

## Purse seine fishery on floating objects: What kind of fishing effort ? What kind of abundance indices ?

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More than half the catch of the Western Indian Ocean purse seine fishery is made on log (floating objects) schools; in the Somali Basin, this percentage is as high as 80 % of the total catch. This type of fishery is well distinguished from the free school purse seine fishery. The main characteristics of log school fishing are recorded world-wide.

When artificial logs and radio-beacons on logs are used on a large scale, searching time is not well suited as effort unit for this fishery and is better replaced by the number of positive sets.

The drop of the catch per set and per day from 1988 to 89 in the Somali area can be a response either to a high level of exploitation of the fraction of the tuna stock passing through the area during the log school season, or a too high fishing frequency on each log (time interval between two sets on the same log). In this last situation, not enough time will have passed between the two sets for the log could be again inhabited by enough tuna in order to obtain the same catch. There is not enough material to confirm either of the hypotheses which have very different implications in terms of fishing strategy and fisheries management.

### 1 Introduction

The Western Indian Ocean purse seine fishery when compared to the East Pacific or East Atlantic fisheries is different, as an average of 50 % of the catch is made on schools associated with floating objects (logs). In Western Pacific fishery the use of logs is also very well developed.

In purse seine fisheries, units of effort generally used are fishing day or searching day (time spent searching for tuna schools). The indices of abundance derived from these efforts are catch per fishing day or searching day. However, one can question the pertinence of these indices of abundance for the log school purse seine fishery. In these fisheries, natural logs spotted by the vessels are marked with radio-beacons and more and more often artificial logs are set at sea. The log can also be equipped with an echo-sounder which sends back its information to the vessel when the captain interrogates the radio-beacon to know the location of the log.

In this last situation, which is not yet developed, but for which the technology already exists, the vessel approaches a log only when one can expect a good catch, then there is no more searching time. In the

Indian Ocean, the Japanese purse seine fishery is already working exclusively with artificial logs with radio beacons attached. EEC purse seiners have used radio-beacons on natural logs since 1984 and during recent years have also started to use artificial logs.

The question of an index of abundance suited to this type of fishery should therefore be addressed by the scientific community working on tuna resources.

### 2 Materials and methods

Data are from all flag purse seine countries operating in the Western Indian ocean tuna fishery except the three purse seiners from Mauritius. The time series goes from 1984 to 1992. For 1992, some results, such as searching effort which has been extrapolated from incomplete 1992 data using the 1984-91 series of fishing times and searching times, are still preliminary.

Searching effort is the fishing effort (days fishing at sea) from which the time spent actually fishing tuna (time with the net at sea) have been subtracted. A positive set is a set with at least a 0.5 t catch. A nil set is a set with no catch or a catch lower than 0.5 t. Fishing success rate in purse seine fisheries is measured by the percentage of positive sets over the total number of sets.

### 3 The western Indian Ocean purse seine fishery

The purse seine fishery in the western Indian Ocean, which really started in 1984, is now well established. Five main fishing areas have been recognised (Fig. 1). Total catch (Fig. 2) and catch on floating objects ("log schools", Fig. 3) and on free swimming schools (Fig. 4) describe the evolution of the fishery from 1984 to 1992. Catch on log schools has constantly increased, while those on free schools, after reaching a maximum of 118,000 t. in 1988, has since slightly decreased. While, during the early years of the fishery, half the catch was taken on each type of school, in 1992 the fishery has caught up to 65 % of its catch on log schools.

### 4 Log and free school catches by fishing area

The five selected fishing areas (Fig. 1) represent 78 % of the total catch of the fishery (EEC, Japanese and Russian purse seiners) in any year since 1984 and for both types of school. Catches on log and free schools for each area (Fig. 5) show the importance of the Somali Basin for log school catch and of the East-Seychelles area for free schools for the period 1984-91.

Each type of school has a characteristic species composition. Log school catches are made of 70 % skipjack, 25% yellowfin and 5 % bigeye for almost any area (Fig. 6). The Somali Basin log catches account for 41 % of the total log fishery catches and 91 % of these catches are made between the 16<sup>th</sup> of July and 15<sup>th</sup> of November of each year, with a remarkable stability for the species composition (Fig. 7). Free school catches are on average made up of 23 % skipjack, 75 % yellowfin and 2 % bigeye (Fig. 8) and their general characteristics are much more variable than those on log schools (Hallier, 1991; Hallier and Parajua, in press).

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As most of the catch in the Somali Basin (80 %) is made on logs and this log catch accounts for the four tenths of the total Indian Ocean log catches, the study will be limited to this area and for any year to the four months between mid-July to mid-November.

## 5 Log school catches in the Somali Basin

### 5.1 Fishing success

In the Somali Basin, the fishing success rate on log school is very high (greater than 90 %) and very stable between months and years (Fig. 9). On the other hand, it is much lower on free schools (slightly under 50 % on average) and more variable (Fig. 10).

The stability of log school characteristics already mentioned for the species composition is very common for this type of school and is so widespread that most log school purse seine fisheries around the world have the same characteristics (species composition, success rate, size frequency of the different tuna species caught, early hours best setting time, etc.) (Fonteneau 1992; Hallier, 1991; IATTC, 1992; ORSTOM, 1992).

### 5.2 Catch per set

Catch per set corresponds in this study to the catch per positive set (sets with at least 0.5 t. catch). For the log school fishery, catch per positive plus nil set and catch per positive set have very similar fluctuations because the success rate is high and very stable.

Catch per set is variable between areas and by type of school for the same area (Fig. 11). However, the average catch per set is higher overall in the Somali Basin and in West-Seychelles for log sets. The yearly variations of catch per set on log schools (Fig. 12) confirm the higher values for the Somali Basin and slightly higher values for West-Seychelles. Nevertheless, catch per set in the Somali Basin, which has remained high from 1984 to 1988, abruptly decreased in 1989 and reached levels similar to those found in the other areas (Fig. 12). The catch per set remained low until 1991, then an increase was noticed in 1992.

Overall, the greater variability of free school catches can be explained by the fact that the purse seine net catches a variable proportion of each free school as the school is by definition "free" with movements more or less unpredictable, while schools associated with logs are generally swimming gently under the log. The fraction of the school caught by the net on logs seems then to be a better sample of tuna schools associated with logs than samples collected on free schools for this last type of school.

At an oceanographic level, the Somali area is made of two very different areas:

- a coastal area where the upwelling is active from May to September;
- an offshore area where currents are circling as gyres which temporarily trap rich waters from the upwelling and drifting logs.

Comparison of log school catches and catch per set between these two areas does not show any displacement of fishing effort between the two areas

which could explain the drop of the catch/set from 1988 to 89, this drop being recorded in the two areas (Fig. 13). Taking into consideration the usually very great stability of log school parameters, this drop of the catch per set limited to the Somali Basin is very remarkable and worth study.

### 5.3 Effort in searching time

Despite the fact that nearly 20 % of the Somali catches are made on free schools, the searching effort of the all fishery fishing on free and log schools is assumed to be an effort on log schools only, as there is no possibility to apportion the effort between the two types of school.

Searching effort in the Somali area has greatly increased from 1984 to 1989 (+151 %), when it reached its peak for the period 1984-92 (Fig. 14). Since 1989, the effort has decreased by 26 %. Only the West-Seychelles area has known a similar increase of the searching effort (+111 % between the periods 1984-88 and 1989-91). This concentration of effort in the Somali Basin is probably the consequence of the good fishing results in this area: high success rate, with no bad fishing seasons in nine years. The decrease since 1989 corresponds to the shifting of some EEC vessels between the Indian and the Atlantic oceans. This EEC searching effort decrease has been partially balanced by an increase of Japanese effort, especially since 1991.

### 5.4 Effort in number of sets.

In the area under study, there has been also an important increase (+120 %) in the number of sets (positive + nil sets) on logs between 1984-87 (on average 555 sets per year) and 1989-92 (on average 1,219 sets per year) (Fig. 14). The number of sets has remained more or less high from 1989 to 91 and has decreased slightly in 1992 (-26 % over 91).

Could this high level of effort in searching days and in number of sets be responsible of the catch per set decrease in 1989 when compared with the 1984-88 period ?

### 5.5 Relationship between searching effort and number of sets

The relationship between the two indices of effort (searching time and number of sets) is well described by a linear regression line with a highly significant correlation coefficient of 0.966 (Fig. 15). The corresponding equation is:

$$\text{No. of positive sets} = 0.673 \times \text{No. of searching days} - 277.3$$

Therefore, an increase of searching time will result in a corresponding increase of number of logs spotted and therefore an increase of the number of positive sets. However, this relationship is not directly proportional because the fishery has also increased the number of sets per day (Fig. 14). From an average of 0.40 for 1984-87 to 0.56 for 1988-92, the highest value was reached in 1992 with 0.63 set/day. The yearly average increase since the beginning of the fishery is 8%.

If the correlation between the two effort indices is high, this is because both indices have increased dramatically between 1984 and 1989 (+ 151 % in days and + 234 %

in sets) while the number of sets per day has increased more slowly (+ 33 % over the same period).

However, on a scientific point of view, the number of sets is a better unit of effort than the searching time which does not take into account of the increased daily effort in number of sets.

## 6 Index of abundance for the log school fishery

### 6.1 Catch per day

Catch per fishing day and per searching day are given in Figure 16.

Catch per searching day which remains more or less above 30 t/day from 1985 to 88 drops to 22 t/day in 1989 and remains low in 1990. But in 1991, the value again reaches the 30 t/day day level.

### 6.2 Catch per set

Catch per set trends have already been presented in § 5.2. Compared to the trends of catch per day, it is obvious the two indices do not follow exactly the same trend. After the drop of 1989, which affected both types of indices, the catch per day started to rise slightly as soon as 1990 and more sharply in 1991, while the catch per set continued to drop in 1990 and 91 and did not start to rise before 1992 without yet reaching the levels of 1984-88. However, in 1992, the French fleet with a catch per set of 53.9 t again reached the average level from the period 1984-88 (54.6 t).

During the two periods 1984-88 and 1989-81, in the French fleet, the catch per set dropped because the percentage of large sets (> 100 t.) decreased from 18.4 % to 8.6 %, while the percentage of small sets (< 20 t.) increased from 26.5 % for 1984-88 to 32.5 % for 1989-91 (Fig. 17) (Hallier, 1992). In 1992, these percentages reached respectively 18.4 % and 20.7%, a level comparable to the 1984-88 period (Fig. 17).

## 7 Relationship between catch per day and catch per set

There is no direct relationship between the two indices of abundance (catch per day and catch per set): the correlation coefficient for a linear regression is not significant ( $r = 0.453$ ).

The trends of the two indices in the Somali area for the 84-92 period can be explained as follows:

- after a training period (1984/85) with relatively low yields, the catch per day and catch per set increased and remained high from 1986 to 88;
- in 1989, the high levels of effort (in days and in number of sets) (Fig. 14) resulted in a strong local competition between vessels which induced decreases of catch rates (in t/day and t/set);
- in 1990, despite a decrease of the searching time, the catch per set continued to decrease maybe because the number of sets remained high as the number of sets per day increased again;
- in 1991, effort (in days and in number of sets) increased again, the local competition was still high, the catch per set continued to decrease but the

catch per day increased because the number of sets per day reached its highest level (Fig. 14);

- in 1992 all effort units decreased - days, number of sets and even, slightly, the number of sets per day - the competition was lower, the catch per day continued to increase and the catch per set started to rise.

## 7.1 Catch and effort relationship

### *Somali Basin*

The plot of the catch versus the effort (in searching days) (Fig. 18) seems to indicate that the maximum yield the fishery can harvest in the Somali Basin during the log school season is in the order of 50-55,000 t; a level already reached in 1988 and 89. The plot of the catch versus the effort (in number of sets) (Fig. 19) gives a similar result, which is not surprising when one considers the strong relationship that exists between the two effort indices (§ 5.5 and Fig. 15).

Do these plots of the catch versus the effort illustrate a fishery with a high exploitation rate on the fraction of the Indian Ocean tuna stock present in the Somali Basin for the period 1988 to 91?

### *Western Indian Ocean*

The plot of the log catch versus the effort (in number of positive log sets) for the all Western Indian Ocean purse seine fishery does not show any maximum level (Fig. 20). In fact, the catch per set decreased slightly in 1989 (-18 % over 88) but with 36.1 t/set it remained comparable to the average for the period 1984-92 (35.8 t/set).

## 8 Results and discussion

### 8.1 A high exploitation rate

From 1989 to 1991, the Somali area is characterised by a dramatic decrease of the catch rate (per day in 1989 and per set from 1989 to 91) when the effort reach maximum levels (the searching days in 1989 and the number of sets in 1991).

According to the plot of the catch versus the effort, the maximum yield would be reached for a number of around 1,000 positive sets.

### 8.2 An increase in the number of logs

Considering the tuna biomass migrating to the Somali area each year to be more or less stable, if there is an increase of logs in the area, one can theorise that the biomass will disperse itself among a greater number of logs, each having a smaller amount of associated tuna. This situation will result in a smaller catch per set and smaller catch per day. The vessels can try to offset this smaller catch per set by increasing their number of sets per day.

This log increase cannot be the result of the development of artificial logs because their use on a large scale did not start before 1991, two years prior to the drop of the catch per set (1989). Furthermore, in 1992, artificial logs then widely used in this area probably resulted in an increase of the total number of

logs. But, during this year catch per day and per set increased.

An increase of natural logs is difficult to explain. As logs are not "produced" in this area (no forests and no large rivers), they are probably coming from the south (Kenya, Tanzania, Mozambique and west coast of Madagascar) where forests and large rivers exist. If these areas produce more logs, the percentage of log school catches versus total catches in the Mozambique Channel and in West Seychelles should increase, but this is not the case.

### 8.3 A high level of fishing effort on each log

Hallier (1991; Hallier and Parajua, in press) in the Western Indian Ocean, Ianelli (1987) in the Western Pacific Ocean have shown that catch per set decreases dramatically when the same log is fished on consecutive days (Fig. 21); this rate of decrease being very similar in both oceans. Therefore, for a given number of logs distributed in an area fished by an increasing number of purse seiners, each log will be fished at shorter time intervals. Below a certain level which remains to be estimated, the amount of tuna migrating to the log is not sufficient to "replenish" the log and therefore the next set catch is smaller.

Most studies on fish aggregating Device (FAD) recognise that it takes a certain time for the FAD to attract a large number of tunas. In the case of tuna schools associated with pole and line vessels off the Senegal and Mauritanian coasts, skippers mention that several days, even one week or more, are necessary to build a large tuna school under the vessel (Fonteneau and Diouf, in press). Accordingly, the biomass that can be fished by purse seines on logs can fluctuate with the density of logs and the frequency of fishing on each log.

The maximum yields given by the catch-effort plots (Fig. 18 and 19) will then not represent the real biomass that can be fished but rather the vulnerable biomass according to the log density and to the log fishing frequency. Thus, any increase in the number of logs (by natural or artificial means) will offer the possibility to a greater biomass of tuna which otherwise will remain non vulnerable to the purse seine (either dispersed or swimming deeper) to associate to logs.

In the East Atlantic purse seine fishery, the use of artificial logs yields good catches of skipjack in an area where usually most catches were made of large yellowfin (Ariz et al., 1992). This increase in the number of logs can also produce a decrease in the log fishing frequency which will result in an higher catch per set.

Presently, it is not possible to prove which hypothesis is true: a high rate of exploitation (hypothesis No. 1) or a high fishing frequency on logs (hypothesis No. 2) in order to explain the drop of catch per set from 1989 to 91. Yet, the implications of these two hypotheses in terms of fishing strategy and fisheries management are totally different:

- in case of hypothesis No. 1, any increase of effort (in days or in sets) will not result in a corresponding increase of the catch and catch rates will decrease;

- in the case of hypothesis No. 2 the use of artificial logs on a large scale will result in an increase of the catch with similar or higher catch rates.

### 8.4 Index of abundance for the log school fishery

In the case of hypothesis No. 1, the catch per day and catch per set can both be indices of abundance of the tuna biomass: the decreasing biomass is more diluted among the same number of logs, therefore catch per set is smaller as well as catch per day, except if an increase of the number of sets per day is sufficiently high to counterbalance the drop of the catch per set.

In case of hypothesis No. 2, catch per day and catch per set will not represent reliable indices of abundance. Catch per day will depend on the catch per set and the number of sets per day, while catch per set will be under the influence of the level of fishing effort frequency on each log.

## 9 General conclusions

Taking into account the characteristics of purse seine log school fisheries, especially with the use of radio-beacons and artificial logs, the number of sets appears to be a more reliable unit of effort than the searching time for the type of purse seine fishery on logs.

Accordingly, catch per set should be a better index of abundance. However, the study of the catch per set, catch per day and catch versus effort in the Somali Basin during the log school fishing season does not permit to conclude which index is best - catch per searching day or catch per positive set, especially when it comes to explain the drop of catch per day in 1989 and catch per set from 1989 to 91.

If the fishing frequency per log (or time interval between two sets on the same log) is too high (a short time interval), the catch per set will drop and the catch per day also.

The use of artificial logs in a natural log fishery could increase the associated biomass and therefore increase the catchable biomass using purse seines. There is certainly a maximum log density above which no beneficial effect can be expected.

Further studies are necessary to clarify these questions which have important implications in terms of fishing strategy and fisheries management.

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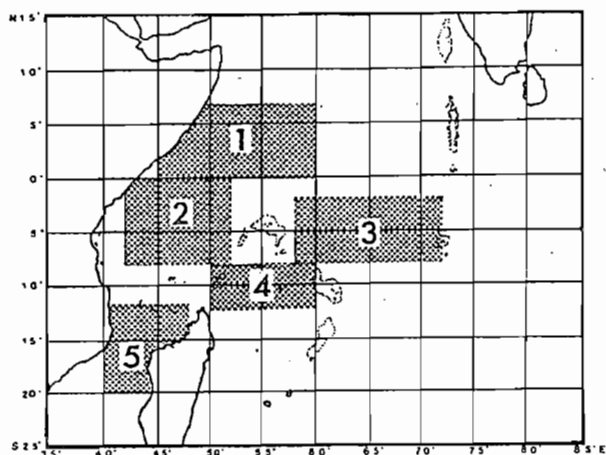


Fig. 1: The five main purse seine fishing areas  
 (1) Somali Basin  
 (2) West Seychelles  
 (3) East Seychelles  
 (4) South Seychelles  
 (5) Mozambique Channel

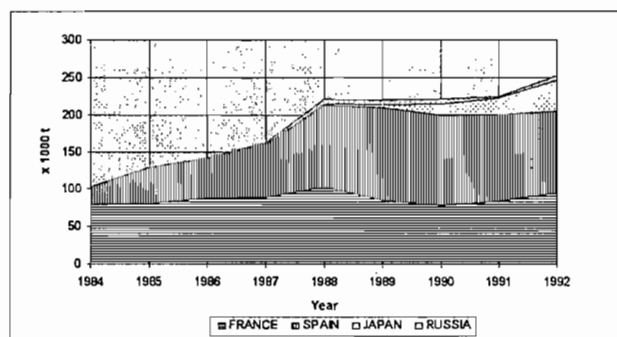


Fig 2: total catch distribution by purse-seine country (Indian O., 1984-92)

1992: Preliminary data

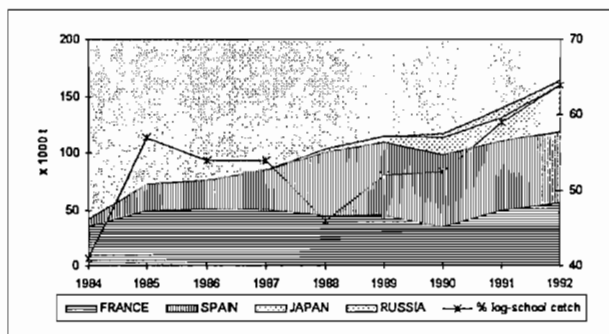


Fig.3: Log school catch distribution by purse-seine country (Indian O., 1984-92)

1992 - Preliminary data; Log/free school distribution unknown for Russia 87-89

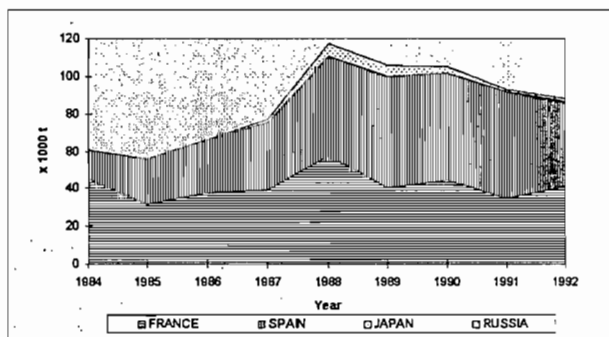


Fig.4: Free school catch distribution by purse-seine country (Indian O., 1984-92)

1992-Preliminary data; log/free-school distribution unknown for Russia 87-89

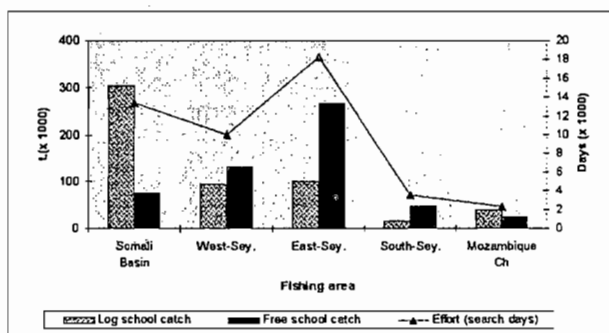


Fig.5: Log and free school catches and research efforts by fishing area

All fleet, 1984-91

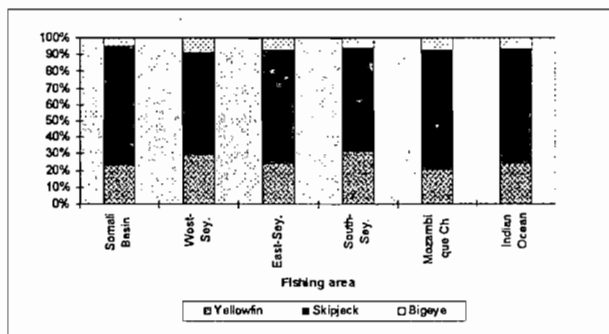


Fig.6: Log school catch species composition by area & for Indian Ocean

All fleet, 1984-91

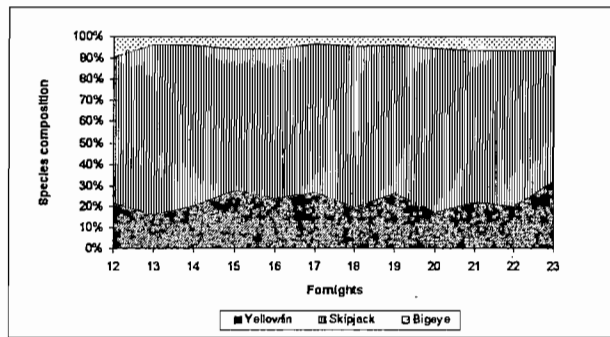


Fig.7: Purse-seine species composition by fortnights in the Somali Basin

All fleet, sum-up 1984-91

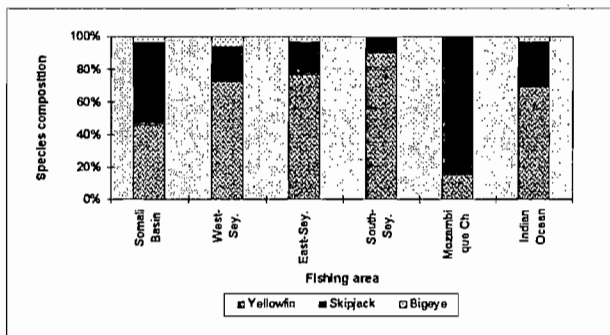


Fig.8: Free school catch species composition by area & for Indian Ocean

All fleet, 1984-91

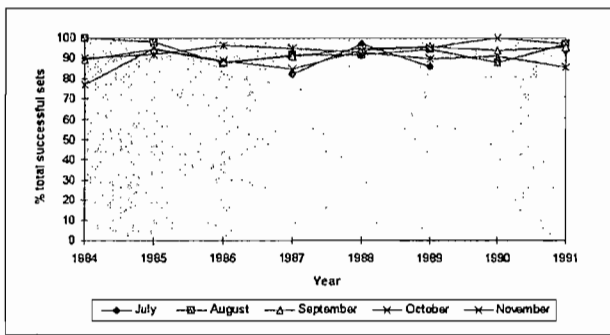


Fig.9: Set success rate on log schools in the Somali Basin - French fleet, 1984-91

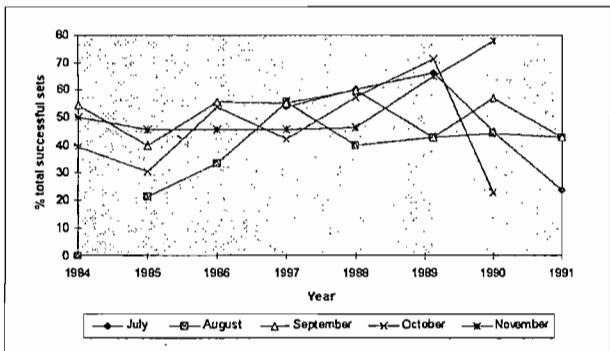


Fig.10: Set success rate on free schools in the Somali Basin - French fleet, 1984-91

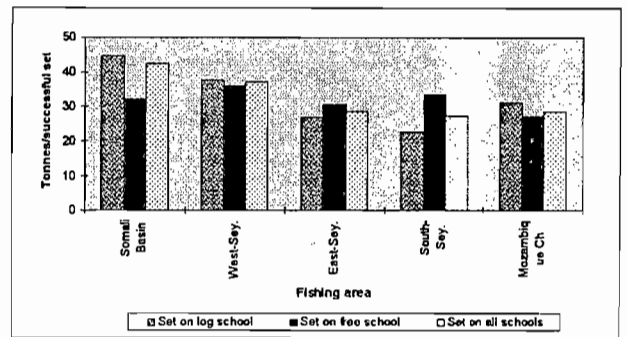


Fig. 11: Average catch per successful set and by type of school

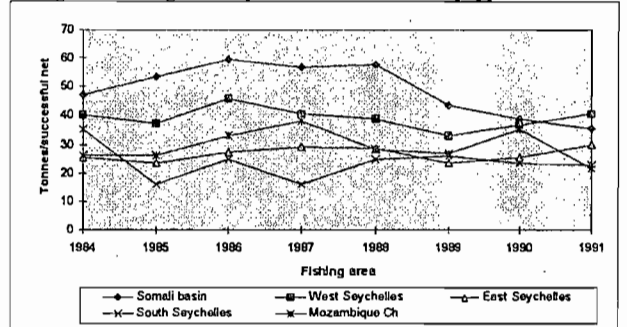


Fig. 12: Average catch per set on log schools by fishing area

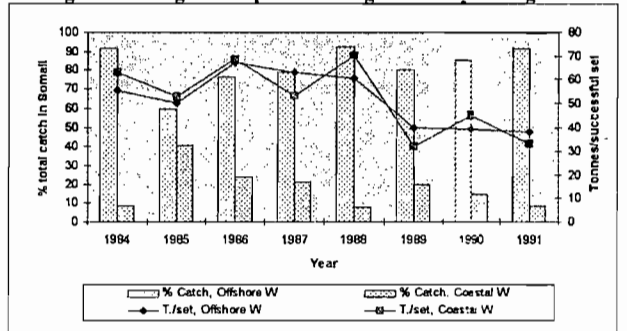


Fig. 13: Catch per set and distribution of log school catch between coastal and offshore waters in the Somali Basin

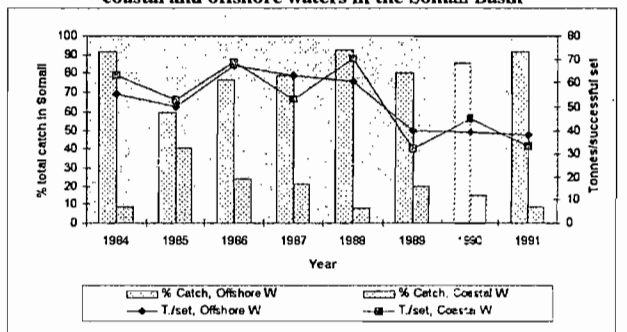


Fig. 14: Number of log school sets and effort in the Somali Basin All fleet, 1984-92  
84-91: Effort in searching days  
92: Effort in fishing days

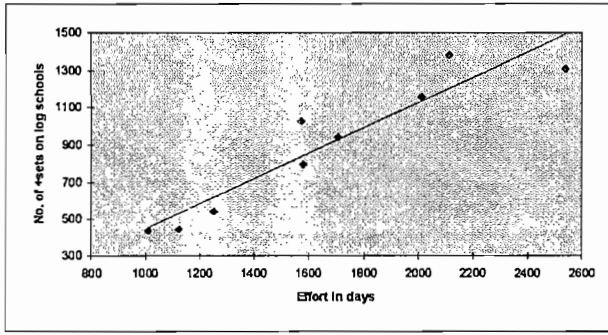


Fig. 15: Relationship between effort in days and in log school sets, Somali Basin (1984-92)

All fleet

84-91: Effort in searching days

92: Effort in fishing days

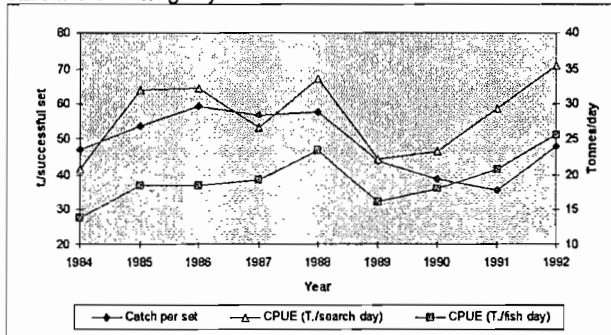


Fig. 16: CPUE and catch per set on log schools in the Somali Basin All fleet, 1984-92

1992: Preliminary data

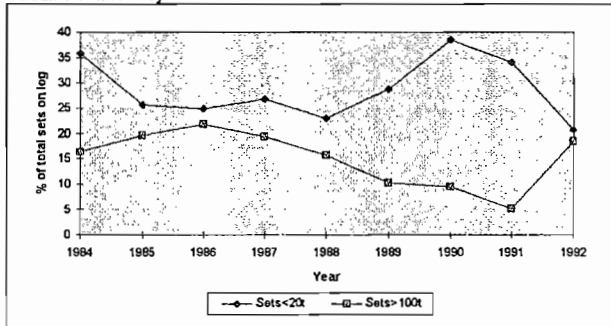


Fig. 17: Set size frequency distribution for log school catch in the Somali Basin

French fleet, Indian O., 1984-92

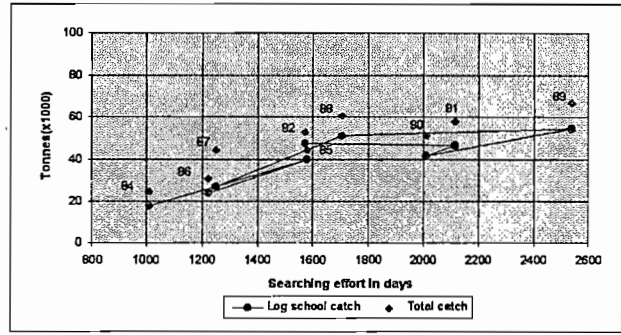


Fig. 18: Relationship between searching effort and catch in the Somali Basin

All fleet, 1984-92

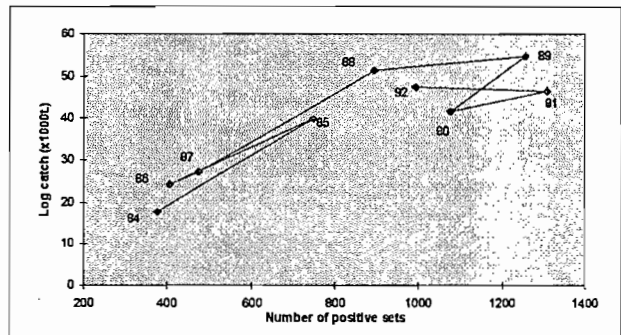


Fig. 19: Relationship between catch and number of positive sets on logs (1984-92), Somali Basin, all fleets

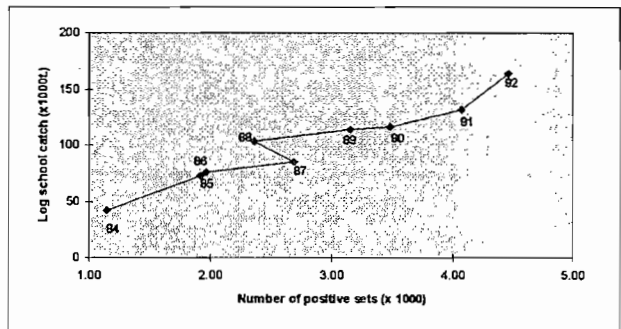


Fig. 20: Relationship between catch and number of positive sets on logs (1984-92), Indian Ocean, all fleets.

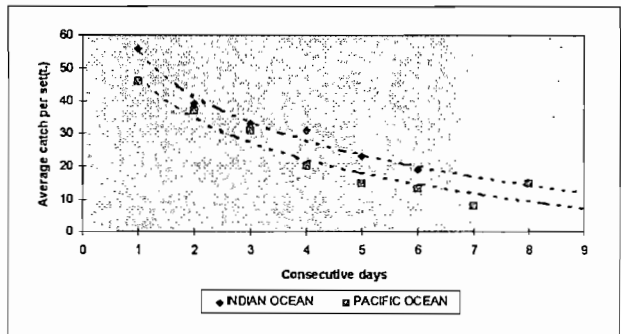


Fig. 21: Catch per positive set for consecutive sets on the same log

Hallier Jean-Pierre.

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