other	✓	✓	✓	✓	✓					✓					✓	

* Isurus spp. (MAK), Alopias spp. (THR)

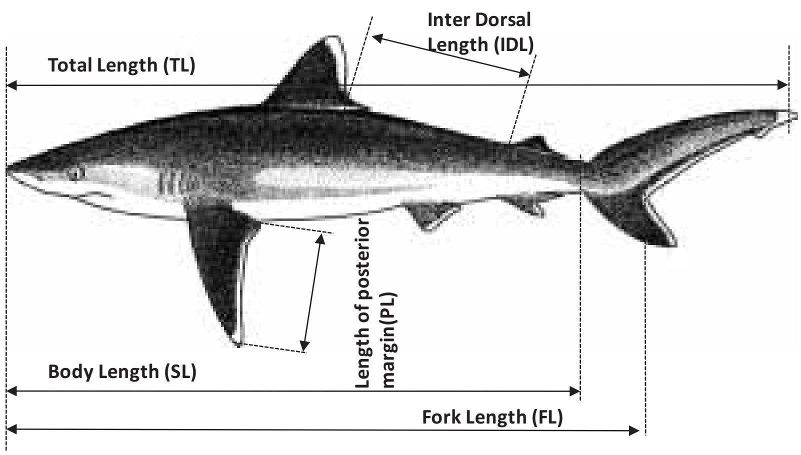
** Optional (depends on time and resources)



A – Tuna and tuna like species



B – Billfish measurements



C - Sharks measurements

Figure 3 – Details of length measurements for tunas (A), billfishes (B) and sharks (C).

4.3 Fishing experiments using instrumented longline

The F/V « Brahma » is a catamaran longliner of 26 m OAL. The crew is composed of 7 persons including the captain. The maximum number of scientists embarked is 4. The F/V "Brahma " is equipped with a nylon monofilament mainline stocked on a spool manufactured by Lindgren Pitman™. The line capacity of the spool is ~ 60 miles for a line diameter of ~ 3.4 mm. This spool is also used for the hauling of the mainline. The longline is a string of hooks attached with a snap to the mainline, which is maintained at the surface of the ocean by buoys also attached to the mainline at regular intervals. A transmitter buoy is fastened at each end of the mainline (Figure 5). During our fishing experiments, the mainline was attached to 10-m polypropylene float lines with 10-l floats at the surface. Monofilament branch lines were 12-m long and snapped on at a constant time interval for a given set. Each brancline is equipped with a weight of 60 g and a circle hook with an offset of 12°. Circle hooks were used because their lower impact on potential capture of non-target species (mainly sea turtles). Squid (*Ilex* spp.) of a individual ranged between 200 g. and 250 g. was used as bait.

For each set, all baskets (the part of the longline between two successive floats) were equipped with time depth recorders. TDRs were programmed to record fishing depth once per minute. The TDRs were placed at the mid-point on the basket mainline which corresponds to its maximum depth (Figure 4). For one experiment the longline behaviour was studied with several TDRs close to each hook of a given basket and with GPS buoys to measure simultaneously the variation of the sag ratio.

Each branch line was equipped with a hook timer. Hook timers indicate elapsed time in minutes between the hooking contact (triggered hook timer with or without capture) of fish on the line and landing on deck, from which the time of the hooking contact is estimated. Hooking depths will be inferred from hook depths at hooking times estimated by a longline shape model by using the COPAL software developed in the frame on the SWIOFP project.

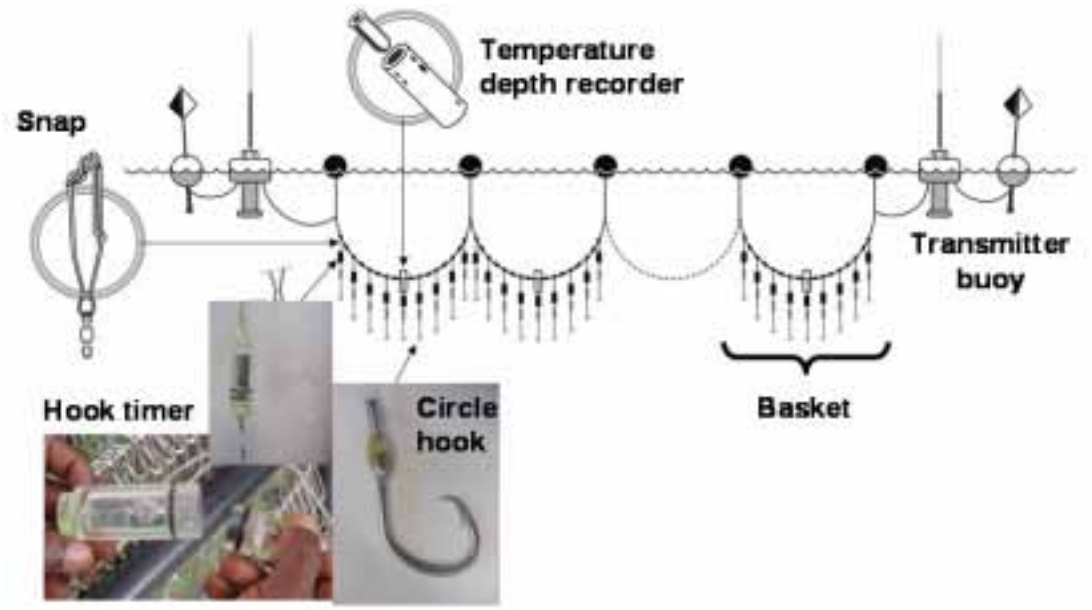


Figure 4 ‑ The instrumented longline deployed during the SWIOFP cruise

5 Preliminay results

5.1 Hydrological situation in the area

Cylonic and anticlonic addies in the Mozambic Channel

Mesoscale gyres in the Mozambique Channel are important oceanographic structures responsible for increased biological productivity of the region. It usually developed in its northern part of the channel demonstrating quasi-stationary behaviour slowly moving southward toward South African coast. Study of the mesoscale dipole (pair of cyclonic-anticyclonic gyre) and its effect on local biological productivity at the various levels of the trophic chain was principal goal of this expedition.

The eddy field in 2010 had two specific characteristics: (1) a strong eastward component as both an anticyclone and two cyclones were part of the structures sampled during the cruise and (2) the presence of a well developed cyclone at the latitude of the narrows instead of the usually observed anticyclone in this location (Figure 5A, B). This resulted in an atypical eddy distribution in early May 2010 when the central Mozambique Channel (MZC) was dominated by a strong cyclone located between 15º and 18°S and a large anticylonic cell in the west between 17° and 22°S (and a weak cyclonic structure in the east of the basin at these latitudes). It should be noted that prior to or during most of previous cruises (2007, 2008, 2009 and - to a lesser extent, 2010), a small cyclonic cell was observed in the eastern part of the northern MZC basin. Such a feature was also suspected to be present during a cruise along the western coast of Madagascar in September 2009.

Following observations carried out on board the R/V "Antea" during our cruise, anticyclones in the central part of the channel were shown to increase in strength when they merged with these positive anomalies.

Vertical temperature structure of water column

A total of 19 CTD profiles were carried out during the cruise with 15 of them associated to instrumented longline set operations (Table 3). Due to a problem on the spool carrying the CTD cable we were not able to obtain CTD profiles for the longline n° 10 and 11.

In this report only temperature profiles are displayed (Figure 6). Vertical profiles showed that a reduction of the surface temperature from the South to the North of Mozambique Channel. In the same direction a reduction of the vertical size of the miixed layer is observed but this size depends also on the position of the hydrological station regarding the eddy structure (cyclone versus anticlyclone). The thickness of the mixed layer appears larger in or close anticyclonic eddies than in or close cyclonic structures.

Kriging maps of temperature values recorded at 50 m and 300 m are displayed on the figure 7. The estimated water masses at 50 m match quite well to the sea level anomalies with weaker temperature values at 50 m in cyclonic eddies than in anticyclonic ones (Figure 6). Estimated water masses at 300 m rather traduce a shift from warmer deep water in the south to colder deep water in the north located at a latitude of about 22° S.

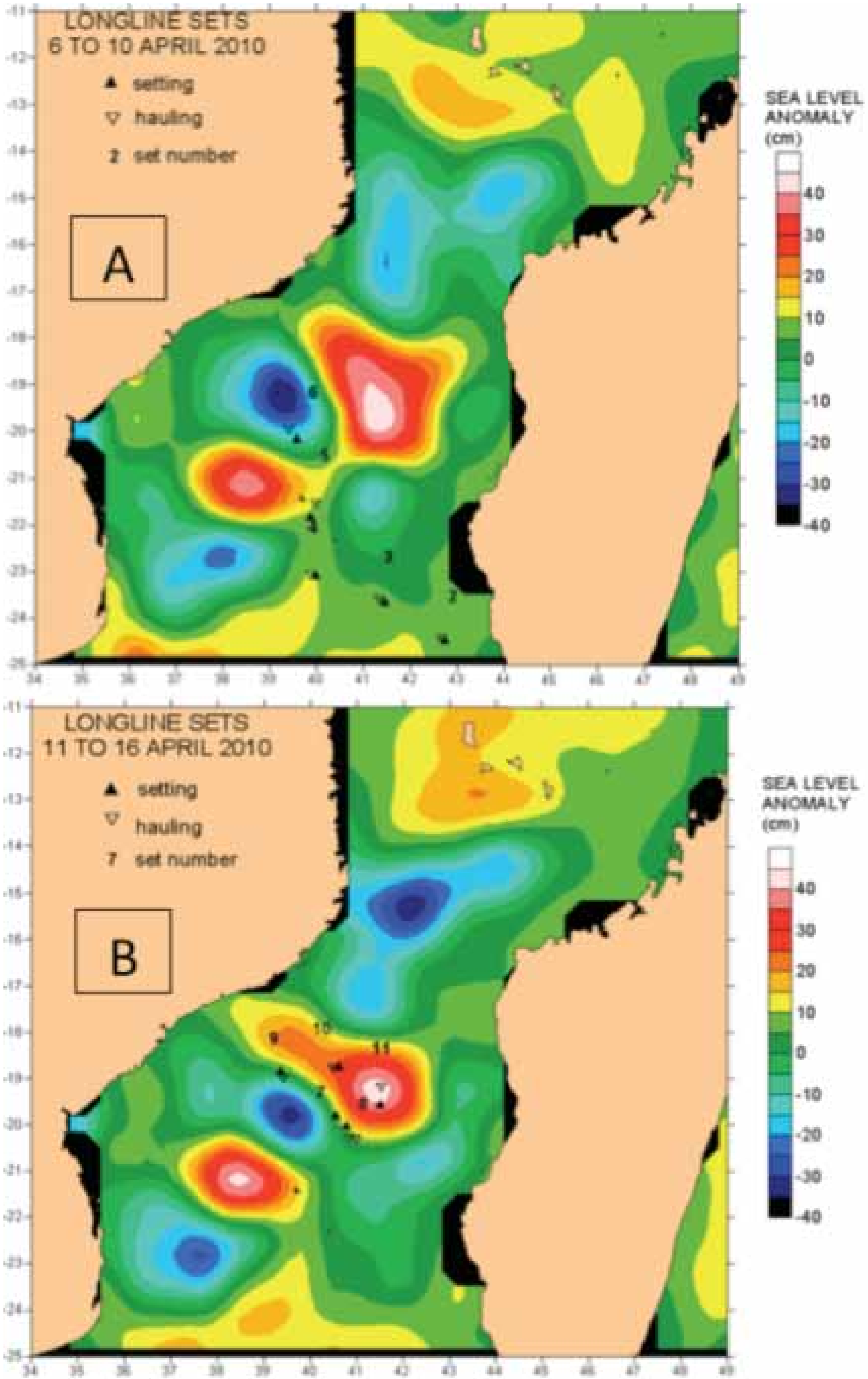

LONGLINE SETS
6 TO 10 APRIL 2010
setting
hauling
2 set number
A
SEA LEVEL ANOMALY (cm)
40
30
20
10
0
-10
-20
-30
-40
LONGLINE SETS
11 TO 16 APRIL 2010
setting
hauling
7 set number
B
SEA LEVEL ANOMALY (cm)
40
30
20
10
0
-10
-20
-30
-40

Figure 5 (page 16) – Positions of the mesoscale eddies in the Mozambique Channel based on sea level height anomalies data obtained through 'OrbMap' channel. Overlap of longline set operations (number). Figure 5A represents average situation for the period 8 to 10 April 2010 and Figure 5B represents the situation for the period 11 to 16 April 2010.

Table 3. Time and positions of CTD profiles carried out during the cruise SWIOFP2

N° CTD Station	Date	Time Reunion	UTC/GMT	Latitude S (°)	Longitude E (°)	Longline n°
1	02/04/10	11:00	7:00	10.506	40.506	xx
2	02/04/10	18:15	14:15	22.335	53.663	xx
3	03/04/10	08:35	4:35	22.883	52.833	xx
4	04/04/10	14:25	10:25	24.3	51.279	1
5	06/04/10	19:30	15:30	24.467	49.941	2
6	07/04/10	10:20	6:20	24.476	42.779	2
7	07/04/10	19:15	15:15	24.346	42.456	**3**
8	08/04/10	11:55	7:55	23.675	41.44	3
9	08/04/10	20:11	16:11	23.525	41.145	4
10	09/04/10	12:24	8:24	23.076	39.987	4
11	09/04/10	19:50	15:50	22.902	39.917	5
12	10/04/10	11:00	7:00	21.851	39.888	5
13	10/04/10	20:20	16:20	21.233	39.967	6
14	11/04/10	11:20	7:20	20.149	39.604	6
15	12/04/10	15:00	11:00	19.953	39.55	7
16	12/04/10	20:20	16:20	20.509	40.91	8
17	13/04/10	12:20	8:20	20.029	40.765	8
18	14/04/10	11:30	7:30	20.417	40.9	xx
19	15/04/10	10:55	6:55	18.82	39.372	9

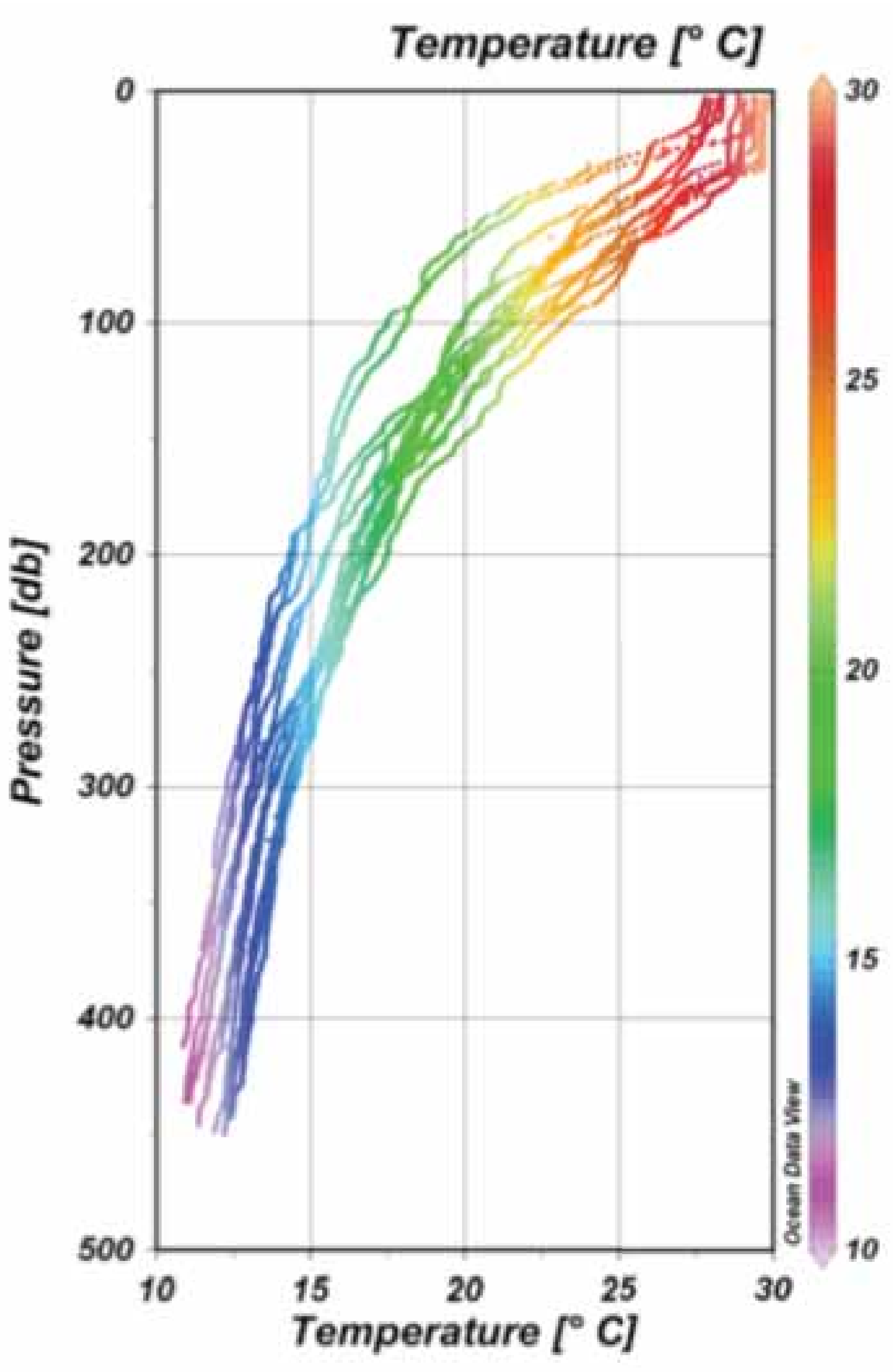


Figure 6 – Vertical temperature profiles obtained from CTD and XBT data collected in the Mozambique Channel.

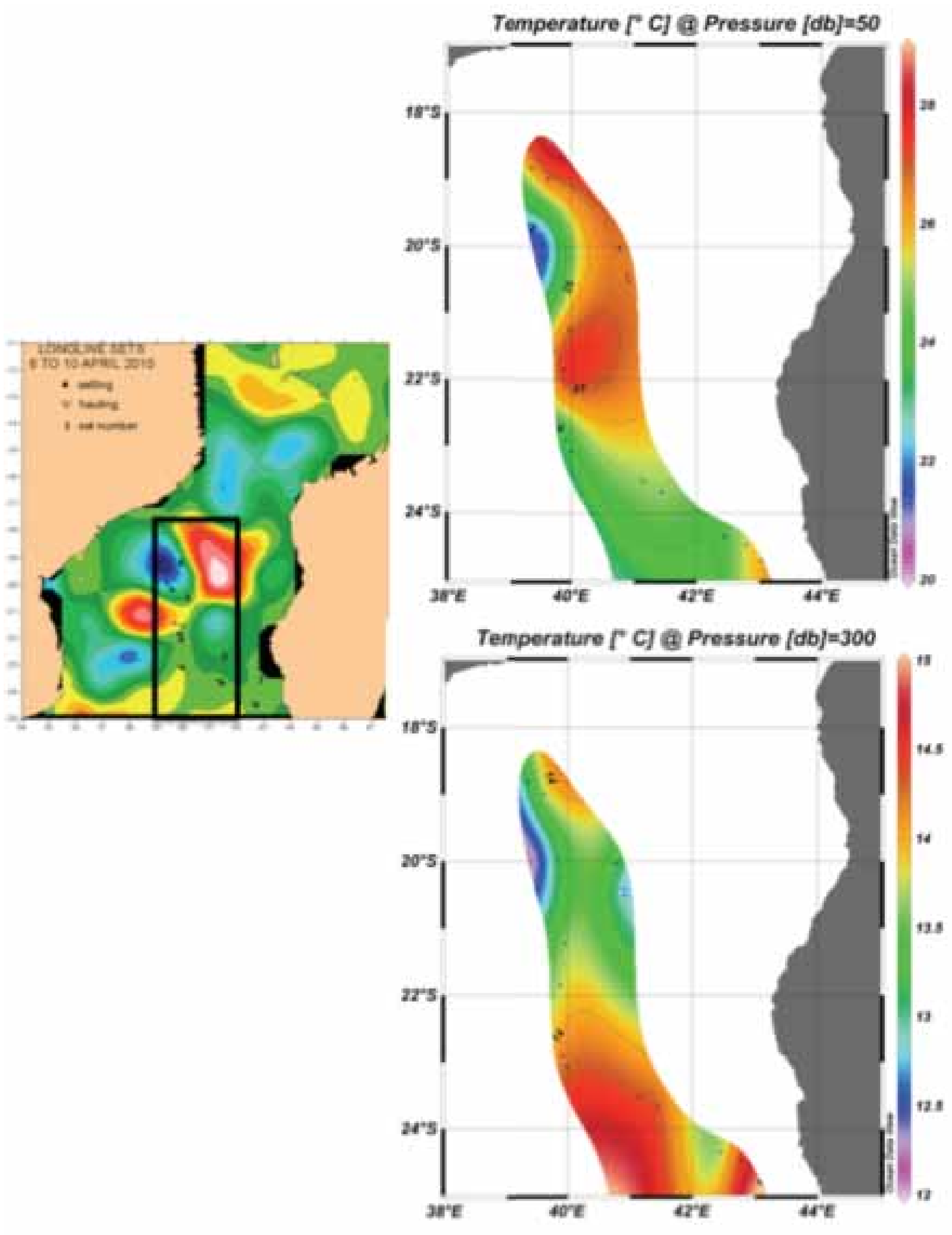


Figure 7 – Kriging map of the water temperature at 50 m depth (top) and 300 m (down) obtained from CTD and XBT data collected in the Mozambique Channel.

5.2 Instrumented longline fishing operations

General presentation of longline fishing operations

The F/V "Brahma" left La Reunion on April 01 and was back at the same location on April 20 after cruising throughout the Mozambique Channel, from South to North. A first fishing set operation was operated 3 days after the departure (03/04/2010) and the entrance in the channel occurred 2 days after (Table 4; Figure 8). The first instrumented longline fishing experiment (ILL) in the Mozambique Channel was set on the 06/04/2010 at night and the others fishing sets were carried out in the Mozambique Channel below the latitude 18° S (Table 4; Figure 8). A total of 10 ILL were set in this region.

Mainline and hook deployments

In order to deploy the mainline at surface or into deep waters the mainline was set in the water by modifying the length of the mainline between floats and then the number of hooks between floats. This strategy was used as the F/V "Brahma" was not equipped with a line shooter which using normally used the set deep longline. To know the maximum fishing depth reached by the line during the fishing time a time depth recorder (TDR) was attached on each basket on the longline. These TDR data will also be used to further estimate the depth and parameters related to depth for each capture (see Bach *et al.*, 2003 [3]).

We present below in the synthetic table 5 a summary of the longline gear deployed for each fishing set. The number of hooks per basket ranged from 6 (for basket at the surface) to 26 (for deep setting). Finally, we deployed 944 baskets for the 11 fishing sets totalizing a number of hooks of 6168 (3277 circle hooks and 2941 J hooks). A total of 5458 hooks was equipped with hook timers them.

Temperature depth recorder and vertical habitat sampled

By modifying the number of hooks per basket (i.e. the mainline length per basket as the distance between hooks was almost the same for each fishing set), baskets were deployed to maximum fishing depths (median value) ranged from 7 m to 291 m (Table 6, Figure 9). A total of 187 baskets was equipped with temperature depth recorder (TDR) to quantify the vertical sampled by the gear (Table 5). For some fishing sets with shallow baskets only (ILL n°5) and with both shallow and deep baskets (ILLs n° 7, 8 and 9), the variability of median values of the depth series suggested a quite strong shoaling of the gear due to environmental forcing. Minimal, maximal and average values of median depth series for each fishing experiments are plotted on the figure 10.

[3] - Bach P., L. Dagorn, A. Bertrand, E. Josse, C. Misselis, 2003. Acoustic telemetry versus monitored longline fishing for studying the vertical distribution of pelagic fish : bigeye tuna (*Thunnus obesus*) in French Polynesia. Fish. Res., 60 (2-3), 281-292.

Table 4 – Date, time and geographical positions of the setting and the hauling of instrumented longline sets

	ILL	START				END				ZONE
		Date	Time	Lat(°)	Long (°)	Date	Heure	Lat(°)	Long (°)	
SETTING	1	03/04/10	19:05	24.677	49.729	03/04/10	21:54	24.803	49.437	GMT-4
HAULING	1	04/04/10	6:54	24.468	49.934	04/04/10	14:14	24.662	49.578	GMT-4
SETTING	2	06/04/10	20:58	24.464	42.738	06/04/10	22:40	24.371	42.511	GMT-3
HAULING	2	07/04/10	5:38	24.449	42.666	07/04/10	9:58	24.378	42.463	GMT-3
SETTING	3	07/04/10	20:29	23.655	41.456	07/04/10	22:09	23.571	41.179	GMT-3
HAULING	3	08/04/10	5:27	23.616	41.332	08/04/10	10:42	23.529	41.149	GMT-3
SETTING	4	08/04/10	20:50	23.058	39.981	08/04/10	22:30	22.843	39.973	GMT-3
HAULING	4	09/04/10	7:20	23.087	39.892	09/04/10	11:45	22.912	39.92	GMT-3
SETTING	5	09/04/10	20:40	21.822	39.89	09/04/10	22:26	21.593	39.903	GMT-3
HAULING	5	10/04/10	6:56	21.554	39.985	10/04/10	10:46	21.237	39.972	GMT-3
SETTING	6	10/04/10	20:38	20.142	39.603	10/04/10	22:22	20.06	39.829	GMT-3
HAULING	6	11/04/10	6:24	19.983	39.426	11/04/10	11:02	19.953	39.55	GMT-3
SETTING	7	11/04/10	21:05	19.794	40.545	11/04/10	22:52	20.02	40.608	GMT-3
HAULING	7	12/04/10	10:55	20.283	40.844	12/04/10	14:50	20.509	40.91	GMT-3
SETTING	8	12/04/10	20:53	20.029	40.765	12/04/10	22:45	20.029	40.545	GMT-3
HAULING	8	13/04/10	6:54	20.312	40.98	13/04/10	12:15	20.413	40.902	GMT-3
SETTING	9	14/04/10	20:45	18.836	39.36	14/04/10	22:37	18.838	39.583	GMT-3
HAULING	9	15/04/10	6:50	19	39.415	15/04/10	10:27	18.988	39.627	GMT-3
SETTING	10	15/04/10	20:28	18.722	40.602	15/04/10	22:35	18.73	40.875	GMT-3
HAULING	10	16/04/10	6:44	18.773	40.476	16/04/10	11:32	18.831	40.641	GMT-3
SETTING	11	16/04/10	20:33	19.567	41.507	16/04/10	22:56	19.238	41.824	GMT-3
HAULING	11	17/04/10	3:16	19.192	41.518	17/04/10	8:26	19.087	41.772	GMT-3

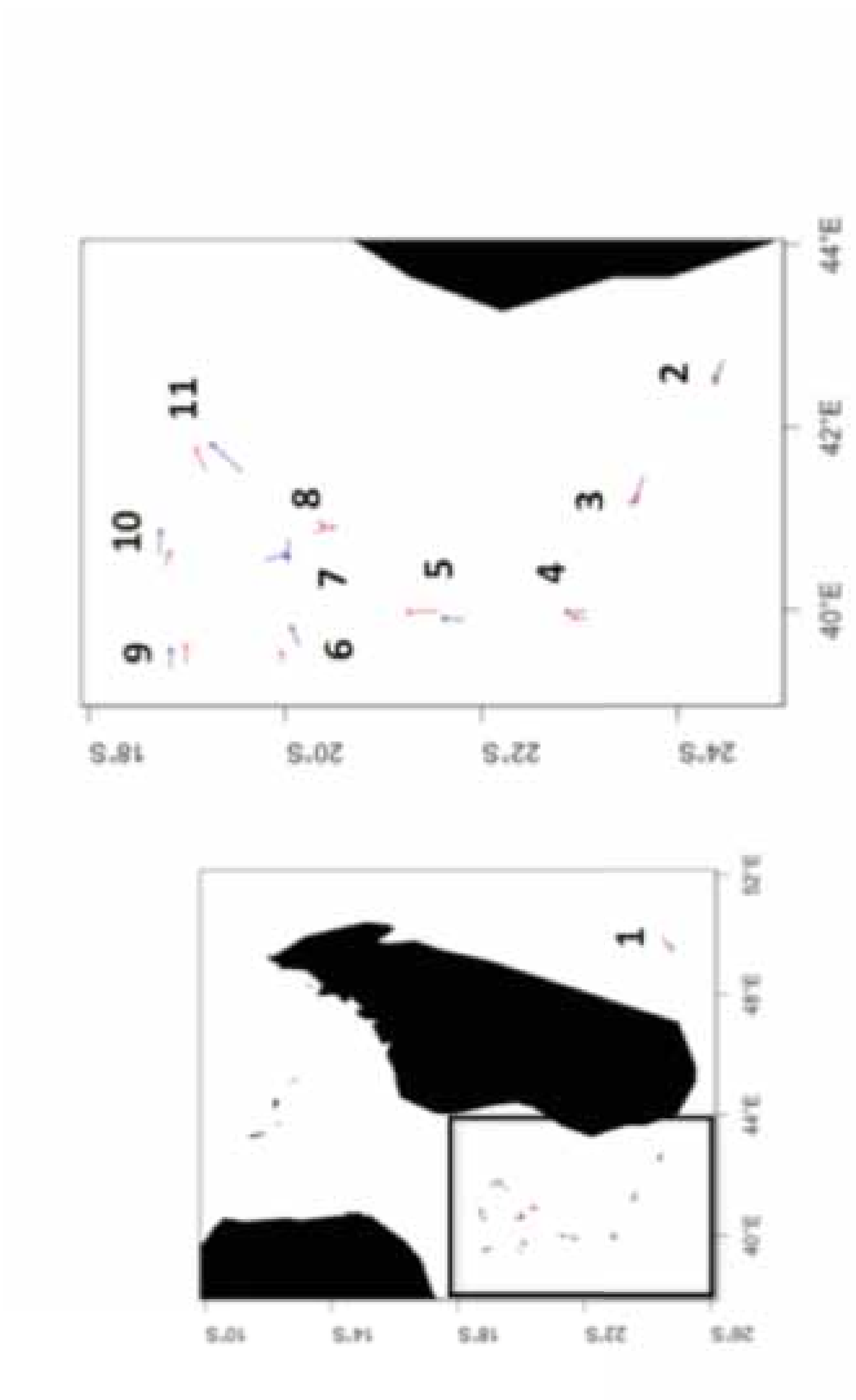


Figure 8 – Geographical locations of longline setting (blue arrow) and hauling (red arrow). (Plotted data from Table 4).

Table 5 – Characteristics of the longline gear for each fishing experiments

Set n°	Setting date	Time start setting	Boat speed (nds)	HPB	TBH (s)
1	03/04/10	19:05	7.2	6	11
2	06/04/10	20:58	8	6	10
3	07/04/10	20:29	6,5 - 8	6	10
4	08/04/10	20:50	8	6	10
5	09/04/10	20:40	8.2	6	10
6	10/04/10	20:38	8.2	6	10
7a	11/04/10	21:05	7.5	6	10
7b	11/04/10	22:14	7.5	20	10
8a	12/04/10	20:53	6.8	6	10
8b	12/04/10	22:03	6.8	20	10
9a	14/04/10	20:45	7.5	6	10
9b	14/04/10	21:55	7.5	20	10
10a	15/04/10	20:28	7.5	6	10
10b	15/04/10	21:42	7.5	26	10
11	16/04/10	20:33	7.7	6	10

HPB = Hook per basket (or hook between floats)

TBH = Time between hooks in seconds

Set n°	DBF (m)	N. sections	N basket/section	N. Baskets
1	285	9.54	13	124
2	288	6	14	84
3	234 - 290	6	14	84
4	290	6	14	84
5	290	6	15	90
6	290	6	15	90
7a	270	4	14	56
7b	810	2	5	10
8a	245	4	14	56
8b	735	2	5	10
9a	270	4	14	56
9b	810	2	5	10
10a	270	4	15	60
10b	1041	2	5	10
11	278	8	15	120

DBF = distance between floats (as no line shooter was used the mainline length per basket is equivalent to this distance).

Table 5 – Characteristics of the longline gear for each fishing experiments (continue)

Set n°	N. TDRs	N. Circle	N. J	N. HOOKS	N. HTs	Distance (km)
1	11	372	372	744	516	35.34
2	18	283	179	462	462	24.192
3	18	240	232	472	472	22.792
4	17	239	237	476	476	24.36
5	18	261	261	522	522	26.1
6	18	286	250	536	483	26.1
7a	6	168	167	335	322	15.12
7b	10	100	98	198	198	8.1
8a	6	154	165	319	302	13.72
8b	10	100	115	215	215	7.35
9a	8	167	167	334	292	15.12
9b	10	100	100	200	167	8.1
10a	8	166	212	378	336	16.97
10b	10	113	147	260	202	10.41
11	19	478	239	717	493	33.36
	187	**3227**	**2941**	**6168**	**5458**	

TDR = temperature depth recorder **HT** = hook timer

Table 6 – Median values of depth series recorded at the maximum fishing point of the mainline. Minimal, maximal and average values of median values of depth records calculated for each instrumented longline fishing experiment.

	ILL1	ILL2	ILL3	ILL4	ILL5	ILL6	ILL7	ILL8	ILL9	ILL10	ILL11
TDR1	81	54	46	40	55	30	31	46	66		55
TDR2	69	48	50	43	35	28	38	40	55	72	64
TDR3	65	43	42	45	27	27	36	35	45	44	68
TDR4	72	29	44	43	29	33	34	24	31	47	62
TDR5	48	37	46	50	16	24	28	11	15	29	53
TDR6	23	30	12	36	7	24	32	38	29	48	40
TDR7	34	39	28	42	22	20	29	29	28	43	36
TDR8	17	37	32	35	23	20	152	26	22	21	32
TDR9	47	35	40	29	16	28	143	92	84	253	37
TDR10	35	36	42	16	23	26	143	97	92	239	29
TDR11	38	37	41	32	30	24	136	108	96	260	42
TDR12		23	21	25	21	16	140	102	103	269	42
TDR13		26	41	32	26	19	169	110	80	257	48
TDR14		26	31	33	23	20	139	78	104	135	34
TDR15		26	46	31	31	22	152	92	112	182	26
TDR16		42	26	40	32	24	164	129	109	208	21
TDR17		39	36	46	23		162	122	133	234	40
TDR18		48	40	40				150	163	291	35
Min	17	23	12	16	7	16	28	11	15	21	21
Max	81	54	50	50	55	33	169	150	163	291	68
Mean	48	36	37	37	26	24	102	74	76	155	42

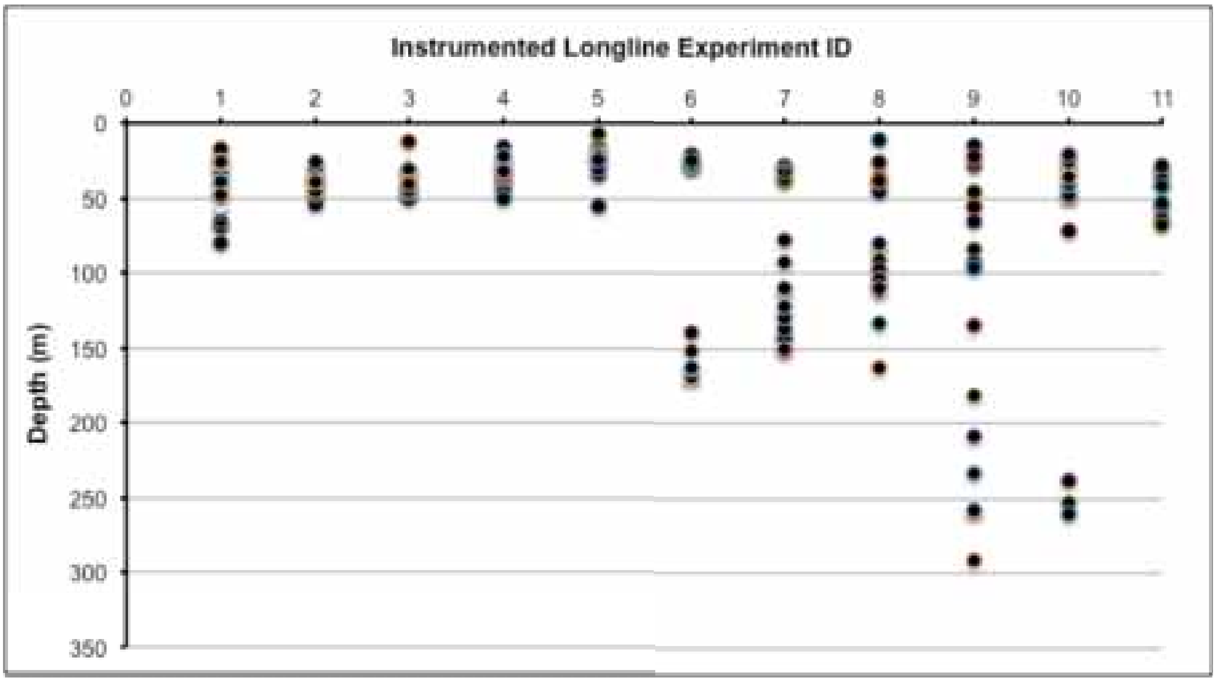


Figure 9 – Median values of depth series recorded on baskets for the 11 instrumented longline fishing experiments.

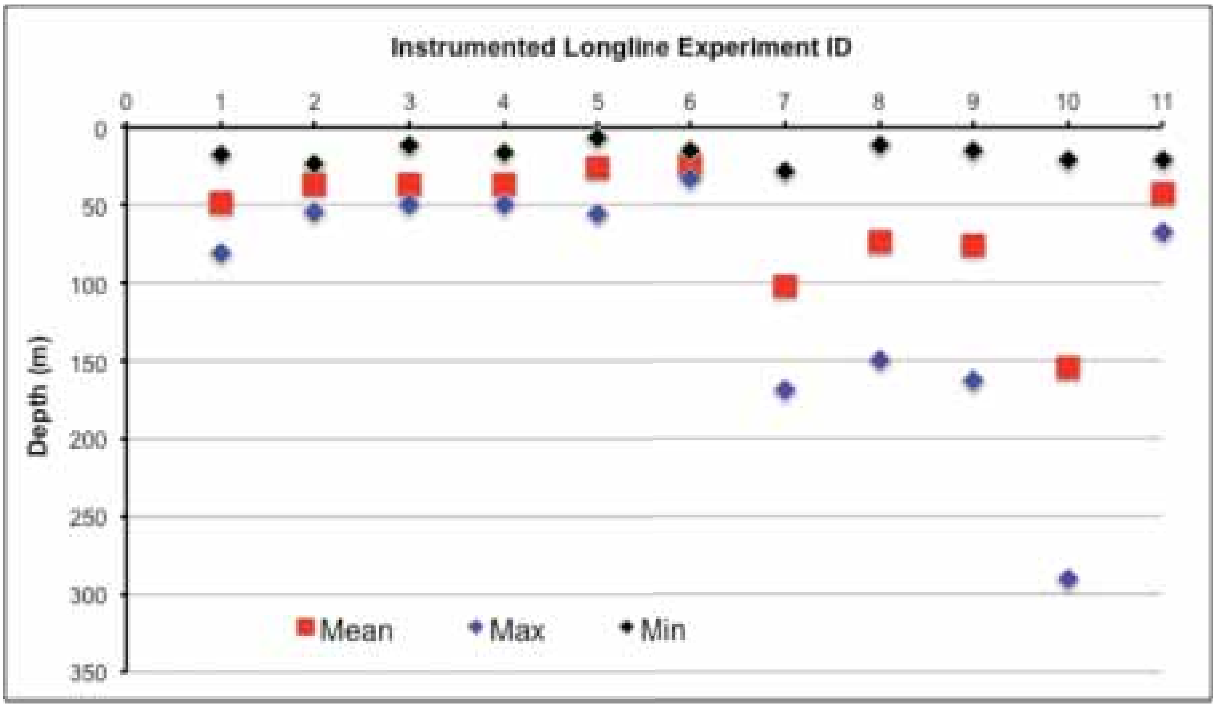


Figure 10 – Minimal, maximal and average values of median values of depth series recorded on several baskets of a given instrumented longline fishing experiments.

Hooking responses and hooking success (capture)

During the cruise a total of 525 hooking responses (HR) was registered. This HR level represents a interaction rate between the gear and the pelagic resources of ~ 10%. Among these hooking responses, 174 represented a success. The success rate is estimated at ~2.8%. Then the hooking efficiency corresponding to the ratio between the hooking success and the hooking response reached 28%.

The 174 individuals caught represent a number of 18 species identified or not (1 shark individual and 1 squid were not identified during the cruise), (Table 7, Figure 11). With 75 individuals (43% of total capture), the swordfish (SWO) as the target species was the dominant capture in capture. Sharks were abundant with 14 individuals for both the blue shark (BSH) and the silky shark (FAL) and 13 individuals for the oceanic white tip shark (OCS), (Figure 11). The group of sharks reached a contribution of ~25% of catches (Figure 12). Tunas (Yellowfin tuna YFT, bigeye tuna BET and Albacore tuna ALB) totalized 13 individuals corresponding to a contribution of 7.5% of total catches (Figure 12).

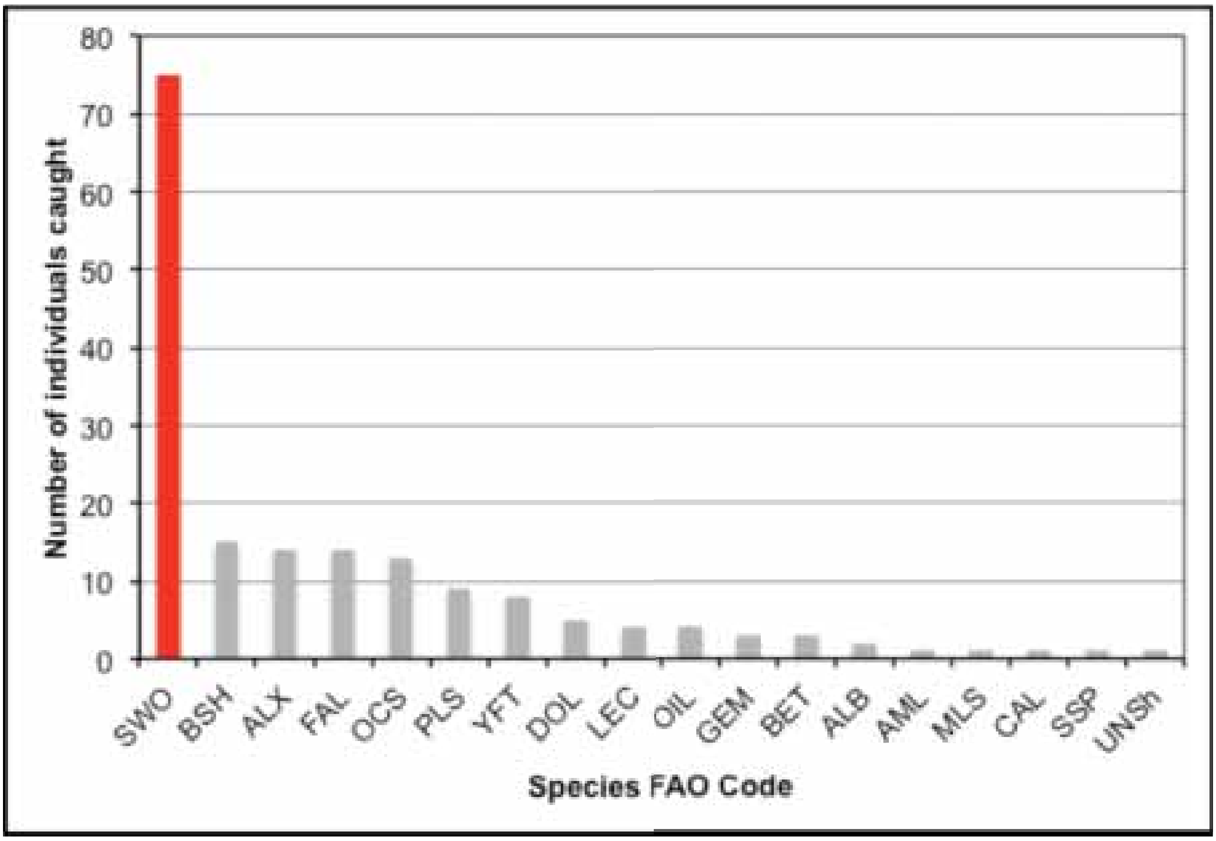


Figure 11 – Species abundance distribution (SAD) of caches recorded during the cruise.

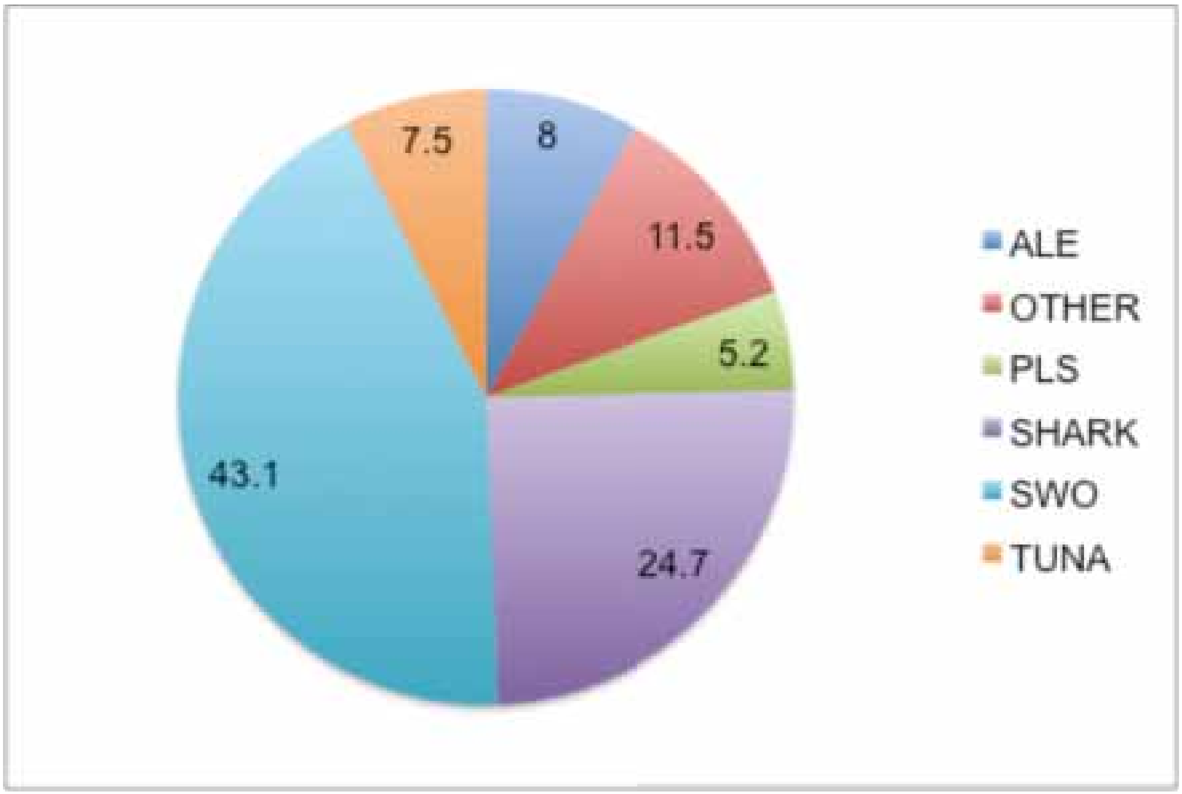


Figure 12 – Contribution of species or group of species in capture sampled during the cruise.

Metadata of PSAT deployments on sharks

The project MADE "Mitigation of Adverse Ecological Impacts of Open Ocean Fisheries" (http://www.made-project.eu/) provided some pop-up satellite tag to be deployed on shark individuals of the three species *Prionace glauca* (blue shark, BSH), *Carcharhinus falciformis* (silky shark, FAL) and *Carcharhinus longimanus* (oceanic white tip shark, OCS) which were the shark species on interest in the project.

We get the opportunity to tag 6 indivudals : 4 blue shark, 1 silky shark and 1 oceanic white (Table 8).

Biological samples collected

This cruise was a great opportunity to collect biological samples for several on going studies related to the genetic structure and the ageing of the swordfish in the Indian Ocean basin (IOSSS project) and the trophic ecology of large predators fishes. A total of 417 samples was collected during the cruise (Table 9).

Table 7 – List of species and specific abundance in capture per longline fishing experiments.

Latin name	Common name	FAO Code	LL1	LL2	LL3	LL4	LL5	LL6	LL7	LL8	LL9	LL10	LL11	Total
Alepisaurus ferox	Longnose lancetfish	ALX	2		1	1			5	1	3	1		14
Carcharhinus falciformis	Silky shark	FAL					2	6	2	2		1	1	14
Coryphaena hippurus	Common dolphinfish	DOL	4	1										5
Carcharhinus amblirhynchos	Grey reef shark	AML					1							1
Carcharhinus longimanus	Oceanic whitetip	OCS		1	1	2	1	3	1	3			1	13
Tetrapturus audax	Marlin striped	MLS								1				1
Calmar sp.	Calmar	CAL									1			1
Gempylus serpens	Snake mackerel	GEM			1						1	1		3
Lepidocybium flavobrunneum	Escolar	LEC		2		1	1							4
Prionace glauca	Blue shark	BSH	2	1	1	1	1	3	1	1		3	1	15
Pteroplatytrygon violacea	Pelagic stingray	PLS	2	4	2					1				9
Ruvettus pretiosus	Oilfish	OIL	3							1				4
Tetrapturus angustirostris	Shortbill spearfish	SSP							1					1
Thunnus alalunga	Albacore tuna	ALB	1			1								2
Thunnus albacares	Yellowfin tuna	YFT	1		2		3		1	1				8
Thunnus obesus	Bigeye tuna	BET		2									1	3
Shark sp.	shark	UNSh	1											1
Xiphias gladius	Swordfish	SWO	16	5	8	5	14	1	1	3	2	9	11	75
		Total	32	16	16	11	23	13	12	14	7	15	15	174

Table 8 – Metadata of PSAT deployments on sharks during the cruise

POP UP TAG SWIOFP2												
Nb day	Tag origin	N° Tag	N°loop	SP CODE	Date	Latitude (°)	Longitude (°)	Deployement time	Lenght (FL cm)	Sex	N° Set	N° capture
90	SFA	08A1021	EM21151	BSH	07/04/10	23.58	41.217	8:04	142	F	3	9
180	SFA	08A1042	EM21163	OCS	11/04/10	19.952	39.5341	10:00	170	M	6	12
180	IRD	09A0051	EM21155	BSH	11/04/10	19.953	39.544	10:26	200	M	6	13
90	SFA	08A1026	EM21153	BSH	11/04/10	19.967	39.45	8:59	210	F	6	7
180	IRD	09A0060	EM21164	BSH	13/04/10	20.397	40.898	9:35	195	F	8	11
180	IRD	09A0057	EM21161	FAL	17/04/10	19.13	41.67	6:24	144	M	11	10

Table 9 – Summary of biological samples collected during the cruise.

	LL1	LL2	LL3	LL4	LL5	LL6	LL7	LL8	LL9	LL10	LL11	
	04/04/10	07/04/10	08/04/10	09/04/10	10/04/10	11/04/10	12/04/10	13/04/10	15/04/10	16/04/10	17/04/10	Total
YFT (Thunnus albacares)												
Lipides	3		5	1			3	3				15
Contaminants			1									1
Isotopes			3				2	2				7
BET (Thunus obesus)												
Lipids		3									2	5
Contaminants		1									1	2
Isotopes		1									2	3
ALB (Thunnus alalunga)												
Lipids				3								3
Contaminants												0
Isotopes				2								2
SWO (Xiphias gladius)												
Lipids	23	10	22	11			3	6		22	31	128
Contaminants		4	8	1						8	11	32
Isotopes		8	16	8			2	4		16	22	76
Genetic		4	8	4			1	2		8	11	38
Otholiths		4	8	2			1	2		7	11	35
Parasites				1						1	1	3
FAL (Carcharhinus falciformis)												
Lipids						7	4	2		2		15
Contaminants										1		1
Isotopes						7	4	2		2		15
OCS (Carcharhinus longimanus)												
Lipids				2		4		6			2	14
Contaminants											1	1
Isotopes				2		4		6			2	14
Total	26	35	71	37	0	22	20	35	0	67	97	410

6 Conclusions

The joint cruise ASCLME/SWIOFP was successful in terms of quality of data collected: hydrological stations, longline behavior characterization, longline capture and associated biometric data and biological samples on selected capture. This cruise allowed us to consider integrated analysis between physical and biological components of the ecosystem investigated.
Conducting such a cruise with two vessels cruising at different speeds was challenging, however we operated with success joined collection of physical and biological data from the R/V "Antea" and the F/V "Brahma" respectively. As shown on the Figure 1B, The R/V "Brahma" spent ~ 55% of its time at sea (without considering the back travel between Mayotte and La Réunion) steaming to reach the appropriate areas (eddies sampled by the R/V "Antea". Nansen).
Taking into account recommendations proposed after the cruise "SWIOFP1" in 2001 in the same area, the scientific team was composed of 4 persons permitting to undertake all the operations (hydrological stations, setting gear deployment, collection of capture data during the hauling, biometry and biological samplings) in satisfying conditions.
Sampling performances of fish caught were facilitated as fishes where the property of the scientific team. At the end of the cruise depending on the condition of fish, capture were sale back to the vessel crew reducing the cost of the charter. Moreover, this gave us a total freedom to use any gear configuration for testing and to select any fishing grounds.

Finally, this cruise was an opportunity to collaborate through the collection of biological samples and the deployment of electronic (PSAT) tag on sharks with two ongoing research project in the region: IOSSS "Indian Ocean Swordfish Stock Structure" coordinated by IFREMER La Réunion and MADE "Mitigation of Adverse Ecological Impacts of Open Ocean Fisheries". Time at sea is too expensive and too time consuming for not sharing it with other research projects when all the objectives of the given cruise are not affected.

So far, some of data collected during this cruise have been analyzed. We present below different works (scientific papers, oral communications, working papers) already done where these data were used:

<u>Integrated analysis between physical and biological components of the ecosystem:</u>

- Potier, M. P. Bach, F. Ménard, F. Marsac - Influence of mesoscale features on micronekton and top predators in the Mozambique Channel (accepted to be published in a Special Issue of Deep Sea Research II).
- Potier M., Marsac F., Bach P., Menard F., 2011 - Do mesocales structures of the Mozambique Channel affect the food web from mid-trophic levels to top predators? Communication orale WIOMSA Scientific Symposium, Mombasa, Kenya. 24-29 octobre 2011.

<u>Hooking responses and hooking success:</u>

- Bach P., Lucas V., Capello M., Romanov E., 2012 - Is the fishing time an appropriate bycatch mitigation measure in swordfish-targeting longline fisheries? Symposium Project 7th FP « MADE », Mitigation of Adverse Ecological Impacts of Open Ocean Fisheries, Montpellier, 15- 18 Octobre 2012.

Capture data of large pelagic fishes in pelagic longlining :

- Bach P., E. Romanov, N. Rabearisoa, A. Sharp and J.-P. Lamoureux, 2012 - Preliminary results of bycatch ratio, catch rates and species CPUE distributions of bycatch of sharks in the pelagic longline fishery based in Reunion Island. IOTC–2012–WPEB08–INF24.
- Romanov E., Bach P., Rabearisoa N., Romanova N. 2012 - Pelagic elasmobranch diversity and abundance in the Western Indian Ocean: an analysis of long-term trends from research and fisheries longline data. Symposium Project 7th FP « MADE », Mitigation of Adverse Ecological Impacts of Open Ocean Fisheries, Montpellier, 15- 18 Octobre 2012.
- Frédéric M., Simier M., Lezama N., Amandè M., Potier M., Romanov E., Bach P., Murua H., Bez N., Chavance P., Delgado De Molina A. ,4, Merigot B., 2012 - Large fish predators diversity highlighted by tuna fisheries data in the Indian Ocean. Symposium Project 7th FP « MADE », Mitigation of Adverse Ecological Impacts of Open Ocean Fisheries, Montpellier, 15- 18 Octobre 2012.
- Laugier F., Mérigot B., Potier M., Simier M., Romanov E., Bach P., Ménard F., 2011 - Spatio-temporal variability in the functional diversity of top predator fishes in the western Indian Ocean. Communication orale WIOMSA Scientific Symposium, Mombasa, Kenya. 24-29 octobre 2011.
- Bach P., Romanov E., N. Rabearisoa, & A. Sharp, 2011 - Note on swordfish catches collected during commercial operations and research cruises onboard pelagic longliners of the La Reunion fleet from 2006 to 2010 IOTC–2011–WPB09–INFO11.

Biology & Ecology of pelagic sharks :

- Filmalter J., F. Forget, F. Poisson, A.-L. Vernet, P. Bach and L. Dagorn, 2012 - Vertical and horizontal behaviour of silky, oceanic whitetip and blue sharks in the western Indian Ocean. IOTC–2012–WPEB08–23.
- Filmater J., 2012 - Horizontal movement behavior of silky and oceanic white tip sharks in the Indian Ocean. Symposium Project 7th FP « MADE », Mitigation of Adverse Ecological Impacts of Open Ocean Fisheries, Montpellier, 15- 18 Octobre 2012.
- Rabehagasoa N., Vigliola L., Romanov E., Campana S., Lorrain A., Bach P., 2012 - Linear growth of two oceanic sharks, *Prionace glauca* (blue shark) and *Carcharhinus falciformis* (silky shark) in the south western Indian Ocean assessed by backcalculation from vertebrae age readings. Symposium Project 7th FP « MADE », Mitigation of Adverse Ecological Impacts of Open Ocean Fisheries, Montpellier, « 15- 18 Octobre 2012.

Genetic studies:

- Muths D., S. Le Couls, H. Evano, P. Grewe, J. Bourjea, 2012 - Microsatellite and mtDNA markers were unable to reveal genetic population structure of swordfish (*Xiphias gladius*) in the Indian Ocean. IOTC–2012–WPB10–15.

Depredation:

- Rabearisoa N. 2012. Etude d'un mode d'interaction entre les cétacés et les requins et la pêche à la palangre dérivante dans la région sud ouest de l'océan indien : la déprédation. Thèse de Doctorat the l'Université de La Réunion, Mention Biologie et Ecologie Marines.