An efficient way of bait-fishing for tunas recently developed in Senegal

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Abstract

A new fishing method has been developed during the last twelve years by the tuna baitboats fishing seasonaly (from July to December) in the area of Senegal and Mauritania (West Africa, 12 to 21° N). Three species of tunas, yellowfin, skipjack and bigeye tunas are caught in similar proportions in this fishery. This method has produced a dramatic increase in the baitboat catch per unit of effort (CPUE). The paper describes this new fishing method where the boat is permanently running associated with a very large tuna school, night and day, during several months. A team of two baitboats exploits each school, operating one after the other. The biological and environmental characteristics of this associated-school fishing are analyzed from detailed log book data. The daily positions of each school and the catches by species and sizes are analyzed for each boat and school. The dynamics of the association between the tunas and the baitboat and the dynamics of this exploitation (*i.e.* input and output of tunas in each school) are discussed in relation to the peculiarities of the local environment (mainly sea surface temperature and bathymetry). The reasons for the increased CPUE in this associated-school fishing are analyzed. Further researches should be conducted in order to better understand how fish behaviour relates to this fishing mode and in order to estimate the potential local yield of the fishery, if increased fishing effort is exerted in the future.

Keywords : Tunas, yellowfin, skipjack, bigeye, schooling, baitboat, fishing efficiency, eastern Atlantic, environment.

Accroissement de l'efficacité des canneurs basés à Dakar grâce à la mise en œuvre d'un nouveau mode de pêche associant pendant plusieurs mois deux canneurs à un banc de thons.

Résumé

Une nouvelle méthode de pêche a été développée durant les douze dernières années par les thoniers canneurs opérant dans la zone du Sénégal (Afrique de l'Ouest, 12 à 21° N). Trois espèces de thons, l'albacore, le listao et la patudo sont capturées en proportions voisines par cette flotille. Cette méthode a considérablement amélioré les rendements des canneurs. L'article décrit ce nouveau mode de pêche dans lequel les bateaux sont associés étroitement avec un banc de thon sur une base permanente, nuit et jour, pendant plusieurs mois. Une équipe de pêche constituée par un groupe de deux bateaux se relaie pour exploiter le banc. Les caractéristiques biologiques et de l'environnement liées à ce mode de pêche sont examinées à partir des données des livres de bord. Les positions journalières exactes des prises sont connues pour chaque banc, de même que la composition en espèces et tailles des captures. La dynamique de cette association entre les thons et les canneurs ainsi que la dynamique propre de cette exploitation (taux d'entrée sortie des thons dans chaque banc) sont discutées en relation avec les particularités locales de l'environnement (principalement température de surface et bathymétrie). Les raisons de l'amélioration des rendements en relation avec cette méthode de pêche sont examinées. D'intéressantes recherches potentielles pourraient utilement être conduites sur cette pêcherie afin de mieux comprendre cette méthode de pêche en fonction du comportement des poissons et du potentiel de captures locales lié à l'éventuel accroissement d'un effort de pêche employant cette méthode.

Mots-clés : Thons, *Thunnus albacares, Katsuwonus pelamis, Thunnus obesus,* bancs, canneurs, puissance de pêche, Afrique de l'Ouest, environnement.

INTRODUCTION

The tuna baitboat fishery in Dakar, Senegal (West Africa), has been operating permanently in the area since the beginning of the fifties (Champagnat, 1968; Fonteneau *et al.*, 1986). In traditionnal baitboat pole-and-line fishing, the boat searches actively for a tuna school. When a school is located, the boat stops and chums with live bait (kept in wells), in order to attract the tunas; the crew then uses poles and lines to catch the tunas. When the school is entirely fished, or when the tunas stop eating the live bait, the fishing operation stops, and the boat searches for another tuna school.

This fleet is based in Dakar, Senegal, and is fishing presently in the coastal areas between 12 and 21° North (*fig.* 1). The catch of this baitboat fleet has been fluctuating without trend at a yearly level of about 10000.10^3 t (*fig.* 2). However, the number of baitboats active has been constantly decreasing during recent years (*fig.* 3) and this stability of catches was obtained through a dramatic increase in the catch rates. This increase is shown by *figure 4,* which gives the yearly catch rates by categories of baitboats active in Dakar during 1975-91. The increasing trend cannot be explained by an increased abundance of the tuna stocks, as it has been clearly shown that most of the Atlantic tuna stocks in the area were fully exploited, and have shown stable or decreasing biomass trends during recent years (Anon., ICCAT, 1992). The goal of the present study is to analyze the changes in the fishing patterns of this baitboat fleet to explain the increased fishing catch rates.

This work was not submitted to ICCAT nor published previously because of an agreement with the skippers of the tuna boats, who provided detailed data upon their new fishing method, in exchange for temporary "confidentiality". This is the first

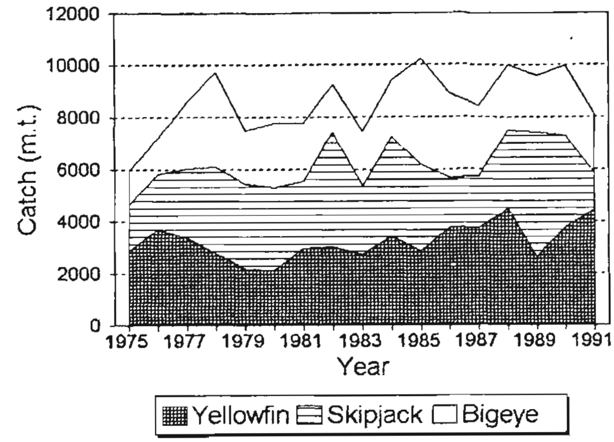

Figure 2. – Yearly catches of tunas (by species) taken by the Dakar baitboats during the period 1975-1991 (in 1 000 t).

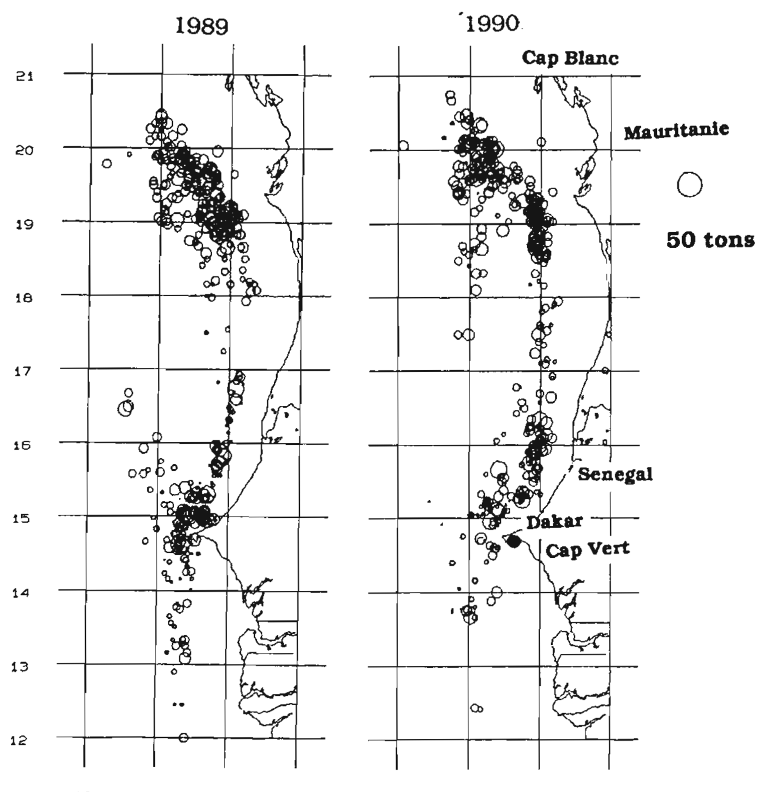

Figure 1. – Fishing areas of the baitboat fleet based in Dakar in 1989 and in 1990. Each circle is proportional to a daily catch, with the exact location of the catch to the nearest minute of latitude and longitude.

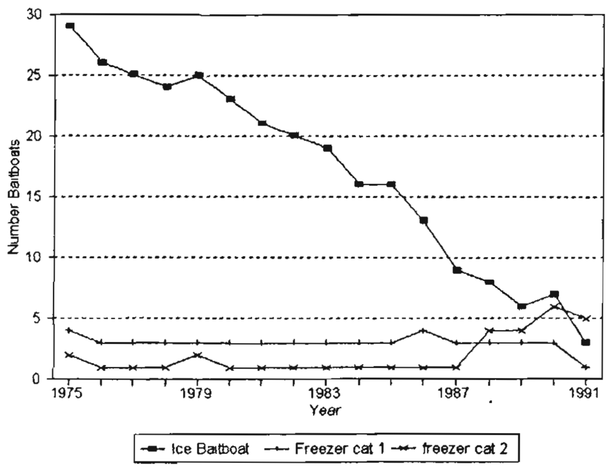

Figure 3. – Number of baitboats landing yearly in Dakar between 1975 and 1991 by type (ice baitboat *i.e.* baitboat which keep the tunas in ice and freezer baitboat) and by size category (cat. 1-100 t of carrying capacity, and cat. 2 +100 t).

preliminary description and analysis of the new fishing method based upon available data. A more comprehensive research program should be developed based in the insights and questions presented in this paper.

MATERIAL AND METHODS

The present study is based primarily upon log book data collected on the baitboats from 1975 to 1991. Approximately 50 to 90% of the fleet was covered during this period, with coverage improving to 90 to 100% during the most recent years. Detailed fishery were analyzed for the year 1990 when 92% of the baitboat catches landed in Dakar were covered by the log books. Log books provided daily position (to the nearest minute of latitude and longitude) for each boat and its daily catch of tunas by species, as estimated (by eye) by the skippers. The fishery data for one school exploited during 1987-88 were also used to show an example of the North to South migration of the schools in relation to changes in sea surface temperatures. Sea surface temperature data were collected by merchant ships crossing the area, by the baitboats themselves and from satellite imagery (METEOSAT data processed in the Unité de traitement d'images satellitaires, UTIS laboratory at Centre de recherches océanographiques de Dakar-Thiaroye, CRODT).

Size data on landings at Dakar were also collected by the technicians from the Centre de recherches océanographiques de Dakar-Thiaroye (CRODT). A total of 9 170 tunas were measured during 1990 from the baitboat landings.

All the fishery data (log book and size data) corresponding to six schools of tunas, exploited during several months in 1990, were selected to be analyzed.

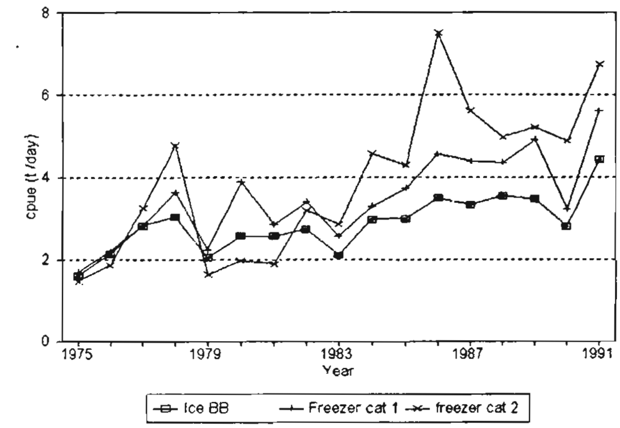

Figure 4. – Yearly average CPUE (t/day at sea) of the Dakar baitboats between 1975 and 1991 by type and category of baitboat (as described in *figure* 2).

In this fishery, each school can be fished for several months and identified in the data set, as the exchange of schools between baitboats are registered in the log books.

Another source of information on this fishing technique was obtained from various skipper's personal communications, who provided to the authors important qualitative information on their fishing operations. Those personal communications, in conjunction to the use of data from the fishery, have been used to establish working hypothesis.

RESULTS

Changes in fishing patterns of the fleet: the new associated-school fishing

An analysis of fleet characteristics showed that most baitboats were small units carrying less than 50 t of tunas and keeping the fishes in ice. The boats became older and the number of boats in activity has been constantly decreasing since 1975; no new boats were added to the fleet until 1988 (*fig.* 3). The number of baitboats equipped with freezing facilities was more or less stable until 1988, when new baitboats of larger sizes and larger carrying capacity (approximately 200 t) were added to the fleet. The only major technological improvement in the fishing equipment was the satellite positioning introduced on every boats during the early eighties.

The major change in the fishery was a change of the fishing method developed and refined by the skippers of the Dakar baitboats since the beginning of the eighties. This original fishing method was never used before and has never been described by scientists, to our knowledge, for any other baitboat fishery in the world. Presently, most of the baitboat catches from Dakar are taken using this new fishing method.

In this new fishing method, the fishing operations are conducted by a team of two cooperating baitboats:

– At the beginning of the fishing season (usually June or July), a first baitboat (boat "A") will search for a tuna school. When a school is located, instead of starting its fishing operations, the skipper will try to associate "permanently" the tuna school to its boat. The baitboat will keep moving with the tuna school to "build" the association and to produce an increase of the school biomass. Thereafter the fishermen start their fishing operations and fishing is conducted for an extended period, keeping the tuna school under the boat and catching tunas every day.

– When the baitboat "A" has reached its full load of tunas, the other cooperating baitboat "B" (empty), will approach its colleague boat associated with the tuna school, and the association with the tuna school will be exchanged between the two boats A and B. A fast manœuvre is made to exchange positions (usually at night).

– Boat "B" will then commence fishing operations until reaching its full load. At that point, if the boat "A" is not yet ready to "catch" again, boat "B" will wait for her (moving with the school).

A third cooperating boat "C", which does not catch tunas, can also be used to follow and maintain the association between the school and vessel while waiting for boat "B". This "Buffer boat C" is working in cooperation with the entire fleet.

Species and sizes of tuna caught

Four species of tunas are usually exploited in various proportions in the baitboat fishery: *Thunnus albacares* or yellowfin, *Katsuwonus pelamis* or skipjack, *Thunnus obesus* or bigeye and *Euthynnus alleteratus* or black skipjack (this last species is always dumped). The average relative contribution of the first three species in the baitboat catches during the period 1980-1991 was 37.5 % yellowfin, 33.8 % skipjack and 28.7 % bigeye. Most of this catch (but not all) was taken using the associated-school fishing. Skipjack was the species with the lowest economic value, especially during recent years. Consequently, it was often dumped at sea (probably alive). *Euthynnus* was also often found in the schools associated with the baitboats. From skipper's accounts, this species often shows more aggressiveness in the plurispecific schools and stays closer to the boat to catch the bait; so, *Euthynnus* may often be a limiting factor and it may be difficult to employ efficiently the associated-school mode when this species is abundant.

The average proportion of each species in the fishery (1980 to 1991) was variable according to the time of year (fortnighly average, *fig.* 5). The catch and proportion of each species also depends on the percentage of tunas caught using the associated-school fishing and on the fishing zone:

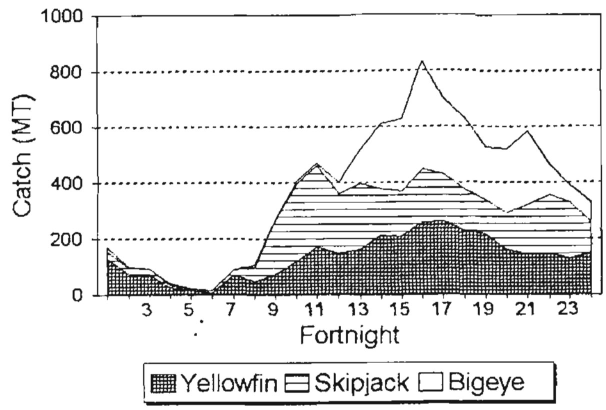

Figure 5. – Average fortnightly tuna catches, by species, caught by the Dakar baitboats (average 1980-1991, in metric tons).

– When the fishing season starts in Senegal, in June or July, skipjack is on the average the most abundant species (more than 60 %) and bigeye is very seldom found in the catches (averaging less than 4 %). During this initial period of the fishing season, a significant fraction of the catch is usually taken on free schools (not yet associated with the baitboats).

During the third quarter, when the fishing takes place in Mauritanian waters, most of this catch is taken on schools already associated with baitboats, and bigeye becomes the dominant species (nearly 40 % of the catches), followed by yellowfin (34 %) and skipjack (27 %); a similar species composition is also observed during the fourth quarter.

– At the end of the year, when the fishing zone moves southward to Senegal, the proportion of bigeye decreases, and during the fourth quarter, the three species are caught in similar proportions (each approximately one third of the catch).

The average sizes (1980-1991) of the tunas caught by this fishery were as follows: skipjack was the smallest species with an average weight of 2.4 kg, followed by yellowfin (6.8 kg) and bigeye (10.4 kg). The fish size samples taken during 1990 at the landing port of Dakar from 6 baitboat-associated schools (*fig.* 6) may show some trend during the fishing season. The sizes were stable for bigeye; all the sizes being caught in stable proportions between July and November. The sizes were more variable for yellowfin and skipjack. The dominant modal sizes of yellowfin was at a predorsal length of 17 and 18 cm (2 to 4 kg) in July, August and September. This modal size became insignificant in October and November, when larger fishes of 10 to 30 kg became dominant in the catches. As for skipjack, the modal size between 45 and 55 cm fork length (1.8 to 3.5 kg) was dominant in July and August and became rare in September, those skipjack being replaced by smaller fishes (in a size range between 40 and 50 cm *i.e.* from 1.2 to 2.5 kg) in October and November.

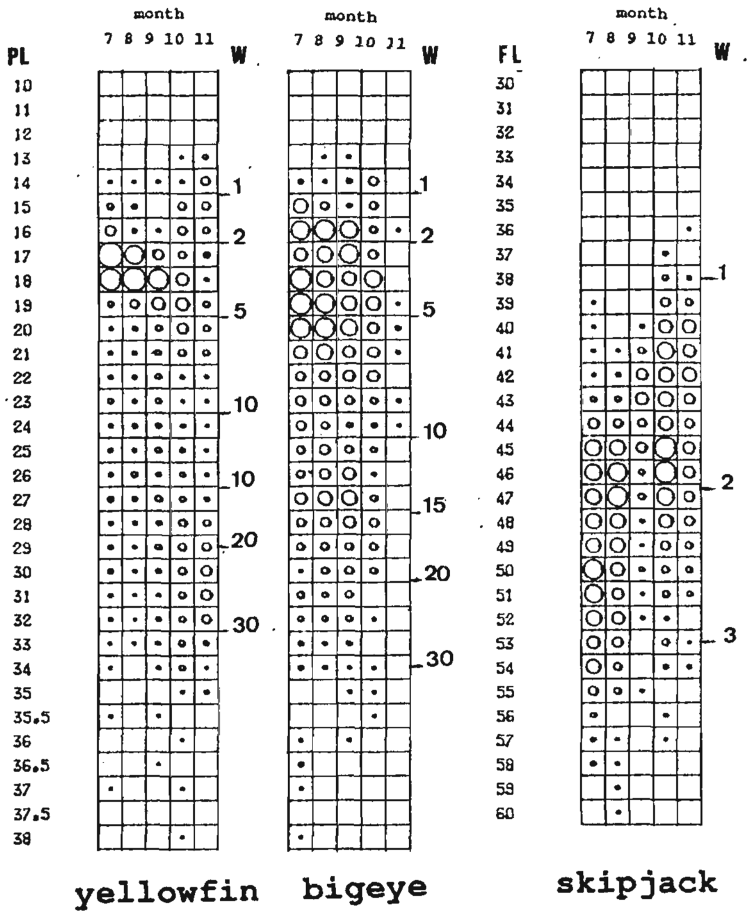

Figure 6. – Monthly sizes taken on the six schools studied during 1990, for yellowfin, skipjack and bigeye. Each circle has an area proportional to the number of fishes sampled in the size class. The sizes for the scale are given for yellowfin and bigeye in predorsal length in cm (PL) and for skipjack in fork length (FL) in cm (scales in the left of the 3 figures). The individual weigths (in kg) corresponding to those sizes are given on the right of each figure (W).

Environment and fishing zones

Seasonality of the sea surface temperature

The dominant characteristic of the environment in the area of Mauritania and Senegal is its marked seasonality: sea surface temperatures in Dakar fluctuate between an average of less than 20°C during winter (because of a wind driven upwelling; Roy, 1991) and an average of 28°C in summer (*fig.* 7). This seasonality is well shown by the average monthly sea surface temperature taken in the area by merchant ships.

As the tropical tunas are seldom found in waters with sea surface temperature (SST) colder than 22°C (Stretta, 1986), this environmental seasonality leads to intensive seasonal North-South migrations of the tunas in the area. This seasonal migratory pattern of the tunas is clear from the monthly locations of fishing zones as shown by *figure* 8. This seasonality of the fishing zones was observed each year in the fishery during all the period under study.

Most baitboat fishing takes place in the area of Mauritania (*fig.* 1). This fishing area is a rich upwelling zone, where huge biomass of potential food (*i.e.* small pelagic species), is to the tunas (Josse, 1991; Roy, 1991). The fishery takes place in warm waters (SST predominantly between 24 and 28°C), south of Cape Blanc. Those warm waters are located immediately south of the Cape Blanc front, where colder waters are found during all the fishing season (*fig.* 7). The available subsurface data indicate that, during the fishing season, the local thermocline depth is approximately 50 to 70 m. A typical profile of temperature versus depth in the fishing zone is given by *figure* 10.

Bathymetry

The bathymetry may be also an important parameter in the fishery: most associated-school fishing is conducted on the edge of the continental shelf, at depths between 500 and 2000 m or more (*fig.* 9), on fishing grounds located approximately at 10 to 20 miles from the continental shelf (*i.e.* beyond the 100 meter depth contour).

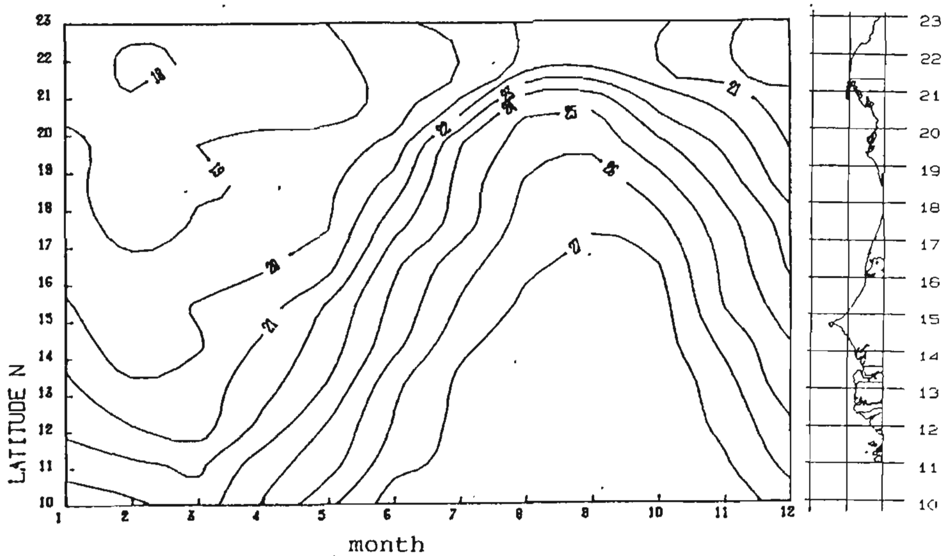

Figure 7. – Average monthly sea surface temperature observed in the fishing area (data from merchant ships and from tuna baitboats).

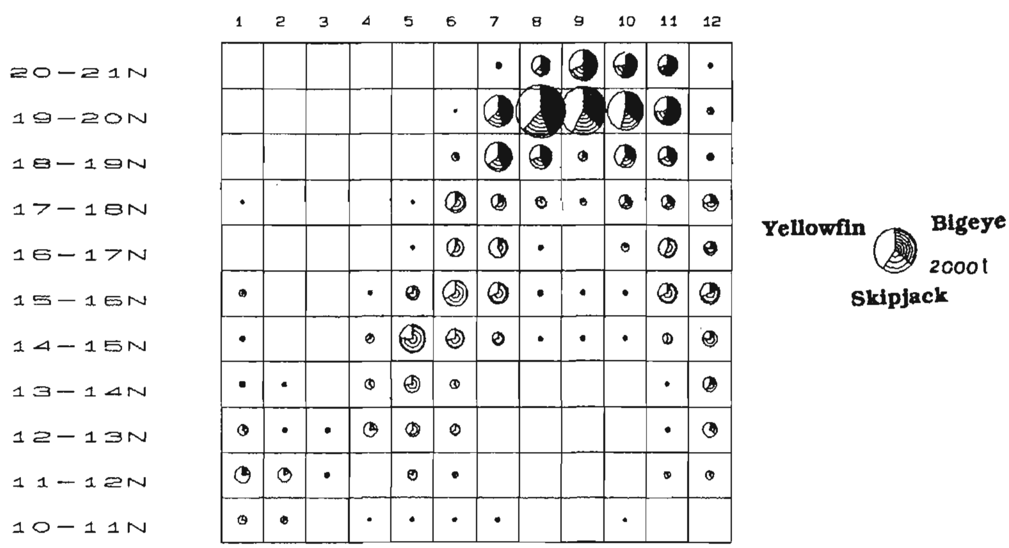

Figure 8. – Seasonality of the baitboat fishing zones: average monthly catches (period 1980-1991) by species, by 1 degree of latitude.

Currents

The literature on surface currents indicate that a geostrophic current, running at approximately 0.2 to 0.4 knots, is flowing southward in the fishing area during the fishing season. However direct measurements of the current in the fishing zone are not yet available. It is also unknown if the fishermen chose the direction of the boat's movement as a function of the surface current (speed and direction).

Wind speed

The peculiarities of the meteorological conditions must also be noted. Strong winds of Beaufort 5 and 6 (or 8 to 14 m.s^{-1}) are commonly observed in the area during the fishing season (Roy, 1990); this strong wind may be a limiting factor for the purse seiners, because the purse seine cannot be easily handled in such conditions.

Colour and transparency of the waters

No scientific observation was available concerning this factor. However, all skipper's accounts conclude that colour and transparency of the water are a very important factor in the associated-school fishing mode. It would appear that the baitboat skippers constantly move their boats to remain in blue and green waters, where moderate transparencies are observed. They constantly avoid:

– The areas with clear and transparent waters: those waters are usually the oceanic waters which are less productive and have less food available for the tunas;

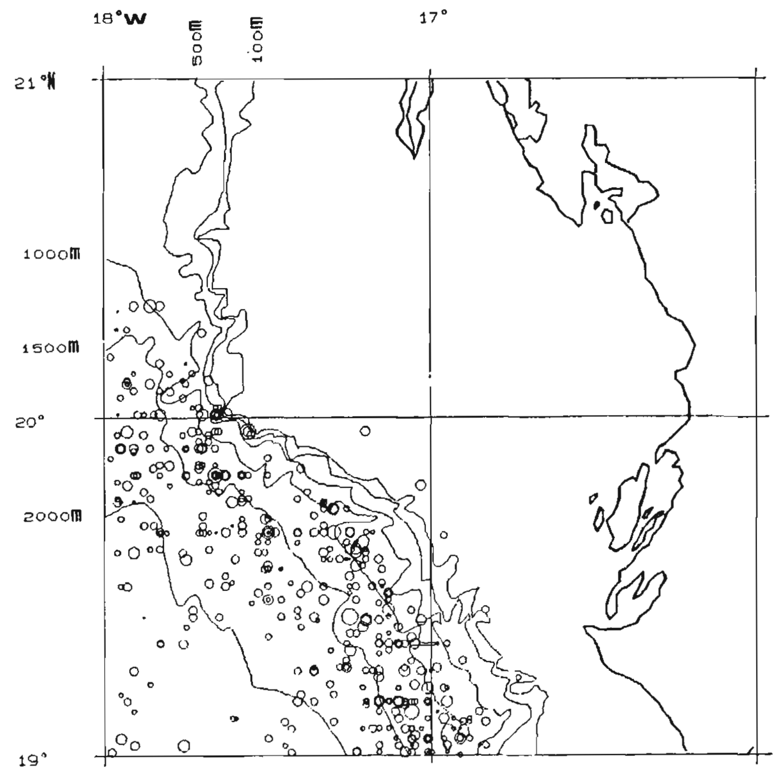

Figure 9. – Detailed bathymetry of the fishing area between 21° and 19° North and exact locations of all individual fishing operations during the period 1989 to 1991.

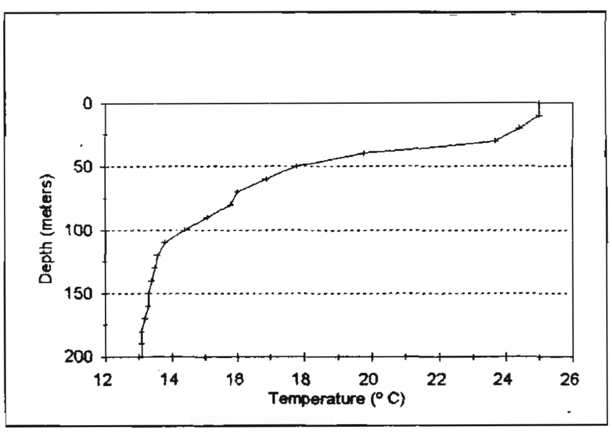

Figure 10. – An example of a typical thermocline structure in the fishing zone (taken at 19°50' N and 17°24' W, the 21th of September 1990).

– The areas with turbid waters, which are common in the coastal upwelling area. The avoidance of turbid waters by the tunas is a well described and well understood behaviour (Murphy, 1959; Magnuson, 1963). Most tunas are active visual predators and they need to locate visually their prey in order to catch them.

Thus, in these two cases of transparent and turbid waters, the risk for the baitboat of loosing its school would be increased.

Dynamics of the tuna aggregation and exploitation

The following observations are done on the associated school fishery:

– The average daily catch rate is high, averaging 5.6 t/fishing day during recent years (1988-1991). The daily catch rates from associated schools can be very high: a CPUE of 10 to 20 t per fishing day is commonly observed (*fig.* 11). A maximum CPUE of 90 t per day was even recorded in 1991. Significant catches are observed every day: fishing days without any catch are extremely rare in this fishery, whereas they are often observed in the traditional baitboat fishery. The total catch from a given school during a fishing season (usually 6 months) can reach or exceed 1 000 t.

– The species composition of the catch from one day to the following was highly variable for several individual school (*fig.* 11 gives the daily catches by species during August and September 1990 for each of the three schools). However, the day to day combined species composition for all six schools under study appears to be much more stable (*fig.* 12). From skippers accounts, this short term variability of the species composition is partly related to the topography of the bottom of the sea: yellowfin are dominant in the more coastal zone (*i.e.* between 500 to 1 000 m depth contours), while bigeye are the dominant species in deeper waters (depth greater than 1 000 m), such as above the canyons which are quite common in the area. Unfortunately, the poor quality of the bathymetric

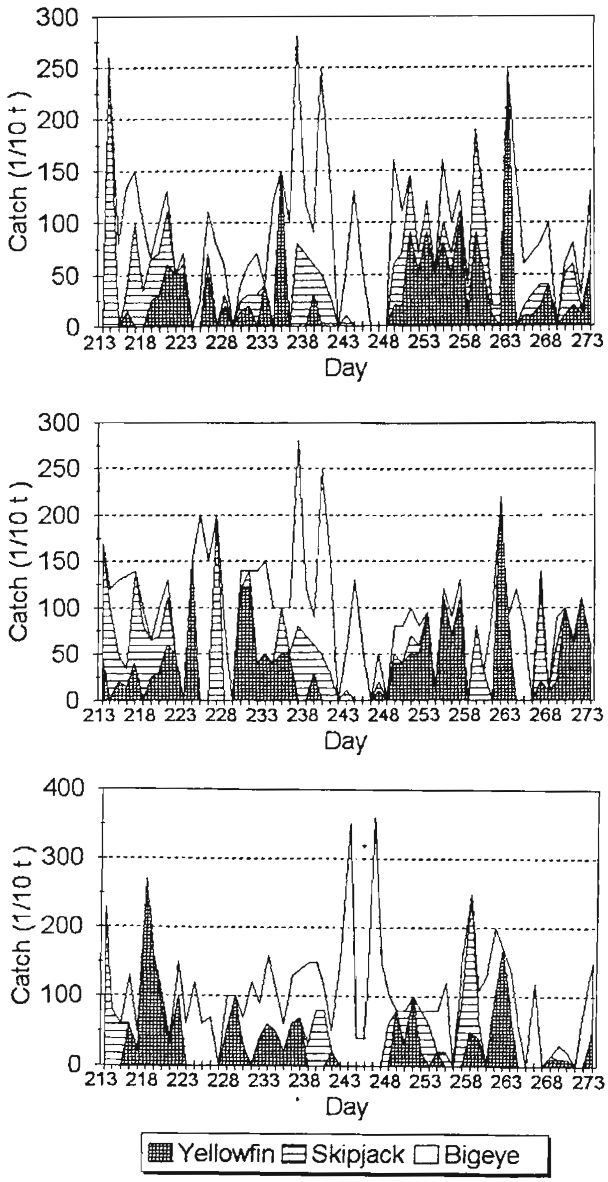

Figure 11. – Daily catches (by species) for three of the six schools under study during 1990, between August 1st (day 213) and September 30th (day 273).

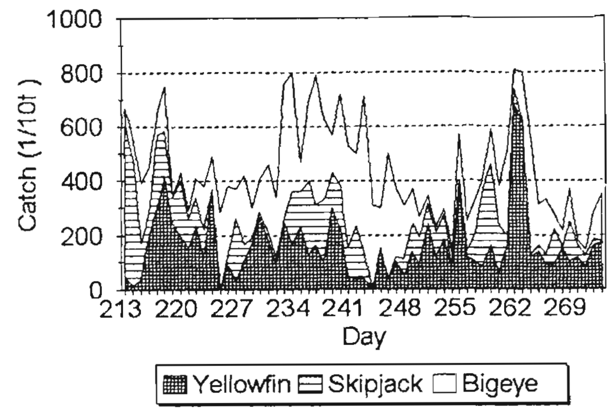

Figure 12. – Total daily catches (by species) for all six schools under study during 1990, between August 1st (day 213) and September 30th (day 273).

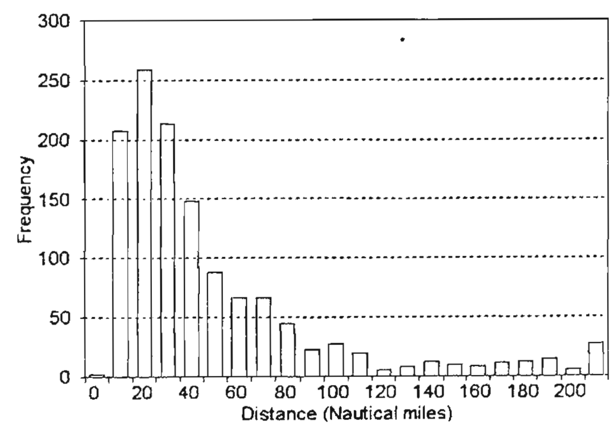

Figure 13. – Frequency distribution (in per thousands) of the daily distances between the 6 schools fished and studied during 1990 (in nautical miles).

maps presently available for the area does not allow a validation of fishermen's accounts.

The average distances between schools associated to baitboats are usually quite limited: the calculated average distance between schools was 48 nautical miles (*fig.* 13) during the 1990 fishing season, which means that all the boats were in operation in the same small fishing zone.

Movements and speed of the tuna school and baitboat associations

The apparent movement of the tuna school and baitboat association can be estimated from the daily positions recorded by the baitboats using the satellite positioning system. This movement is the apparent movement on the bottom of the sea, not on the water column as the surface currents are still unknown.

This analysis indicates that the average apparent distance travelled in 1990 was quite limited. The average daily distance was 18 nautical miles (corresponding to an average daily speed of 0.75 knot) (*fig.* 14). The fishery data clearly shows that between August and October the fishery is stabilized in a small area south of Cap Blanc. It appears however that at the end of the fishing season, when the upwelling is developing in Mauritania, the speed of the school and baitboat association often increases (e.g. *fig.* 15). In the example shown by *figure* 15, the school exploited covered a distance of nearly 180 nautical miles between Nov. 30th and Dec. 8th (at an average speed of nearly 1 knot). The same school moved between 19 degrees North the 25th of November 1987, and 12° North on the 5th of January 1988. This southward movement was probably in relation to the sea surface temperature changes and

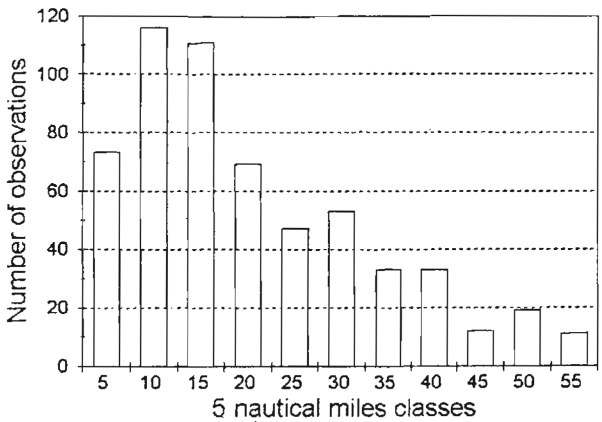

Figure 14. – Number of daily distances travelled (apparent straight distances between daily positions) for the 6 boats and associated schools studied during 1990, by classes of 5 nautical miles (*i.e.* class 15 = 10 to 14.9 miles).

the development of the upwelling which is shown in the same figure.

From skippers accounts, it appears that the real speed of the baitboat would be faster than the speed calculated from the distances between daily positions. A permanent speed of 1 to 3 knots is the typical average speed of the baitboat and the associated school, as reported by skippers, and speeds of 5 knots are in some circumstances maintained for several hours.

Association of the tuna school with the baitboat

This behaviour of the vessel associated tunas is typical and seems very similar to the tuna schools associated with any floating object. A mixture of several species of tunas, predominantly of small sizes, are observed in both the log associated schools (Fonteneau, 1993) and the schools exploited by the Dakar baitboats.

It seems clear that the tuna and log association is not a trophic relationship, in most cases, since the small quantity of food available for the tunas under a log could not be sufficient to feed the large biomass of tunas usually found there. This conclusion was obtained by Hunter and Mitchell in 1967, and confirmed by the IATTC working group on tunas and log associations in February 1992 (summarized by Fonteneau, 1993). The same conclusion is also probably valid for the initial association of tuna schools with baitboats, as these schools can probably reach a biomass of several hundred tons (from skipper's estimates), when only a limited food would be available for this huge tuna biomass in the immediate vicinity of the moving boat (except at night as described below). As well shown by the results obtained from sonic tagging, the association between individual fishes and the boat is probably a temporary one, each fish being able to leave temporarily the boat (Holland *et al.*, 1990). Furthermore each of three species having a different behavior and different physiological requirements, may have different movement patterns (both horizontally and vertically) (Holland *et al.*, 1992) and an heterogeneous association scheme with the moving boat.

The dynamics of the initial aggregation of the tuna schools to the baitboats can be followed (to some extent) from the log book data. Those data show that a duration of several days (1 to 8) was usually necessary to "build" a school associated with the baitboat. During this initial period, the boat moves slowly without fishing. Fishing operations start only when a sufficiently large school of tunas has been "permanently" associated with the boat (skipper's personal communication). It appears (also from fishermen's accounts) that the school biomass is increasing faster than it is diminished by the catches taken by the baitboat, at least during its first several months of exploitation. The sizes of the schools associated with the baitboats are usually very large: from skipper's estimates, a biomass of 500 t would be a reasonable average. This biomass could be reduced to 200-300 t at the end of the fishing season during the southward migration of the fishes.

During the night, the boat usually stops its engine and drift. The tuna school is kept aware of the boat using powerful lights reaching 25 000 watts. From skippers accounts, this powerful light attracts a large biomass of food. The skippers suggest that this food could be eaten by the tunas during the night. This is a significant behavioural change, as most tunas are visual predators and are not usually able to feed during the night (Roger and Grandperrin, 1976). This food available for the tunas during the night may help to keep the tuna associated with the boat during the day.

DISCUSSION

Biomass and dynamics of the tuna schools

The exploitation of schools "permanently" associated with fishing baitboats is probably a dynamic process. In this associated-school fishing, the biomass of the tuna school is simply a balance between a positive rate and two negative ones:

The aggregation rate: there is an active aggregation of tunas to the associated school, due to the continuous movement of the boat which works like a "tuna rake". When the baitboat moves and encounters a tuna, this fish will join the school already associated and moving with the boat;

The fishing rate: the removal by the baitboat catching fishes, which is done at an average rate of approximately 8 to 10 t per fishing day (nearly everyday);

The departure of tunas from the school associated to the boat: there is probably a "natural" output of tunas from the school, individually or in groups, to join

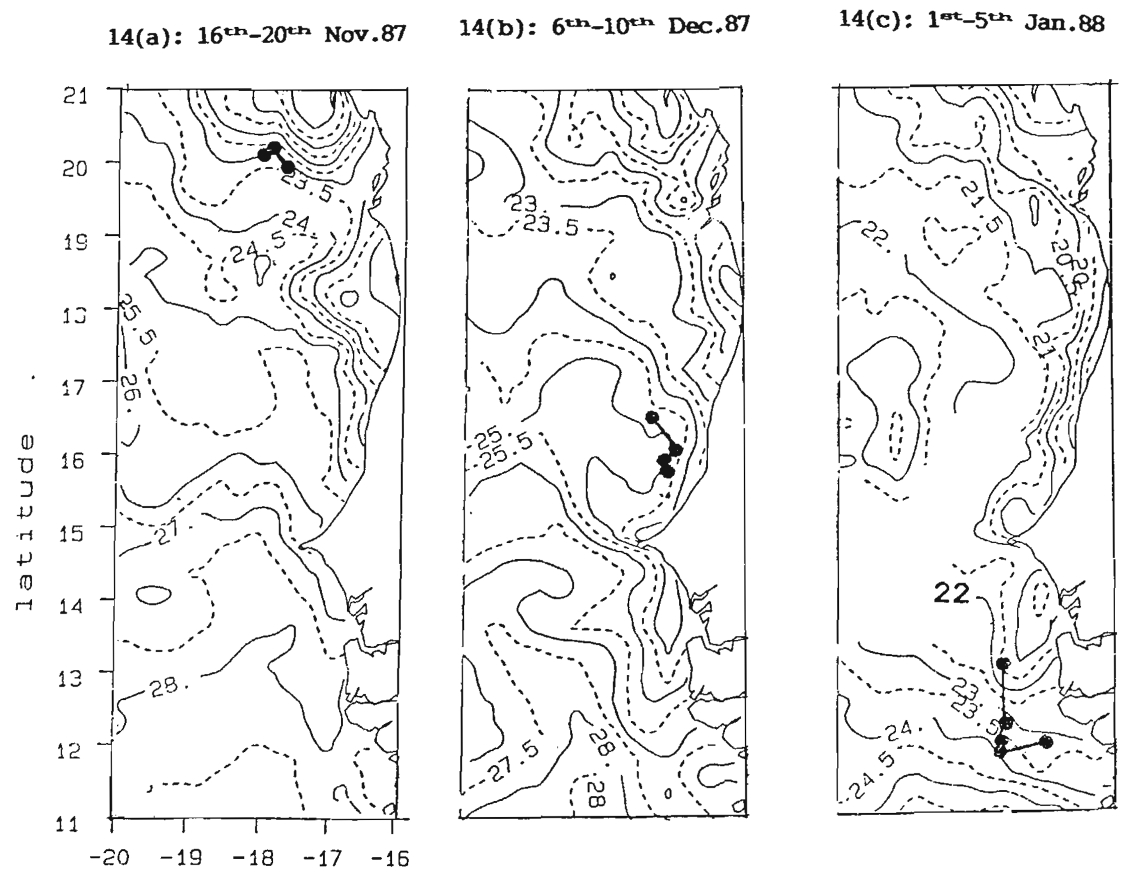

Figure 15. – Exact locations of the daily catches (by 5 days periods) and corresponding sea surface temperature measured by Meteosat satellite (processing made by the UTIS laboratory, courtesy of Mrs Marec and H. Demarcq) for a school exploited between November 1987 and January 1988. 15 (a): 16th to 20th of November 1987. 15 (b): 6th to 10th of December 1987. 15 (c): 1st to 5th of January 1988.

other tuna schools in the area, for feeding reasons or for environmental reasons (transparency, temperature, depth, etc.).

The subsequent changes of the school biomass (both the day to day and the changes during the fishing season) could easily be measured using echo sounders and signal integrators. The day to day variability of the species composition of the catch is a surprising characteristic of this associated-school fishing. It may correspond to large short term (*i.e.* daily) input and output of tunas to and from the school associated with the baitboat. In this hypothesis, the biomass of tunas which was associated with the baitboat on a given day could be entirely replaced very quickly by another group of tunas.

This quick change of the species composition of the catch may also be related to daily changes in the fish behaviour related to feeding. In this hypothesis, the multispecific school of tunas may be stable under the baitboat, but only one specific fraction of it can be caught a given day because this group of fish is more hungry to catch the bait.

The relative stability of the species composition taken by the overall baitboat fishery during 1990 (*fig.* 12) and the small distances between boats (*fig.* 13) also suggests that the tunas may be constantly moving from one baitboat to the other. This exchange could be linked to the ceaseless search for food, characteristic of tunas. Tuna searching for food will have a good probability of encountering another large school of tuna in the vicinity already associated with another baitboat. The observed changes in the size of fishes taken during the fishing season suggest, at least for yellowfin and skipjack during 1990, a progressive change in the available population. This change may be due either to tuna movements (*i.e.* medium size yellowfin moving outside the area), or to the depletion of a particular group of tuna (*i.e.* the local biomass of medium size yellowfin decreasing to reach a very low level in October and November).

Tagging (both ordinary and sonic tagging) would probably be an efficient method to provide some direct measurements of both the input and output flow of tunas between baitboats fishing in the area and the input and output flow of tunas to and from the fishing zone.

Role of the local environment

Further scientific analysis would be necessary to evaluate more precisely the importance of local environmental parameters on this associated-school fishing, but it seems that the conditions found in the area are unique and favourable. The abundance of food that is attracted to the immediate vicinity of the boat at night, and the transparency of the waters are two interesting (and often contradictory) components that probably contribute to fishing success in the area. The difficulties in "building" and maintaining tuna schools associations with baitboats in Senegalese or Guinea Bissau waters may be an indication that Mauritanian waters are especially conducive to practicing this associated-school fishing.

At this stage, it remains unknown if this associated-school fishing can be efficiently used in other areas of the Atlantic or in other oceans under other environmental conditions; however, there are some positive indications (J. Ariz from IEO Canary islands, pers. comm.) that two baitboats successfully used a similar method of fishing in the Canary Islands during 1993.

How are the baitboat CPUE increased?

Three major factors can easily explain the increased baitboat CPUE of the present mode compared with the traditional mode:

Reduced searching time: in the new associated-school fishing, the searching time is reduced to zero, as the baitboat is permanently associated with the school: when the boat is running associated with "her" school, good catches are taken nearly every day, with very few exceptions (*fig.* 12). The rare days when a null CPUE is observed, are most often due to the activity of the buffer boat "C" (which cannot fish) or to situation when the fishing baitboat is full and waits for the arrival of the cooperating baitboat. The boats also spend an average of 60 hours to reach the fishing zone and to come back to Dakar. This lost time of 2.5 days is quite significant for the average trip duration of 16 days (1990 average).

Improved catch per fishing day: the average catch per fishing day for the new mode was 7.4 t during 1990. The 1990 catch rate was relatively low compared to other years exemplifying the associated school fishery (*fig.* 4). This catch rate was very high in comparison with past performances of the baitboat fleet, and very high for such small boats. The average 1990 CPUE for the category 1 ice baitboats (20 t carrying capacity) was at 4.3 t/day and 6.2 t/day for category 2 (40 t of carrying capacity). Such catch rates are rather spectacular for small baitboat.

Part of the increased CPUE was probably also due to the dramatic decrease of baitboat fishing effort observed in the area: the dramatic increase of CPUE's recently observed could partly be the consequence of less competition between boats to catch the available biomass of tunas.

What is the potential average local yield of the baitboat fishery?

A definite answer to this question is very difficult, as the fishery exploits temporarily (during a 5 month-season) three major species of tunas which have probably different migration patterns and residence durations in the area. Furthermore, the local fishery exploits small fractions of three tuna stocks which are exploited at the Atlantic scale by various fisheries which may have a yield per recruit interaction with the Dakar fishery (as they catch the tunas at a smaller size than the Senegalese fishery).

However, this question of the "average local potentials" is obviously of major importance for fishery managers in Senegal, and the scientists have an obligation to provide at least a qualitative and global answer to it. On this topic, two types of global hypothesis can be developed. The catch-effort relationship and the CPUE-effort relationship corresponding to the two hypothesis are given in *figures* 16 and 17.

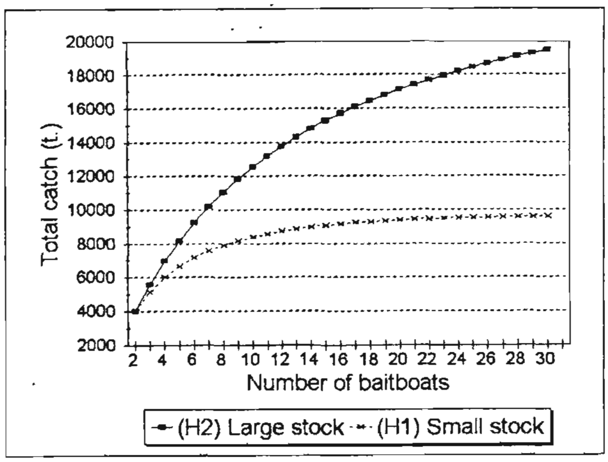

Figure 16. – Two hypothetical relationship between yield and fishing effort in the baitboat fishery: (H1) Small stock and high exploitation rate: local potential yield limited for baitboat to approximately 10 000 tons. (H2) Large stock and low exploitation rate: local potential yield for baitboat unknown but with a potential for a large increase.

(H1) *Small local stock: a local resident fraction of stock which is already highly exploited:*

In this hypothesis, the exploitation rate of the local stock is high, and the potential local yield of tunas in the area would be on the average a flat curve (Sathiendrakumar and Tisdell, 1987), with a maximum average yield of approximately 10 000 t (*fig.* 16). If so, part of the recent increase of CPUE could be explained by the reduction of the fishing effort in the local fishery (less exploited schools leading to less competition between boats to catch a limited biomass). In this hypothesis, any significant increase of fishing effort in the future could produce only a limited increase of the

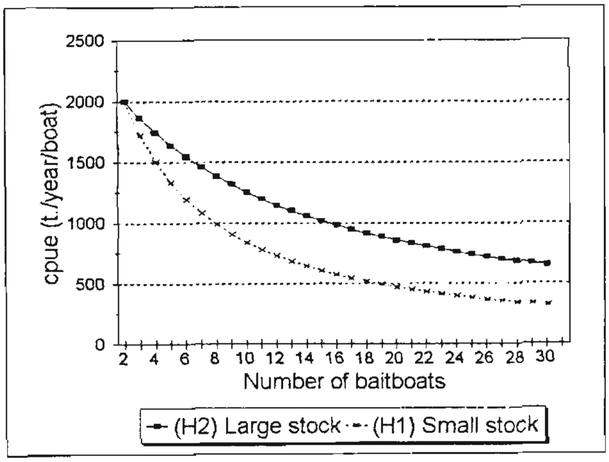

Figure 17. – Two hypothetical relationship between the baitboat catch rates and fishing effort (hypothesis are the same that in *figure* 16).

catch (or no increase), because of a quick subsequent decrease of CPUE (*fig.* 17).

(H2) *Large stock: a low exploitation rate of the local fraction of stock.*

In this hypothesis there can be

(1) either a *very large biomass temporarily resident* in the area,

or

(2) *a large permanent flow of migrating tunas* temporarily stabilized in the feeding area of Mauritania during the fishing season.

In such an hypothesis, a moderate decrease of the catch rates (or no decrease) could be expected from a limited increase of effort (*fig.* 17); the local catches could then be significantly increased (but to an unknown degree) with further increased effort (*fig.* 16).

Those diagnosis on the local potentials of catches may be different for each of the three locally exploited species: the present equal proportions of the three species may be modified with increased fishing efforts and catches, depending of the potential of each species.

The local dynamics of exploitation and the potentials yields of each species should be further analyzed, as this parameter would be of key importance for any plan to develop the baitboat tuna fishery of Senegal.

CONCLUSION

The new associated-school fishing developed during recent years by the local baitboat fleet from Dakar is probably quite unique in the world. Its impact upon the local tuna fishery has been very significant. This method, which developed an optimal use of some peculiarities of tuna behaviour, is now conducted as a "scientific" technique, efficiently conducted by experienced tuna fishermen in order to increase their catch rates.

This new associated-school fishing is similar, to some extent, to "off-shore sea ranching" for tunas, in which wild schools of tunas are temporarily kept "in captivity" by the fishermen during several months while covering several hundred nautical miles.

However, the present analysis was based upon limited fishery data, and many questions regarding this associated-school fishing are still pending. It is obvious that an *ad hoc* research program should be developed by scientists to understand better all the peculiarities of this unique fishery, for instance those concerning the schooling and feeding behaviour of the fish, the effects of environmental parameters (such as thermocline depth, speed and direction of currents, bathymetry, etc.), the dynamics of the tuna and baitboat association, etc. One major uncertainty in this baitboat fishery is the potential level of catches which could be obtained in the area if a further increase of fishing effort is planned. In order to answer this question, it would be necessary to estimate both the dynamics of the tuna and baitboat association, and the small scale dynamics of the tunas in the fishing zone (especially seasonal biomasses and migration rates).

This research program would also be useful to evaluate the potential use of the associated-school fishing in other geographical areas. This problem may be of major relevance to facilitating new deployments of traditional baitboat fisheries in other areas, if this Senegalese fishing method can be developed successfully in other fishing zones.

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