Baitboat as a tuna aggregating device

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Abstract

The original baitboat fishing technique using a permanent association between the fishing boat and the tuna school has been developed by the baitboat fleet of Dakar, Senegal and is also in use in the Canary Islands. This new fishing technique, the result of 20 years of improvements still on, has induced a dramatic increase of the catch yields which, in turn, has sustained the survival and even a recent development of the fleet. This technique is based on the aggregating behaviour of tropical tunas. However, it contains a dynamic component which is not found in tuna fishing on drifting or anchored FADs. The specifications of the method, its refinement over the years and its main consequences for the fishery are described together with the school exchanges between baitboats over months even from one year to the next. Based on the analysis of 1228 recoveries from 5500 tagged fish, tuna movements among associated schools, between associated schools and free schools fished by purse seiners and movements in and out of the baitboat fishing grounds help to better understand the dynamics of tunas and schools of this peculiar tuna association. These data show a very high recovery rate, a remarkable tuna fidelity to the original school for all species, a small number of recoveries within the purse seine catch as well as the rare tuna movements outside the baitboat area. The study highlights the complexity and the numerous consequences of tuna and school behaviour.

Introduction

The tuna baitboat fishery based in Dakar has developed along the years a very efficient new fishing method: the associated-school fishing method whereas the baitboat maintains a permanent association with the tunas it fish. This was described for the first time by Fonteneau & Diouf (1994). In their publication, they raised many questions and made different hypotheses regarding the parameters involved in this association, the dynamics of the tuna and baitboat association and the level of the exploited biomass. A research programme was specifically designed to address these questions and this publication presents some of the preliminary findings in regards with this type of tuna association.
At first, the characteristics of this new fishing method are described together with its long refinement period and the main consequences

on the fishery. Then, the dynamics of the associated schools of tunas are presented and discussed in comparison with other types of association in order to characterise this peculiar tuna association. Tagging results give some knowledge into the tuna behaviour such as their movements between different associated schools, between associated schools and free schools which lead to interaction between baitboat and purse seine fisheries, between the baitboat fishing grounds and the rest of the Eastern Atlantic Ocean.

Material and methods

The present study is based upon log book data collected on baitboats on a routinely basis and data collected by the research programme especially during trips at sea.

As other tropical tuna fisheries whose boats called in Dakar harbour, the baitboat fishery is permanently followed through the collection of log books and the sampling of their catch. Log books provide daily position for each boat and its daily catch of tunas by species as estimated by the skippers. Later on, catch is corrected by the weighted catch provided by the harbour authorities for each boat. Log books provide also data on environmental conditions (sea surface temperature (SST), wind, sea condition, currents) and on school exchanges between boats. This set of data goes back to 1978, as far as 1969 for some data, and certain data from 1999 are also included in the present study. Size data on landings at Dakar were collected and processed by the technician from Crodt (Centre de recherches océanographiques de Dakar-Thiaroye), the period covered goes from 1969 to 1998.

So far, during the course of the research programme, thirteen trips at sea have been completed on board baitboats including a pre-programme trip in 1994. During these trips, detailed informations were collected on the fishing operations (location, duration and speed of the steaming or drifting periods with the associated schools), exchanges of schools between boats, tuna sizes and diets and environmental data (SST, sea color, sea condition, wind and current). For all fishing operations, the time the fishing operations start and end as well as the estimated catch species composition were recorded. An estimation of the size of the school associated to the boat was regularly recorded with the help of the skippers. Ordinary tagging with spaghetti-type tags was used on a large scale in order to monitor tuna movements among associated schools, between associated and non-associated schools and movements in and outside the fishing area. Overall, from 1994 to 1998, 5 496 tunas were tagged and released. Some data from the first 1999 cruises are also included.

Results

A brief description of the school-associated fishing method

The study of the historical data of the baitboat fishery of Dakar demonstrated that the development of the associated-school fishing method was a very long process which started in the mid seventies (Hallier *et al.*, 1998). For many years, skippers made benefit of the fact that tuna gathered at night under the drifting boat by fishing them early in the morning. However, most tuna left the boat at sunrise. Then, skippers decided to keep drifting during daylight hours with the remaining tuna and eventually to give the school to another boat. These boats were drifting in a south-westerly direction under the influences of prevaling winds and currents. After a few days, they were carried outside of the favourable fishing grounds, therefore they had to abandon the school or were abandoned by the school and they had to steam back to their original position. It was only at the beginning of the eighties that the real associated-school fishing method was developed by shifting from a passive state to a dynamic one where boats moved with the school. But, this was not done overnight and today skippers recognized that there are still room for improvements. Nevertheless, their maestria in this field is very astonishing as schools are kept for months, even from one fishing season to the next, they are exchanged partially or totally between boats during daytime or nigth-time and baitboats can travel with them on long distances. During the recent period, the associated-school fishing method has become the exclusive method practiced by the Dakar baitboat fishery. Today, whatever the season, the area, these boats always try this method and it almost always works.

The main consequences of the associated-school fishing method

As the method was perfected over a long period of time, its main consequences appeared gradually. The CPUE (in tons per fishing day) increased from 2 t/day in the beginning of the seventies to 5.5 t/day in the mid-eighties and then fluctuated with no tendency. These higher catch rates improved the profitability of this fishery, therefore the long decreasing trend of the fleet was stopped and since 1992 the fleet is increasing in number of boats of bigger carrying capacity. These changes together with the higher CPUE resulted in an increasing yeatly catch per boat from 200 t in the beginning of the 1970's to 800 t in 1998. Consequently, the yearly catch of the fleet which remained more or less stable at 9 500 t from 1985 to 1996, despite the dectease of the fleet, increased to 14 000 t in 1998. Another effect of the adoption of the new fishing method was the concentration of the catch in a very localized area from July to October in the Mauritanian waters: from 18°N to 21°N and from 16°W to 19°W (fig. 1).

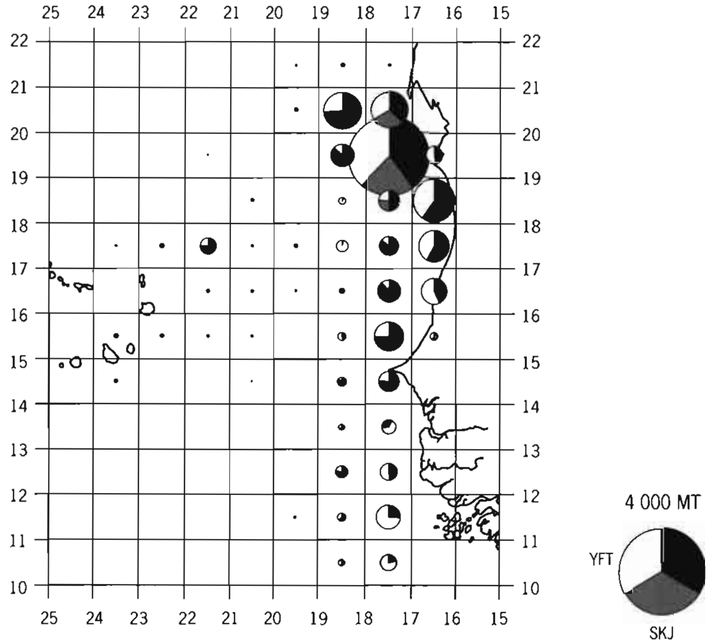


Figure 1
Average fishing area of the Dakar baitboat fishery (period 1991-1996). Each pie of a circle is proportional to the annual species catch by one degree square of latitude and longitude.

Fonteneau & Diouf (1994) demonstrated that during this period, fishing took place south of the Cape Blanc thermal front, in very productive waters. The area off the Senegal coast was gradually more or less deserted by the fleet. In this last area, baitboats are catching mainly skipjack and yellowfin while the catch in the north area is made of the three species (yellowfin, skipjack, bigeye) in a balanced composition. Therefore over the years, the baitboat catch species composition resemble more and more the catch species composition of the Mauritanian waters, i.e. one third of each of the three species (fig. 2). Some very recent changes need to be mentioned. The last two years (1997 and 1998) were abnormal in terms of species composition (skipjack was by far the dominant species) (fig. 2), fishing season duration and fishing areas (Hallier, 1999). Fishing generally lasts mostly 7 to 8 months from July to January or February and for these last two months fishing takes place south of 14°N. In 1997 and 1998, fishing does not stopped and during the first term of the year takes place north of 14°N. These anomalies are related to higher than normal SST during the first term of these two years (Hallier, 1999).

For the period 1991-1998 and the area north of 15°N, where almost all baitboat catches are made on associated-schools, the species composition is 25.4% yellowfin, 41.6% skipjack and 33.0% bigeye. It is interesting to note that the purse seine catch in the same strata is 5.4% yellowfin, 93.2% skipjack and 1.4% bigeye. If the type of school is taken into consideration for purse seiners, the species composition is for log

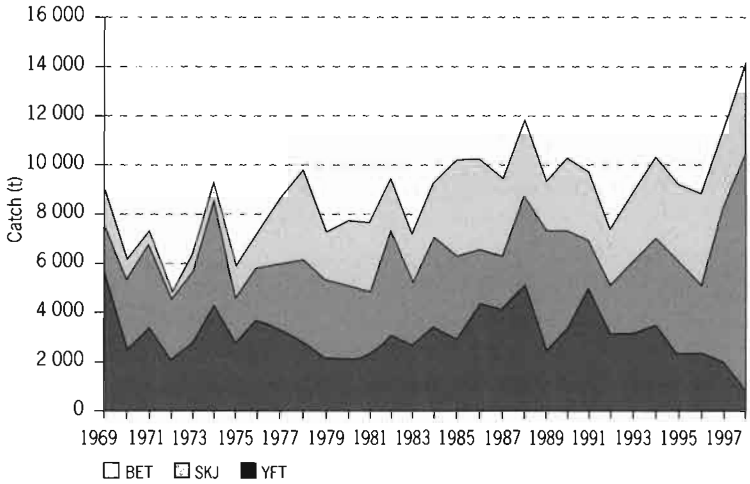


Figure 2
Yearly average catch species composition of the Dakar baitboats fishery between 1969 and 1998.
BET: bigeye tuna;
SKJ: skipjack;
YFT: yellowfin tuna.

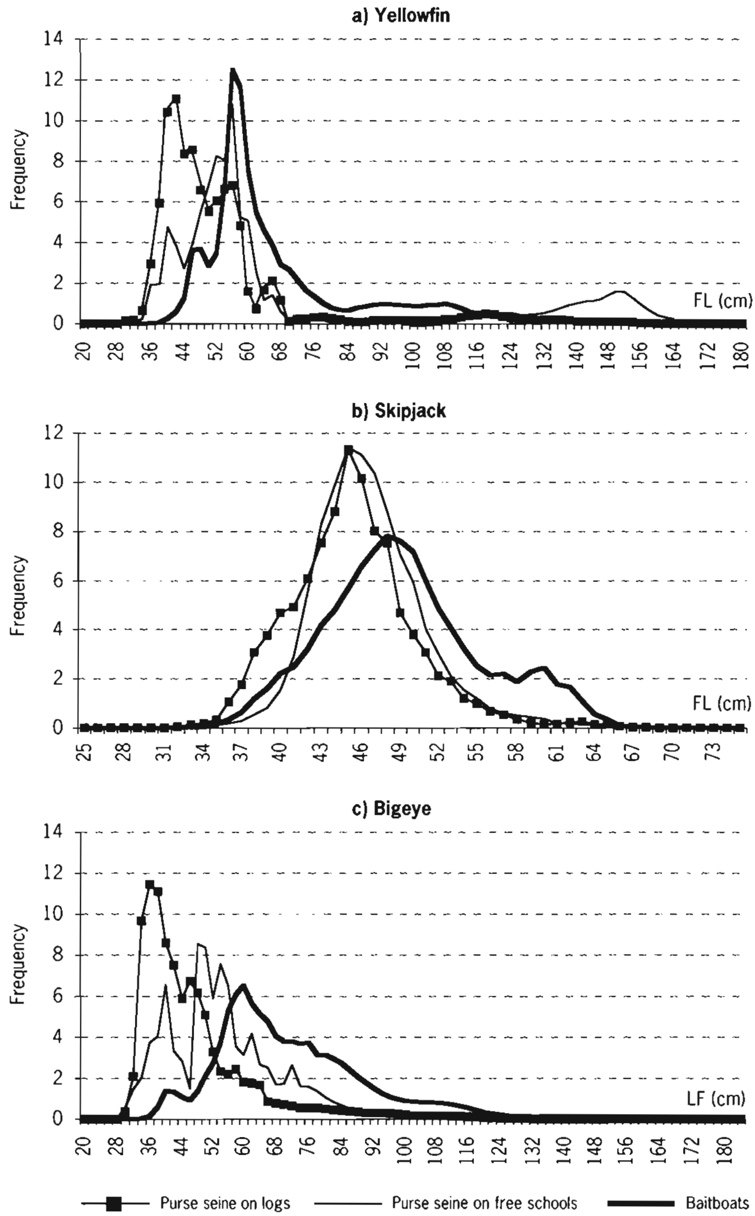
schools 13.6% yellowfin, 78.1% skipjack and 8.3% bigeye, for free schools it is 4.6%, 94.6% and 0.8 per cent. It should be recalled that log catch by purse seiners accounts for only 8% of the total purse seine catch in this strata.

Distribution of the catch by size frequencies for the area north of 15°N and the period 1991-1998 are given in figure 3 for baitboat, purse seine fishing on log schools and on free schools. For yellowfin, the most common length is the same for baitboat and purse seine on free school and higher than the mode for purse seine on logs. However, average size yellowfin (fork length between 65 and 120 cm) are more common for baitboat than for free schools while yellowfin larger than 140 cm, quite common for free schools, are lacking for baitboat catch. For skipjack, size frequencies are very similar for purse seine whatever the type of school; for baitboat the main mode is slightly higher and fish greater than 55 cm, poorly represented for purse seine, are quite common. For bigeye, the main mode for baitboat is higher than for purse seine and fish with FL greater than 80 cm, poorly represented for purse seine, are quite common for baitboat.

The refinement of the associated-school fishing method

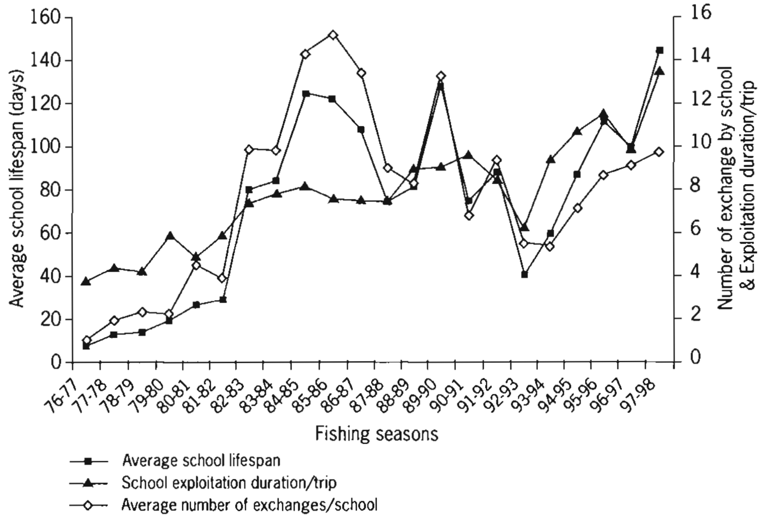
The first records of school exchanges between baitboats dated back to the 1976-1977 fishing season. A file was built up from that period to the 1998-1999 fishing season and several parameters which characterise this school exchanges were calculated. The time between the build up of a school and the end of its exploitation, either when lost or abandoned by the baitboat, is defined as the lifespan of the associated school. The average yearly lifespans of associated schools are represented for this period of 23 years on figure 4 together with the number of time a school was exchanged during its lifespan and the duration a school was

Figure 3
Size frequency distribution (in % of total catch) for baitboats, purse seine on logs and on free schools, area 15°N-25°N/15°W-25°W, period 1991-1998; a) Yellowfin, b) Skipjack, c) Bigeye.



exploited during each boat trip. All indices went up with the refinement of the method and in 1998 the highest school lifespan and school exploitation duration per trip were recorded. This reflects the lenghtening of the fishing season and the bigger size of the boats which require more time to be filled but also an overall mastery of this new fishing method.

Figure 4
Average school lifespan (in days), number of exchanges by school and duration of school exploitation by trip (in days) for the Dakar baitboat fishery from 1976-1977 to 1997-1998 fishing seasons.



The adaptability of the associated-school fishing method to other environments

The method was first developed and refined in the time-area strata July-October in the north of Mauritania. Then, it was progressively extended to new environments to the south and south-west. Today, the method is sufficiently mastered to be used in different oceanographic environments such as the waters of Senegal, Cape Verde Islands and in the vicinity of seamounts. In 1991, the tuna baitboat fleet from Canary Islands started to practice this new fishing method. The consequences were an overall increase of the catch, a lengthening of the bigeye fishing season from March-June to March-December with a corresponding increase of bigeye catch and total CPUE. This increase of baitboat CPUE initialized an increase of the size of the fleet and of the average size of the boats. In 1989, baitboats greater than 50 t numbered 22 and 35 in 1998; the vessels greater than 100 t represented 55% of the fleet in 1989 and 63% in 1998. As well as for the Dakar baitboat fishery, 1998 was abnormal in the Canaries' baitboat fleet (but not 1997!) with very low bigeye catch, more yellowfin and a lot more skipjack. The Canaries' baitboats use the associated-school fishing method in the area offshore the islands together with the traditional baitboat fishing method off the coasts of the Sahara (Morocco). One point remains unclear: why skippers from the Canaries' baitboats do not used this method off the Sahara coast?

The new fishing method was also tested in Azores where it seems to be working but it is still not well developed as it does not fit with the fishermen habits (Peirera, pers. comm.).

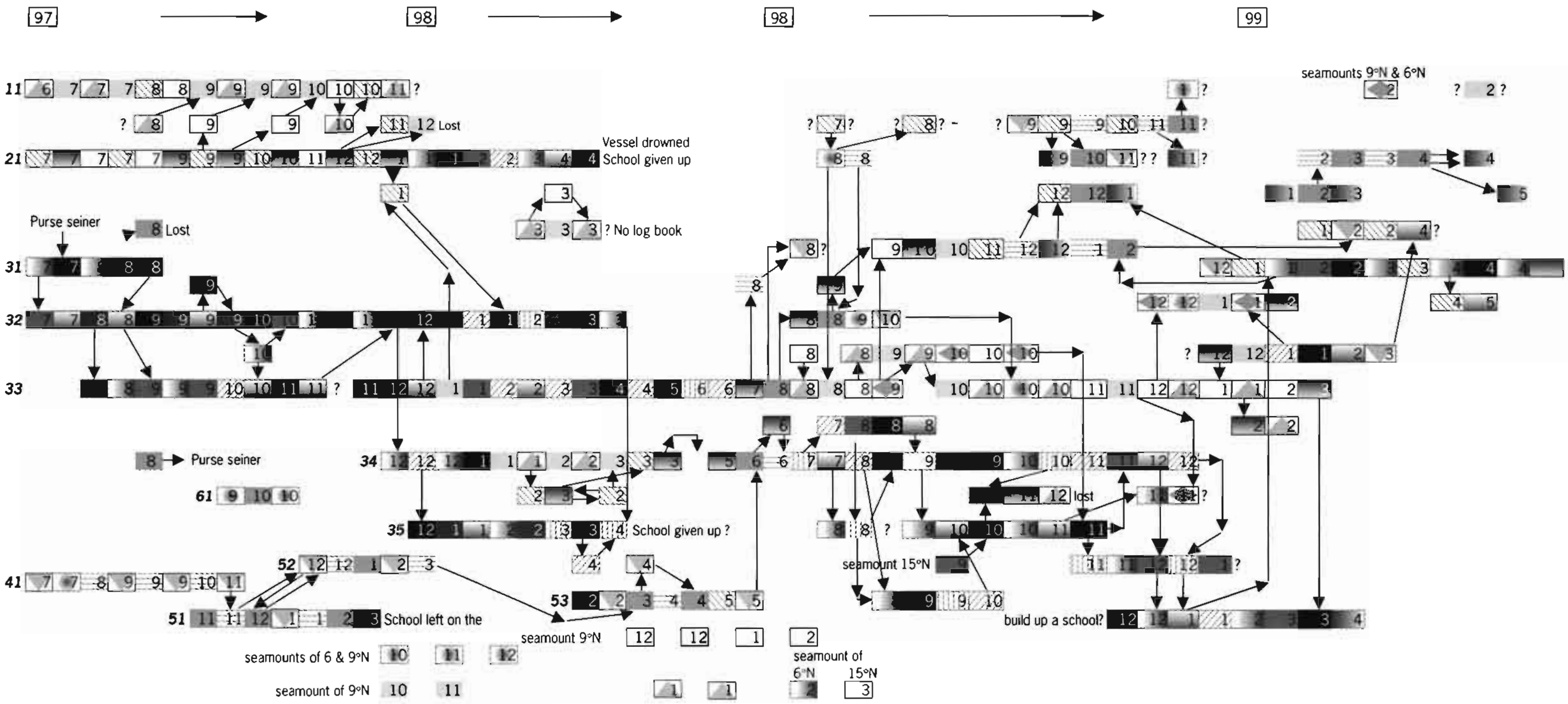
Dynamics of the tuna aggregation

The school exchanges

The exchanges of schools between boats are followed on a routinely basis from log book data and skippers'interviews. Baitboats are more or less associated in groups, each exploiting one or two schools. But outliers are not so rare and the composition of the groups tends to change during the fishing season. Therefore, criss-cross exchanges between schools of different groups can occur; they were almost the rule at the beginning of the 1998-1999 fishing season. These data are illustrated in figure 5 for the fishing seasons 1997-1998 and 1998-1999. At the start of the fishing season in June-July 1997, five associated schools were identified which have had different lifespans, some of them were carried out through the next fishing season. Taking into account the geographical seasonality of the fishery, this means that baitboats can cover great distances with their associated schools. It should be noticed on figure 5 that at certain periods (October 1998 to March 1999) some boats did not participate into the exchange process. Some of these boats were banned by the rest of the fleet because they let purse seiners to set on their associated schools, others did not take fishing licenses in Mauritania EEZ after December. Generally these boats went to fish on the different seamounts of the region where they tend also to build associated schools they can exchange with other baitboats.

During the 1997-1998 fishing season, the school average lifespan reach 144 days, nearly 5 months (fig. 4). The school no. 33 (fig. 5), built in August 1997, was passed entirely from one boat to another one 42 times until March 1999 when it was merged with another school. Meanwhile, this school received parts of other schools 6 times and gave parts to other schools 9 times. The school no. 34, built in December 1997, lasted until December 1998 after been passed from boat to boat 27 times. It received parts from other schools 7 times and gave parts to other schools 8 times. These two examples illustrate the complexity of the school exchange process. As mentioned previously the first part of the 1998-1999 fishing season was characterised by the multiplication of school exchanges between baitboats (fig. 5). Interviewed, skippers explained that the lower abundance of tuna in general and of bigeye in particular prompted them to multiply the school exchanges. They feared that if they lost their school it will be very difficult for them to build another one. With numerous exchanges, they accumulate credit with their colleagues for asking, if necessary, part of their schools and thus avoid to stay without school. From August to December, the percentage of bigeye into the baitboat catch was on average 35% from 1985 to 1994, but for the same period of 1997 bigeye accounted only for 19% of the catch and 23% in 1998.

This fishing method requires well-developed cooperation links between skippers which were previously quite attached to their independancy. Today, the method is sufficiently well-mastered in order to absorb anomalies in the fisheries such as experienced in 1997 and 1998.



Légende
10 one rectangle by boat trip
11 is a number to identify each school
10 is the month of arrival in Dakar
Arrows designed exchanges between different schools (partial exchange of the school)

Baitboat names :
Étoile d'Esperance · Brisas De Torrontero · Corona Del Mar · Magatte Diack · Leona · Almike · Waksman · Erika · Sardara
Santa Gema · Aigle des Mers · Chevalier Bayard · Ernai · Garoupa · San Francisco · Gure Balenziaga · Pilar Torre · Matar N'Diaye

A. Hervé, IRD, Programme MAC

Figure 5 - Exchanges of tuna schools between baitboats: fishing seasons 1997-1998 and 1998-1999.

The catch species composition with time

If stability of the catch species composition is generally recorded from year to year for the all fleet (fig. 2), variability is more the rule at a lower scale as demonstrated by Fonteneau & Diouf (1994). They pinpointed the rapid daily changes of species composition of the catch for an individual boat but a more stable composition when catches of several schools are combined. The species composition on a daily basis can vary rapidly along the year as illustrated for 1994 in figure 6a. Data from 1998 are different in many ways as stated in pages 563-564 and are shown to illustrate differences between a normal year (1994; figure 6a) and an abnormal one (1998; figure 6b).

This species composition variability is even noticed during the course of each single fishing operation. To illustrate this situation, the catch of the three or four fishermen closer to the galley was recorded during different fishing operations of a boat trip. These fishermen were choosen because they were the closest to the place where it was save to observe without disturbing the fishing operations and also close enough to see properly in order to identify the species caught as fishing starts before dawn. It was not possible to follow all fishing operations until their end (i.e. operations no. 5, 10 and 12). Yellowfin and bigeye were visually distributed between three size classes: small (fish more or less 3 kg), medium (between 3 and 7 kg) and large (more than 7 kg). Results are presented in figure 7 for eight fishing operations recorded between the 10th to the 20th of August 1999 on the baitboat *Ernai* fishing on the same associated school. At that time of the year and in this location (20° N), dawn was at 6.30 am and sunrise at about 7 am. Except for the fishing operation no. 23 which ended when all fish holds on board were full, all the other operations were ended by the skipper when skipjack (especially small-size skipjack less than 1.8 kg) became dominant into the catch. From these records (fig. 7), bigeye, when biting, is an early-morning fish, especially when it is large. Large yellowfin are also biting early morning together with bigeye but their catch rates decrease strongly at dawn to increase again at sunrise. More or less, when large fish occupy the volume closest to the boat, they tend to exclude the small-size tunas. But, this is not a rule as it is frequent that skipjack (smaller in size than early biting yellowfin and bigeye) bite at the same time as large tunas as shown by operations no. 12 and 13 when they were caugth together with large yellowfin. These results are based on a single set of data, however they are confirmed by similar data recorded during two other cruises from 1998 and 1999 (Hervé, 1998, 1999) and by the observations made during all cruises conducted during the course of the programme. These data reveal the changes of species composition from day-to-day catch on a single school but also changes during the course of a single fishing operation.

When all catches by species according to the time the fishing operation starts are combined for all cruises conducted by the research programme from 1997 to 1999, this general pattern is still visible (fig. 8).

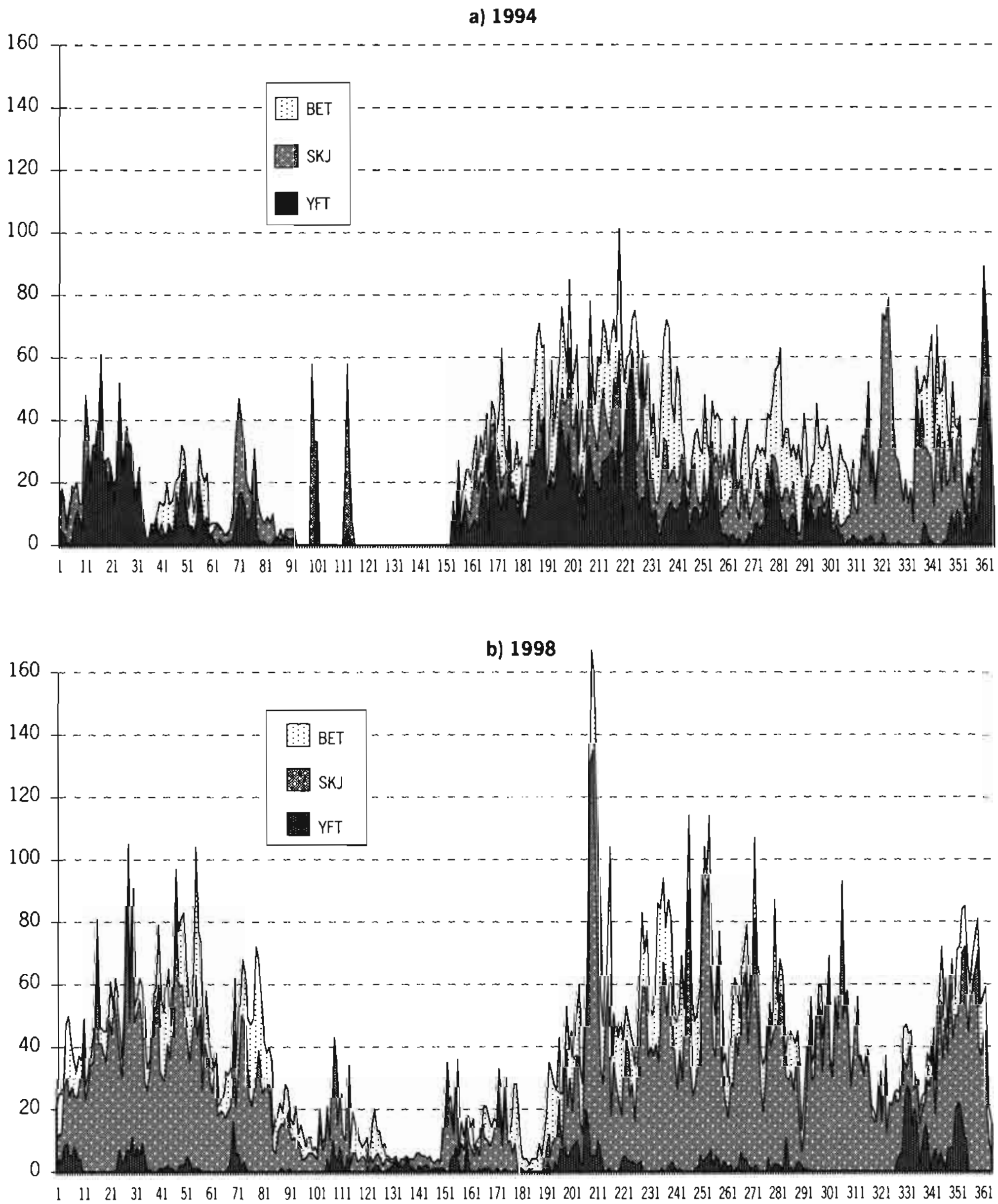


Figure 6
Daily catch by species for the Dakar baitboats a) in 1994, b) in 1998.
BET: bigeye tuna;
SKJ: skipjack tuna;
YFT: yellowfin tuna.

It is also apparent from this figure that some bigeye and yellowfin are biting again in the afternoon but in small numbers. The bulk of the catch is made during the first fishing operation which takes place early morning and lasts on average a little bit more than one and a half hour. A second fishing operation is sometimes launched between 8 am and 10 am or later on until dusk but yields on average little catch.

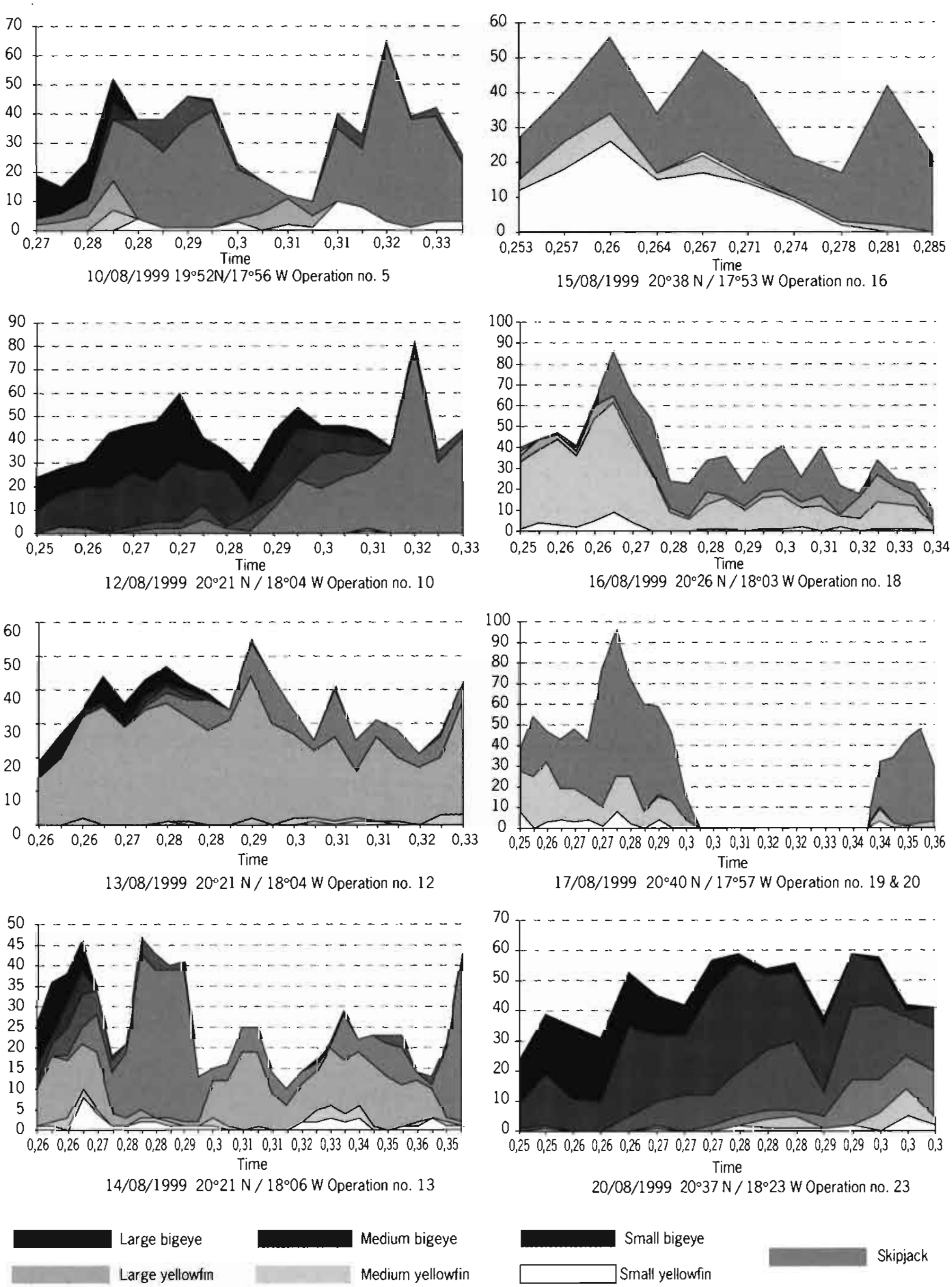


Figure 7 - Variations of the catch species composition on a timely basis during several fishing operations of a 1999 scientific cruise on the baitboat *Ernai*.

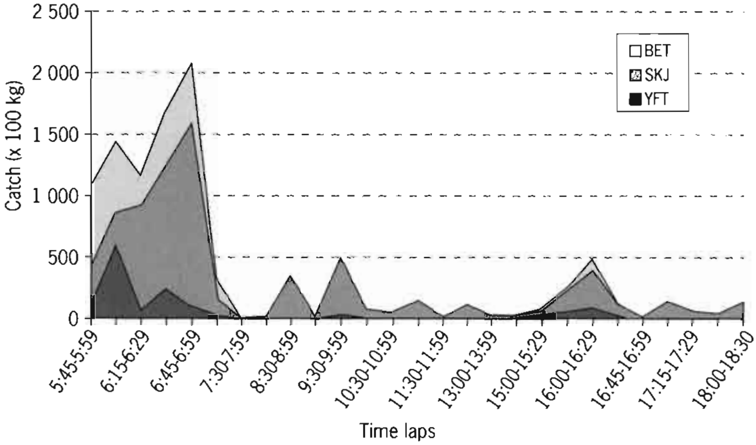


Figure 8
Variation of the catch species composition on a timely basis for all baitboat scientific cruises from 1997 to 1999.
BET: bigeye tuna;
SKJ: skipjack tuna;
YFT: yellowfin tuna.

The catch species composition with the proximity to the continental shelf

As shown on figure 1, the main part of the catch is made in a small area off the coast of North Mauritania. The distribution of the catch by species according to the proximity to the continental shelf (yellowfin would be closer to the shelf and the two other species would be distributed from near shelf to off shelf areas) related by Fonteneau & Diouf (1994) from skippers accounts is not easy to demonstrate. Futhermore, depth is not one of the parameters recorded by skippers on log books. First of all, fishing grounds are always quite close to the coast (fig. 1), therefore it is not easy to discriminate variations of the species composition on such a small scale. Secondly, even if a vessel will come closer to the shelf and collect more yellowfin, then after it can steam with its associated school more offshore and therefore its yellowfin catch will be spread off from near shelf area to more off shelf area. Generally, skippers will not like to stay near the shelf as this area is also rich in little tunny (*Euthynnus alletteratus*), a species not sought by the fishery. In 1997 and 1998, fishing operations took place in the traditional zone but also more offshore than usual. The distribution of the catch by square of 10' and by species, illustrated in figure 9 for 1998, shows a more coastal area for yellowfin than for the two other species; skipjack and bigeye are not showing differences in their areas of distribution. This also means that yellowfin collected in coastal areas might not stay with the boat if it steams too much offshore.

The movements of tunas associated to baitboats

Movements inside and outside the fishing area

Ordinary tagging was performed on differents baitboats with associated schools. Of the 5 496 tuna tagged (473 yellowfin, 4 318 skipjack, 705 bigeye) during the period 1994 to 1998, 1 228 were recaptured (172 yellowfin, 762 skipjack, 294 bigeye). This represents recapture rates of 36.4% for yellowfin, 17.7% for skipjack and 41.7% for bigeye.

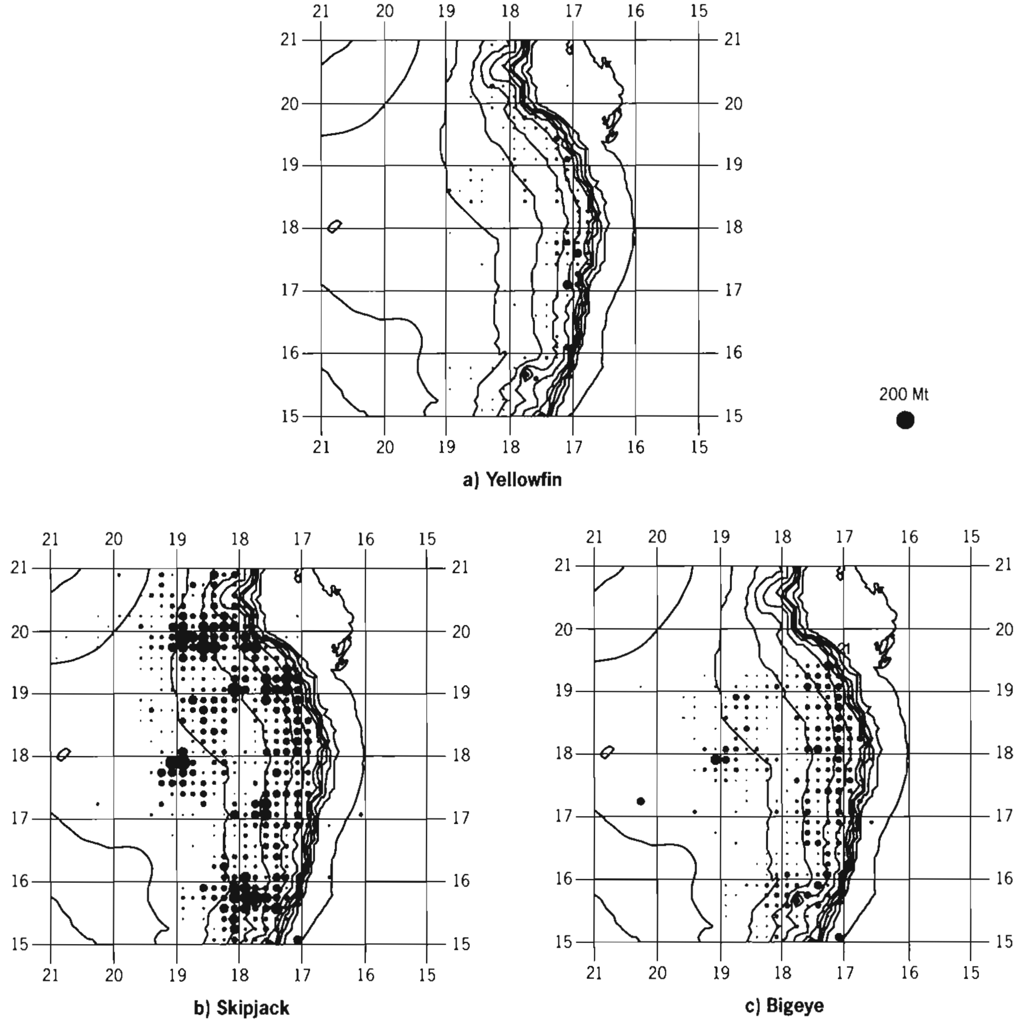
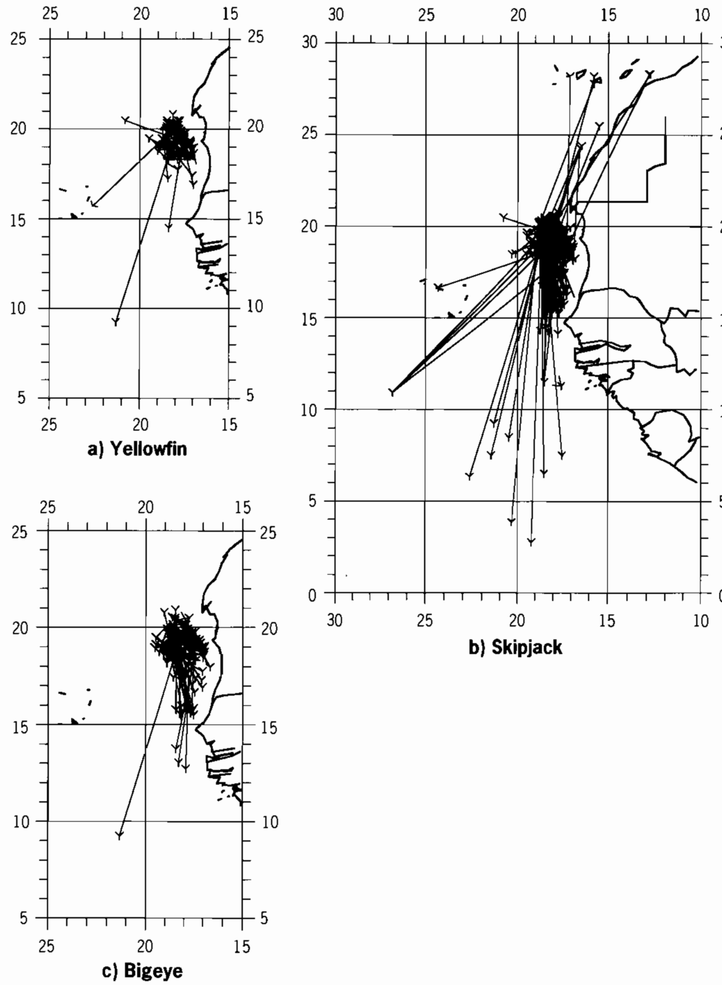


Figure 9
Distribution of the 1998 Dakar baitboat catch by 10' squares according to the proximity of the continental shelf;
a) Yellowfin,
b) Skipjack, c) Bigeye.

These rates are quite high when compared to results from previous tagging operations in the Eastern Atlantic Ocean, especially for yellowfin and bigeye (Bard & Amon Kothias, 1986; Cayré *et al.*, 1986, 1988; Peirera, 1995) but more or less expected when considering the associated-school fishing method. The theoretical movements derived from the recapture data are given on figure 10. For all three species, very few recaptures were recorded outside of the fishing zone (fig. 1); in fact none for yellowfin and bigeye. Only skipjack were more mobile with recaptures recorded north of the fishing zone, off the coast of Morroco and in the Canary Islands, all from the Canaries' baitboat fleet. Recaptures were also recorded for this species south of 10°N towards the equator, most of these were from purse seiners.

Figure 10
Theoretical tuna movements between tagging and recapture from 1994 to 1998. a) Yellowfin, b) Skipjack, c) Bigeye.

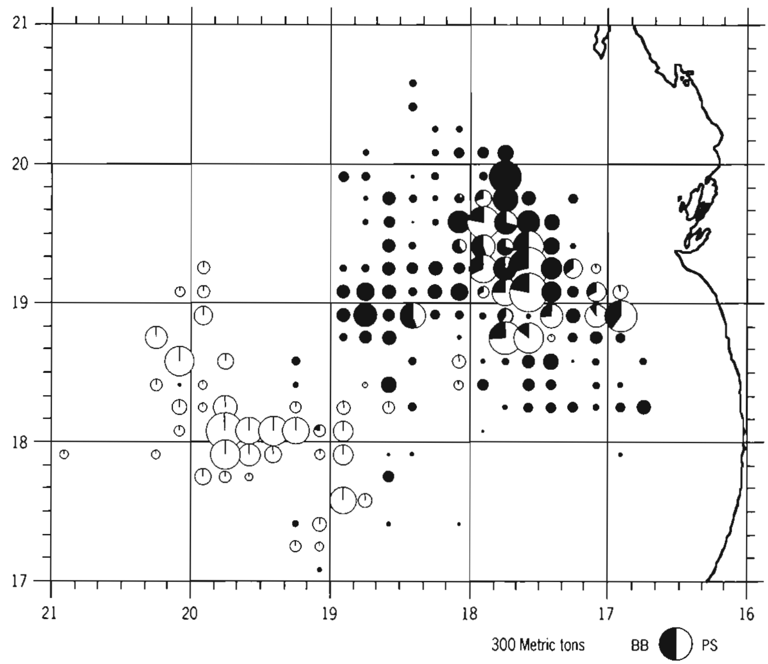


Movements into the purse seine fishery

Despite the fact that a purse seine fleet is very active in the Eastern Atlantic Ocean all year round and seasonally in the Senegalese and Mauritanian waters from May to October, very few recaptures were reported by purse seiners. From 1994 to 1998, 75 tagged tunas (6.1% of the recaptures) were recaptured by purse seiners including 47 from sets on schools associated to baitboats. Only 13 recaptures were recorded by purse seiners north of 16°N in schools not associated to baitboats. This very limited number of recaptures by purse seiners is very surprising as this fleet has been fishing north of 16°N regularly since 1991. From 1991 to 1998, 54% of the tuna catch north of 16°N were made by purse seiners. In August and September 1997, 2501 tuna were tagged north of 16°N (45% of the total tuna tagged from 1994 to 1998).

During the same months and north of 16°N, baitboats caught 3577 tons of tuna and recaptured 434 of the tagged tunas, purse seiners caught 4465 t and recaptured 51 tunas including 47 from sets on schools associated to baitboats. During this period, purse seiners fished in two different areas (fig. 11), one south-west of the baitboat fishing area (between 17°10'N and 19°20'N and 18°50'W and 20°20'W), the other right in the middle of the baitboat area (between 18°10'N and 20°10'N and 16°40'W and 19°W). Of the 4 skipjack not caught in schools associated to baitboats, all were recaptured by purse seiners in the baitboat fishing area. Compared to the catches, these recaptures represent one recapture for every 8.2 t of tuna caught by baitboat and one for every 87.6 t for purse seiner (one for every 1 116 tons if only recaptures from sets on non-associated schools are taken into account). It is also remarkable that purse seiners are catching almost exclusively skipjack in this area (95% ot the 1994-1998 total catch) while the catch of baitboat is made of 18% yellowfin, 48% skipjack and 34% bigeye for the same period.

Figure 11
Geographical distribution of purse seine (PS) and baitboat (BB) catches in August and September 1997 in area 17°N-21°N/16°W-21°W.



At the beginning of the fishing season in 1998 (from April to June), purse seiners fishing south of Senegal or in Senegal waters caught 7 skipjack from the 1997 tagging operation and baitboats 3. These fish were probably on their way to return to the north Mauritania fishing ground where they were tagged the year before.

Movements with time

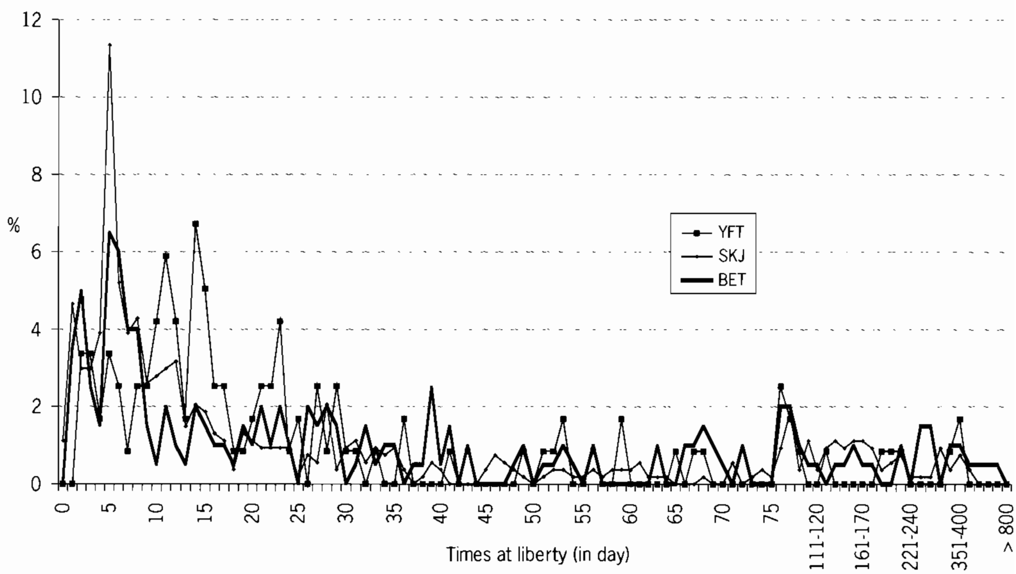
The distribution of the times at liberty (duration between tagging and recapture) are given in figure 12 for the entire set of data (1994-1998). Times at liberty are decreasing rapidly but recaptures are still recorded more than 365 days after tagging (1 yellowfin, 5 skipjack, 6 bigeye) and even nearly two years later for 2 bigeye. Times at liberty tend to decrease more rapidly for skipjack and bigeye than for yellowfin. Movements measure as the distances (in nautical miles) covered by tuna between tagging and recapture are very short and apparently very slow (see the table).

Table - Average displacements and mean displacement rates of tagged tunas in the Dakar baitboat fishery (1994-1998).

	Yellowfin	Skipjack	Bigeye
Average displacement (nautical miles)	63	86	66
Whatever the time at liberty (miles/day)	1.70	2.14	1.16
For times at liberty ≤ 100 days (miles/day)	2.24	3.69	2.19
100 < times at liberty ≤ 200 days (miles/day)	1.85	1.32	1.18
Times at liberty > 200 days (miles/day)	0.53	0.85	0.34

The apparent lower speed after more than 200 days at sea express the return of tuna to their original fishing grounds the next fishing season and the lack of long distance recaptures by purse seiners, especially for bigeye and yellowfin.

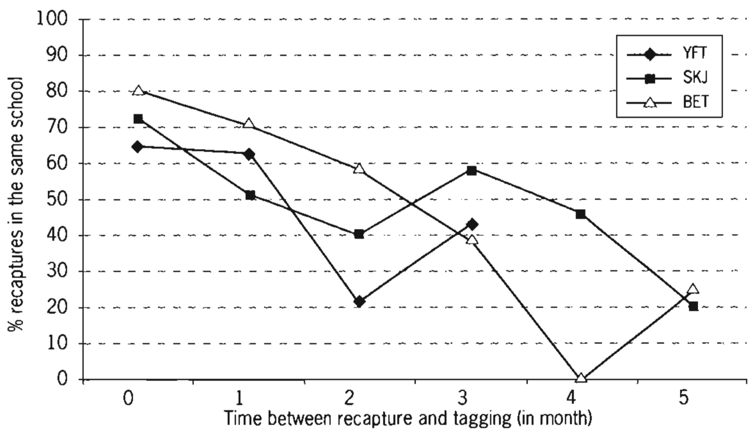
Figure 12
Distribution (in % of total number of recaptures for each species) of the times at liberty for tunas tagged and recaptured between February 1994 and December 1998.
BET: bigeye tuna;
SKJ: skipjack tuna;
YFT: yellowfin tuna.



Movements within associated schools

As associated schools and their exchanges are documented (fig. 5), it is then possible to assign each recapture by baitboats to a particular school. All species together and for the 1994-1998 data, 61% of the tunas were recaptured in the same school where they were tagged and 39% in different schools, either in other associated schools or in non-associated schools (by baitboats or purse seiners). The results for each species is respectively 56% in the same school for yellowfin, 60% for skipjack and 67% for bigeye. The proportion of recapture in the same school is decreasing with time in a quite similar way for all species (fig. 13). For yellowfin, it decreases from 65% the month they were tagged to 0% five months after, for skipjack the corresponding proportions goes from 72% to 20% and for bigeye from 80% to 25%. Seven months after tagging, 2 skipjack out of 8 were recaptured in the same school; eleven months after one out of two; similar results are recorded for yellowfin. For bigeye, thirteen months after tagging 2 out of 4 bigeye were recaptured in the same school. Therefore some fish remain in the same school for many months. Overall bigeye appeared to be more faithful to its original school. Holland *et al.* (1999) found the same results for bigeye associated to a seamount near Hawaii Islands.

Figure 13
Percentage of recaptures into the same school as the one where tunas were tagged; data from 1994 to 1997 scientific cruises.
YFT: yellowfin tuna;
SKJ: skipjack tuna;
BET: bigeye tuna.



Discussion

The associated-school fishing method compared to other tuna aggregation methods

Gathering of tropical tuna under natural or artificial objects, anchored or floating, (also called Fish Aggregating Device, FAD) is well known even if it is not yet properly understood. Fishermen have use this behaviour to their advantage. Artisanal fisheries using anchored objects are well-developed around the world and purse seine fishing on floating drifting objects is practised on a very large scale by all tropical tuna purse seine fleets (Fonteneau, 1993; Fonteneau *et al.*, 2000). Between these last two types of FADs, the main difference is one is fixed as anchored while the other is free to drift under the influences of currents and winds. At night, the association of tuna to baitboats can be compared to their association to drifting FADs used by purse seiners. Even, if baitboat skippers modulate their drift by slowing the boat using a floating anchor when winds or currents are too strong or, on the contrary, increasing their drifting speed by setting a bow sail in case of currents or winds too weak, their vessel is still like a floating object. Skippers recognize that most tunas are gathered at night; this is why they use powerful lights to illuminate the volume of water around the boat in order to increase their attractiveness. However, during daytime, the boat is no more a drifting object as the propellers are on and the boat is steaming at speed between 1 to 5 knots. It should be noted that sometimes boats steam at night or drift during daytime. When the boat is leading the school in the direction it wishes we have no more a passive state as for the drifting log or boat but a dynamic process that may be comparable to tunas associated to whales or whales sharks. This type of association is quite common among tropical tuna and even if it is mentioned in the literature (Gaertner & Médina-Gaertner, 1999; Ariz Telleria *et al.*, 1993; Hallier & Parajua, 1999; Hampton & Bailey, 1999), it is not well-documented. Hampton & Bailey (*op. cit.*), for the Western Pacific Ocean (WPO) purse seine fishery, mention: "the schools found with live whales do not form long-term associations with the whales; they seem only to come together to feed and separate once the anchovy are consumed". For whale shark association, they write: "it appears to be intermediate between live whales and logs in that shark and tuna often come together to feed on anchovy but are able to maintain the association for some time, very much like tuna aggregation under logs". However, they do not mention if these statements are based on observations and/or data. In WPO, while purse seine log sets include 78% skipjack, animal sets (considered mostly as sets on whales or whales sharks) include 55% skipjack; free-school sets are between those last two with 67% skipjack (Hampton & Bailey, 1999). Bigeye are not properly identified at sea and in port, therefore, their proportion into the WPO purse seine catch cannot be compared.

The catch species composition on log schools fished by purse seiners worldwide varies according to oceans between 21% and 34% for yellowfin, 55% to 78% for skipjack and 1% to 19% for bigeye (Fonteneau *et al.*, 2000). The associated-school fishing method is characterised by a higher proportion of bigeye to the detriment of skipjack. But the most remarkable point is the tremendous difference with the species composition of purse seine catch on logs and on free schools in the same strata (see p. 556-557). Before baitboats performed this technique, not even as a passive process, their catch species was more similar to the purse seine one. From 1969 to 1974 and north of 15°N, baitboats caught on average 53% yellowfin, 36% skipjack and 9% bigeye; purse seiners in the same strata but from 1978 to 1983 (1978 is the first year where data for purse seiners are completely available) caught 59% yellowfin, 38% skipjack and 3% bigeye. The divergence between the species compositions of the two fisheries deepened when the baitboats started to develop the passive school fishing method from 1976 and when the occurrence of yellowfin dropped suddenly and never recovered in the purse seine fishery north of 15°N from 1984. Baitboat skippers consider bigeye as the keystone of their technical success. They pretend that without bigeye it is very difficult to keep the school with the boat. This statement still need to be tested, however bigeye seems to be the more faithful to the school where it is tagged (see p. 570). Nevertheless, associated-school fishing method does not show a catch species composition similar to purse seine fishing on log, especially regarding its higher proportion of bigeye. This characteristic is also noticed for the baitboat fishery of the Canaries (from 1991 to 1997, 46% of the total catch were bigeye).

Size distributions of tunas caught in baitboat schools do not differ very much from size distributions of tunas caught on purse seine log schools. By-catch, a characteristic of purse seine fishing on log school (Stretta *et al.*, 1993; Fonteneau *et al.*, 2000) cannot be compared to by-catch from baitboat associated schools as data are lacking. However, observations made at sea during the research programme reveal a low occurrence of by-catch in this fishery but a very similar species composition when compared to purse seiners (small tunas, "mahi-mahi", sharks, rainbow runner, wahoo, billfish).

The association of tuna with baitboats could be the combination of two types of association: an association of tuna with drifting FADs at night and an association of tuna with whales or whales sharks during daytime.

Tuna dynamics

The average baitboat carrying capacity is 125 t and during the main fishing period, from July to December, boats come back to port with their holds full every two or three weeks. Schools associated to baitboats have an average biomass of 100 t even if some estimations reach 300 tons. Therefore, new migrant tunas into the associated schools are necessary to maintain the catch rates and skippers always try (night and day) to increase the size of their associated school.

Tuna associated with baitboats seem to be quite faithful to the school in which they are tagged as three months after tagging almost half (49%) of the recaptured tuna are still caught in the same school. Recapture rates recorded for all species are very high and could suggest a high exploitation rate. It is obvious that if tunas tend to remain in their original school or to move into the other baitboat associated-schools, their probability to get recaptured will be high. However, the rapid decline of the number of recapture is remarkable. Fourteen days after tagging, 50% of all the recaptures have already been registered (43% for yellowfin, 55% for skipjack and 41% for bigeye). This is probably the result of the diffusion of the tagged tunas among the associated schools, the immigration of new comers in the different associated schools and the emigration of tagged tunas outside the associated-school biomass. The rates of these movements are yet to be estimated when all tagging operations would be completed.

The very low catch rates of tagged fish by purse seiners and the predominantly skipjack catch by purse seiners lead to the following hypothesis:

- in this area almost all yellowfin and bigeye are either associated to baitbaots or in schools not available to purse seiners; within this last group a steady migration into the associated schools will compensate catches from baitboats;
- two groups of skipjack are present, one is associated to baitboat, the other is in free schools available to purse seiners; a third group might not belong to any of these two groups but could at some stage migrate into the associated schools;
- movements of skipjack between the two groups (baitboat-associated schools and free schools) seem to take place in only one direction from free schools to baitboat-associated schools, but very rarely in the other direction.

The rapid day-to-day changes in species composition (fig. 6) could reflect either a real change of the school species composition or a change in feeding behaviout of different groups of tunas among the school. To get caught, tunas associated to baitboats need to respond to baiting and/or to the attractiveness of the hook lures. A particular tuna or group of tunas will not respond to baiting every time but at a particular time space. From the observations made by Josse *et al.* (1999) using acoustic echosounding on tunas associated to anchored FAD, a general distribution of fish by species and by size around the FAD is proposed. Small fish would be closer to the FAD and near the surface while larger fish would be deeper and more distant from the FAD, even some would be more than 4 km away from the FAD. If this fish distribution is also accepted for schools associated to baitboat, this could explain the important changes of species composition and of fish sizes during a single fishing operation and from day-to-day operations on a particular school. According to their needs, different groups of tuna would come closer to the boat and get caught. Larger tunas will avoid the proximity of the boat during most of the day but will come close at night to feed on preys attracted to the lights and at dawn when baits are thrown (when looking at the food frenzy of these mostly large tunas around the boat, one wonders why skippers do not fished at night). Apparently, some of them will come closer in the afternoon and get caught again but in a much lower quantity than in the early morning. Once, larger tuna tend to leave the proximity of the boat, smaller ones will approach and remain in the vicinity of the boat for the rest of the day. It is difficult to know if the larger tunas belong to a particular school or swim freely between associated schools as none of them were tagged. As boats are not chartered, tagging performed during the research programme is not taking place during fishing operations but in midmorning or in the afternoon. So far, as big tunas are mostly early-morning biting fish, they are not available during tagging operations. From 1994 to 1998, the largest yellowfin tagged was 80 cm and 82 cm for bigeye. Hopefully some larger-size bigeye were tagged in August 1999 and their recaptures might shed some lights on the whereabouts of these large-size fish among the associated schools.

Baitboats: a meeting point for tunas?

Fréon & Misund (1999) have proposed the hypothesis that logs in general (drifting or anchored) or seamounts would be a meeting point for tunas in order to increase their probability to meet conspecifics and form schools, an indispensable need for these pelagic fish. When schools under logs are sufficiently large, groups will leave to form free schools mostly monospecific or to join other multispecific schools associated to other logs. From tuna tagging in the WPO, Hampton & Bailey (1999) demonstrate that mean displacement rates are highly dependant on the type of school the tuna are associated with. The higher displacement rates are noticed for the three tuna species when they are associated to drifting logs, natural or articial (between 12 to 23 miles/day). From the example of a single log school, Hampton & Bailey (*op. cit.*) show that movements recorded were mostly from active swimming than passive drift with the log. On the opposite, lower rates are recorded for tunas associated to anchored FADs or seamounts (1.1 to 2.7 miles/day). Rates for tunas associated to animals are slightly higher (between 2.5 and 3.3 miles/day). With average rates between 1.2 to 2.1 miles/day (see the table), tunas associated to baitboats look like tunas associated to anchored FAD or seamount. Tuna tracking with sonic tags around anchored FADs (Holland *et al.*, 1990; Marsac *et al.*, 1996; Marsac & Cayré, 1998) have also demonstrated the relatively small distances tunas are travelling around the FAD and their tendency to come back to the original FAD. The behaviour of tuna associated to drifting FAD seems to well respond to the meeting point hypothesis: tuna will join logs and build large school and then left in free schools or join other logs. Therefore, there will be a continuous flow of tuna under logs with a turnover that will depend on the abundance of tuna in the log area. Results from tuna tagging (ordinary tagging or sonic tagging) under anchored FADs, seamounts or baitboats show a different pattern. These structures can still be a meeting point for tuna but, once associated, these fish will tend to remain for lengthy periods of time, up to several months as proved for baitboat-associated tunas. In this case, schools associated to these structures would become bigger and bigger; a fact that has not be observed. In the case of tuna associated to baitboats, the every day withdrawal of tuna through fishing operations can well explain why schools remain more or less the same size. It will also explain why so few fish are recaptured by purse seiners in the vicinity of the baitboat schools. As some tunas remain associated to baitboat schools for very long periods of time, it is necessary that the baitboat school environment meets their requirements, notably in terms of food availability. As already mentioned, the area of North Mauritania is very rich and observations at sea show that during daylight hours fish are often seen feeding on natural preys around the steaming baitboat; feeding at night is also well noticed. However, the associated-school method is also working in areas that might not be as rich in food as the main baitboat fishing ground (for instance: Cape Verde Islands from January to March or the waters off the coasts of Canary Islands).

Baitboats: an ecological trap for tunas?

Marsac *et al.* (2000) put forward the idea that drifting FADs used by the purse seine fishery on a large scale in all oceans can represent gathering points which will retain fishes even if it is to their disadvantages (slower growth by lack of food, higher natural mortality by predators and modifications of the natural migratory pattern). They qualify drifting FADs as "ecological traps". Could baitboats be such sort of ecological trap? It is obvious from tagging return that tunas associated to bait-boat schools can remain with them for lengthy periods of time (fig. 13). At this stage of the data analysis, there is no evidence that this long-term association would be maintained to the detriment of the fish. Anyway, as no tuna were tagged outside the associated schools during the course of this programme, it is difficult to compare the associated tuna with non-associated ones.

Research problems

The study of this new type of association is still underway and will probably remain so for some time as it addresses many questions related to the dynamics of the schools and of individual tuna within schools which are not yet well understood. Many questions are still unanswered: do all tuna that get associated to baitboat schools behave the same way? Or do schools are made of different groups with different history and future? Do some groups get associated for a very temporary period while others will remain associated for long time? What benefit tuna will get from these long-term associations? Why tuna, once they get associated to baitboat schools, rarely leave to form free schools available to purse seiners? Do the association to baitboats has an effect on the spatial distribution of the tuna? Is it possible that the selectivity of the gear give access only to some groups and not to others? Would tagged tunas behave in a different way than untagged ones? How to measure the fishing effort of the baitboat fishery with such a fishing method? and so on...

It is obvious that the behaviour of tuna and their schools have strong consequences on the availability of the ressources to the different fishing gears, the biology of the fish but also the assessment of the state of their stocks. Hopefully, new research tools to apprehend some of these questions become available to tuna research such as sonic, pop-up and archival tags as well as new developments in mathematical models.

Conclusion

The associated-school fishing method developed by Dakar baitboats in the eighties increases the baitboat CPUE and the percentage of bigeye into the catch. The mastership of this fishing method requires a strong cooperation between the boats of the fleet. Catch species composition is highly variable from day-to-day and even during a single fishing operation underlying different behaviours according to the tuna sizes and species. Movements of tunas outside of the fishing ground are limited and recaptures in the same spot one or two years after tagging are reported. Once associated to baitboats, tunas rarely leave to join free schools available to purse seiners but can change for another baitboat-associated school even if some can stay with the same school for several months. Tunas in associated schools are heavily exploited but are regularly replaced by new migrants. The associated-school fishing method might be compared to a tuna association with drifting log at night and an association with whales or whales sharks during daytime. Results presented in this document are still preliminary and give a complex image of tuna and tuna-school behaviour that needs to be clarified by further analyses of the data and more research on the ethology of tuna. These studies are not easy with regard to the tuna oceanographic requirements, the magnitude of their movements and the immensity of their habitats but Dakar baitboats with their associated-schools represent a very pertinent research platform.

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actes de colloques 28

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Pêche thonière et dispositifs de concentration de poissons

28

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Pêche thonière et dispositifs de concentration de poissons

(Caraïbe Martinique - octobre 1999)

Le colloque international « Pêche thonière et dispositifs de concentration de poissons» organisé en octobre 1999, en Martinique, permet de dresser un bilan, sous forme de synthèses régionales, de l'exploitation des grands poissons pélagiques à l'aide de DCP dans les trois océans et en Méditerranée. La technologie, les méthodes de pêche, l'impact sur les ressources, le comportement agrégatif des poissons et les aspects socio-économiques de l'utilisation des DCP sont les principaux thèmes développés. Ces travaux permettront d'assurer une diffusion large des résultats à l'échelle de l'océan mondial, de favoriser les échanges entre les scientifiques et les gestionnaires impliqués dans le développement des systèmes DCP, de promouvoir l'émergence de thèmes et projets de recherche scientifique et technologique, de mettre en œuvre un réseau de communication et d'échanges entre les sites et les régions concernées.

The international symposium "Tuna Fishing and Fish Aggregating Devices", October 1999, in Martinique, takes stock of the exploitation of large pelagic fish around FADs, based on regional synthesis for the three oceans and the Mediterranean Sea. Main themes include technology, fishing methods, impact on resources, biology of fish aggregation, anthropology and economic aspects of FAD exploitation. The meeting will gather and disseminate results from recent and ongoing studies on FADs in the different oceans of the world, enhance collaboration between scientists and managers involved in the development of FADs, promote the emergence of scientific and technical research, form a network for cooperation and enhance communications between researchers in the different locations concerned.

28

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