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Species composition of FAD and free swimming schools fished by purse seiners in the Western Indian Ocean during the period 1990-2006

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Summary

This document analyzes the Basic data of quantitative species composition conducted by scientists on a large number of purse seiners landing in the Indian Ocean. This first analysis has been conducted on the 1990-2006 data. The main goal of this paper is to study the time and area species composition of FAD and free swimming tuna schools landed by purse seiners in the Western Indian Ocean. This analysis has been done on a subset of selected samples, keeping only the multispecies samples done on 9253 well identified and homogeneous sets during the period. Each of the set has been classified within 7 categories as a function of its species composition. The paper analyses the importance and changes of each category of sets in the five main fishing zones of the purse seine fishery, the analyses being stratified between FAD and free schools. A total number of 3813 free schools and of 5440 FAD schools samples were analyzed (a total weight of tunas= 32400 tons). These species compositions of each of the 2 groups appears to be typical and consistent in each area during the studied period: FAD schools samples are dominated by the 3 tropical species (72 % of schools) or by a mixture of yellowfin and skipjack (22 %). Free schools samples often show pure species (yellowfin 50 % or skipjack 12 %), but also a wide range of diverse species composition combining the 3 tropical species, and also albacore (a species found in 10 % of the free schools). Species composition of free schools has been showing a much greater variability, especially north and south at the periphery of the main fishing zones.

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Résumé

Ce document analyse les données de base relative à la composition spécifique des échantillonnages qui ont été réalisés à grande échelle sur la composition spécifique des débarquements des senneurs opérant dans l'ouest de l'Océan Indien. Cette première analyse traite les données collectées durant la période 1990-2006. Le but principal de l'article est d'examiner la structure spatio temporelle de la composition spécifique des débarquements de thonidés capturés par les senneurs sur des bancs sous objets et des bancs libres. Cette analyse est réalisée sur un sous échantillon d'échantillons retenus du fait qu'ils ont été réalisés sur des bancs homogènes et/ou bien identifiés. Un total de 9253 échantillons multispécifiques de tailles a ainsi été employé. Chacun de ces échantillons a été classé selon sa composition spécifique en 1 catégorie choisie parmi 7 groupes potentiels. L'article analyse l'importance moyenne et les changements spatio temporels au sein de chaque type de calées, et ceci dans 5 grandes zones de pêche de l'ouest Océan Indien, ces analyses étant stratifiées en bancs libres et sur DCP. Un total de 3813 échantillons sur bancs libres et de 5440 sur DCP ont été analysés, totalisant un poids échantillonné de 32400 tonnes. La composition spécifique de ces deux groupes est typique et consistante dans chaque zone durant toute la période étudiée. Les échantillons sur DCP sont toujours dominés (72% des échant.) par le mélange des 3 espèces de thons tropicaux ou par un mélange d'albacore et de listaos (22% des échantillons). Les échantillons sur bancs libres montrent la présence fréquente de gros albacores seuls (50%), ou de listaos seuls (12 %), mais aussi divers mélanges d'espèces combinant les 3 espèces de thons tropicaux, ainsi souvent que du germon (une espèce observée dans 10% des échantillons sur bancs libres). La composition des échantillons sur bancs libres montre une beaucoup plus grande hétérogénéité et variabilité spatio temporelle que celle sous DCP qui est beaucoup plus homogène.

1-Introduction

It is well known that the EU scientists from Spain and France and the Seychellois scientists and technicians from SFA have been permanently conducting (since the early eighties) a systematic sampling of the species composition of landing by purse seiners. The main goal of this intensive sampling, that has been also conducted in Madagascar and in Mombassa, was to obtain a corrected species composition of the tuna landings by purse seiners (following the method described by Pianet et al 2000). This method resulted from the EU funded project “ET” (Multispecific analyze of the sampling scheme of tropical tunas, 1995-1997) run by French and Spanish scientist on a 10 years sampling data set in both Atlantic and Indian Ocean.

This intensive sampling scheme was justified by the fact that most log book and commercial transhipments data from purse seiners were estimated to be highly biased in their species composition, and showing a systematically underestimating the catches of small bigeye and of small yellowfin (these small tunas being often classified as skipjack in both log books and transhipments records). The results of these species samplings have been routinely used each year to correct the species composition of the log books of the EU, EU related and Seychelles purse seiners and to estimate the corrected figures of catches by species that have been submitted routinely since the early eighties to the IPTP and later to the IOTC. These corrected data have been permanently used by scientists for all their stock assessments and other statistical analysis (as in the Atlantic). Corrections of species composition and of sizes taken have been done during recent years using large time & area strata (4 quarters and 7 areas that have been considered as being homogeneous in terms of their species composition) (cf Pianet et al 2000).

The main goal of this paper is to make a first review of the real species composition observed in these original samples since 1990, as well as to examine the size categories observed in those samples (for each species), this analysis being stratified by fishing mode (free schools and FAD schools). The results of the analysis will be presented for the entire period or classified at a yearly scale in each of the statistical areas used to estimate the corrected species composition of the tuna landings. Only the 5 major areas shown by figure 1 will be examined in this study.

2-Material and methods

The basic data used in the analysis have been the samples that have been collected under the ad hoc EU programme described by Pallares and Hallier 1997. The first step of this work was to create from the original sampling files of the mulstispecies sizes samples a new working file called SPECIES[6]. The content of this file is given by table 1.

The second step was to select in this file of the original samples, a subset of samples that have been done, either on well identified large sets, or on a combination of homogeneous smaller sets (same types), taken by a given purse seiners in the same location and at similar dates. All the “ambiguous” samples (for instance those mixing fishing modes) were first eliminated from the present analysis, then only the samples taken on schools caught at a maximum distance of **120 miles** and separated by a maximum period of **10 days** have been kept in the present analysis. Such working hypothesis was based on the hypothesis that species composition of the sets (for a given fishing mode) should be stable at such a short distance and within such a short duration (such hypothesis could easily be changed in future work). As a result of this selection, a sub set of 9253 multispecies samples have been selected

[6] SPECIES : **S**omme des **P**oids **E**chantillonnés par **C**atégor**IES**

on a total number of the 11456 multispecies samples done on free or FAD schools (eliminating then 20% of the samples done within wider time and area strata). Among these 9253 samples, it can also be noted that 53% of the samples were taken on tunas fished the same day in the same 1° square, and the other 47% in the neighbouring strata. These 9253 samples collected during a period of 17 years correspond to an impressive total weight of 32425 tons of tunas that have been measured or counted by field technicians during these sampling (e.g. an average weight of 3504 kg per sample and about 0.6% of the total tuna catches by purse seiners during the period). None of the ambiguous samples collected in Seychelles during the 1998-2000 period (Fonteneau and Lucas 2003) has been included in this analysis.

This new SPECIES file provides for each sample a summary of the observed species and size composition (small and large yellowfin and bigeye, weight of each species in each sample), for all the tuna species landed (counted or measured). The data presently used have been obtained during the period 1990-2006 and the numbers of samples that have been selected each year for each fishing mode are given on table 2. It can be noted that similar species sampling data could also be soon available since the beginning of the purse seine fishery in the Indian Ocean (in 1984), however, as the format of these data needs a further rehandling before allowing their conversion to the present format of the SPECIES file, these early sampling data were not used in the present study.

The third step of the analysis was to classify each of the species samples in the 7 categories of species composition (and an 8th group of “others”) that are shown by table 3. In this present classification of the species composition, a minimal percentage of 1% of the total sampled weight has been used as a limit allowing to consider that the species was significantly present in each sample (if the species catch is less than 1% of the sample, this species has been classified as being quantitatively absent). The frequency of each of these species groups was then estimated in each area at a yearly scale, for FAD and free schools.

Catches of minor tunas (*Euthynnus* and *Auxis*) are often sampled, but they were not used in this first analysis that has been only targeting the main tuna species.

The present work will be mainly limited to a visual examination, mapping and discussion of the frequency of each set type, but further in depth statistical analysis of this SPECIES file should of course be recommended.

3-Results

3-1- Basic fishery data: catches by species and by sizes in the purse seine fishery

The total 1990-2006 average catches by species estimated by the species correction scheme TTT[7] used by the EU and Seychellois scientists is given on figure 2 for the FAD associated and the free schools catches. The same catches can also be shown at a yearly scale and stratified according to the large areas used in the species composition scheme (figure 1); these yearly catches by species and by area are shown in figure 3 (elle commence en 91). Figure 4 shows the average size distribution in weight of tuna catches taken by the EU/Seychelles purse seiners during the period 1990-2006, for yellowfin and bigeye, and by fishing mode. It appears from these size data that:

- Skipjack catches are always taken at sizes lower than 10 kg (their size distribution are not shown).

[7] TTT :a French acronyme (Traitements des Thons Tropicaux) that can be translated as “Tropical Tuna data processing”

- Bigeye catches on FADs are predominantly taken on fishes lower than 10 kg (76%) whereas bigeye taken on free shools tend to be at larger sizes (86% of fishes over 10kg)
- Yellowfin catches on FADs are taken 50/50 on fishes lower and larger than 10 kg, whereas yellowfin taken on free shools are most often taken at large sizes (97 % of these fishes over 10kg)
- Albacore catches are always taken at sizes larger than 10 kg (their size distribution are not shown).

These two groups of fishes lower and larger than 10kg play an important role in the sampling scheme used to sample the species composition (see Pianet et al 2000).

The spatial distribution of the average species composition of the purse seine tuna catches (as estimated after data processing of log book and sample data) during the period 1990-2006 is shown in percentages in figure 13 (free schools) and 14 (FAD schools). These data are the result of the species correction done on the combined analysis of log book and of species and size sampling data collected during the landings, this analysis being done at quarterly levels and in wide geographical areas (figure 1) as defined in the ET project.

3-2- Overview of the SPECIES file: FAD schools species composition

The species composition of FAD associated samples appears to be quite typical and homogeneous, with two types of species mixture being widely dominant in these schools (figure 5):

1) The most important type belongs to a group **showing simultaneously the 3 tropical tuna species** (yellowfin, skipjack and bigeye): a group that was found in a wide majority of the FAD samples (71.7 % during the period 1990-2006), this conclusion being more or less valid each year and in all the 5 fishing areas under study.
2) The second most important group of samples (22% of the FAD samples) comprises a **mixture of yellowfin and skipjack** (then without significant quantities of bigeye or of albacore). Outside these two major groups of mixed species, each of the other groups of species are seldom observed (these other groups amounting for a total of only 6.3 % of the observed frequencies, see table 3)

The yearly species composition of FAD associated samples (figure 6) also shows that there is very little variability of the species composition between years and between areas: the 2 dominant groups are always the mixture of the 3 tropical species, or less often the mixture of yellowfin and skipjack (except in 1990). The other 10 groups are most often (or always) rare or very rare in all the areas during the entire period studied.

It is also interesting to map at a fine 1° square level these results contained in the FAD sampling file:

(1) The numbers of FAD samples available in each 1° square are shown by figure 8a, and the exact species composition of the sampled catches during the whole period 1990-2006 by figure 9 (a map done for all 1° squares where at least 1 ton of tuna has been sampled during the period).

(2) the frequency of the various types of species composition observed in the samples during the same period (figure 10) (a map done for all 1° squares where at least 5 samples has been collected during the period). Both maps are done in term of percentages.

It is also interesting to identify within the samples classified as “FAD samples” all the samples done on **whale sharks** and on “whales” (this global wording corresponding to a wide range of species: whales *sensu stricto* as well as cachalots). It appears that these two peculiar types of biological association shows a pattern of species composition and associations types (revoir aussi légende figures) that are similar to FADs (pure schools of large yellowfin are not dominant in these associations), but there is an apparent greater diversity of species composition in these peculiar associations (see figure 17 and 18). It should also be noted that yellowfin and bigeye taken in association to whale sharks tend to be larger than fishes associated to regular FADs: in our samples, 79% of large bigeye (over 10kg) on whale sharks (vs 33% on FADs) and 94% of large yellowfin (over 10kg) taken on whale sharks (vs 72% on FADs)

The large numbers of species samples available also allows the analysis of the monthly patterns and changes in the percentages of each sampled species (and it sizes composition) as well as the mixtures of the various species in these samples. This analysis is more interesting in the main fishing areas where large quantities of tunas are caught all year round, such as the area West of the Seychelles (Figures 21 and 22). These figures show a global homogeneity of the monthly species composition sampled each year, most often typical of FADs. However it should also be noted that there is also some variability in the monthly samples, some of this variability being possibly significant and interesting to further study.

3-3- Overview of the SPECIES file: free schools species composition

The average species composition of free schools samples is widely different from the species composition of FAD associated samples, as it shows typically a much wider diversity of its species composition, 7 categories making the bulk of the observed samples (table 3 and figure 5). These most frequently observed categories can be described (by decreasing importance in the average data set) as following:

1) **Pure Yellowfin**: a type of sample frequently observed, in 49.7 % of the multispecies free schools samples during the period 1990-2006. These yellowfin are most often taken at large sizes over 10 kg (more than 99% of samples).
3) The mixture of **yellowfin and bigeye** has been also quite frequently observed, 13.7 % of the samples, both species being most often caught at large sizes (99% of these fishes being larger than 10kg)
4) Pure **skipjack** schools have been also commonly observed, in 11.9 % of the samples.
5) The mixture of **yellowfin and skipjack** (then without bigeye) has been also commonly observed on free schools, 9.6 % of the samples, only 8% of the yellowfin catches (in weight) being taken at small sizes <10kg, most of these yellowfin being large fishes (at least in weight); such frequent association of large yellowfin and small skipjack may appear as being quite strange but based on this sampling, it has been commonly observed.
6) The mixture of the **3 tropical species** –yellowfin, skipjack and bigeye- (that was highly dominant in the FAD associated schools) has been identified in the free schools, but only at a 5.4 % rate. These 3 species showing in the samples a diversity of yellowfin and bigeye sizes caught (small and large fishes)
7) The mixture of **large yellowfin (100%) and large albacore** is also quite frequently observed at a rate of 5.0 % of free schools samples. Albacore was significantly identified in these samples at an average rate of 16% (in weight).
8) The last type of species mixing significantly identified in the free schools samples (3.5% of the samples) has been the combination of 3 species: **yellowfin, bigeye and albacore** (these 3 species being taken at large sizes over 10kg sinon c'est du 6, non?).
9) The other 4 groups of species (bigeye alone, albacore alone, bigeye and skipjack, 4 species and the mixture of yellowfin+skipjack+albacore) were very seldom observed in the samples, with a total contribution of only 1.2% of the samples.

Figure 6b shows that the time and area patterns of these species compositions tend to show some consistency in the complexity of the species composition: this species composition of free schools has been always (at least during the studied period) and in each of the 5 areas, much more complex than the species composition associated to FADs, and always quite different from it. It can also be noted that the time and area variance of this species composition is much wider than on FADs. The species composition appears to be more consistent in the Equatorial areas, and more variable from year to year in the fishing areas located in the periphery. For instance there is a wide year to year variability in the species composition samples from the Mozambique Channel (these patterns being quite different from the areas around Seychelles), when FADs samples had a quite stable specific pattern in all the areas during the entire period.

It is also interesting to map at a fine 1° square level these results contained in the free schools sampling file:

(1) The numbers of free schools samples available in each 1° square are shown by figure 8b, and the exact species composition of the sampled catches during the whole period 1990-2006 by figure 11. This map shows that the sampling of the catches was done more or less in proportion with the importance of the catches in each fishing zone (shown by figure 15 a and b).

(2) the frequency of the various types of species composition observed in the samples during the same period (figure 12). Both maps are done in term of percentages.

3-4- Average percentages of each species (in weight) in the FAD and free schools samples

It is interesting to make synthetic figures of the frequencies of the relative weights of each species that have been estimated during the entire period 1990-2006 in the FAD and free schools samples. Figure 8 (a , b and c, for yellowfin, skipjack and bigeye), show this result: samples are shown on the horizontal axes at the same scale, the 5440 FAD samples and the 3813 free schools samples being transferred in the same scale of percentages. The weights of each species in each type of schools/samples have been sorted in each figure by decreasing relative amounts (again in % of the total weights of the sampled tunas).

These figures are showing the following patterns:

(1) Yellowfin (figure 8a revoir ordre des figs): free schools and FAD sets are showing widely different patterns: 50% of free schools showing 100% of yellowfin (most often large sizes: 99% of these sets), and only 12% without yellowfin, and the other 38% with a slowly declining highly significant proportion of yellowfin in the samples. On the opposite, yellowfin is very seldom the only species observed on FADs, but tend to be observed in nearly all the FAD samples

(2) Skipjack (figure 8b): again free schools and FAD sets are showing widely different patterns: only 12% of free schools samples showing 100% of skipjack and 73% of samples without skipjack, and the other 15% with a rapid decline of the skipjack proportion in the samples. On the opposite, skipjack has been more or less always observed on FADs in great proportion, being absent in only 3% of the FAD samples.

(3) Bigeye (figure 8c): Percentage of bigeye observed in the FAD samples shows that a very high proportion of bigeye has been seldom observed in these samples: only 1.0 % of the FAD samples had more than 50% of bigeye (in weight) and only 13 % of these samples had more than 20% of bigeye (in weight). Furthermore 54% of these FAD samples had less than 5 % of bigeye (in weight). A majority of these bigeye are small fishes under 10kg (68%). The pattern of bigeye percentage in the free schools appears to be surprisingly quite similar, but at much lower quantitative levels (bigeye being absent in 75% of the free schools samples). Furthermore, these bigeye taken on free schools are predominantly taken at large size (96% of large bigeye in weight in the sampled catches), these large sizes being equivalent to sizes observed for yellowfin in these free schools samples. The sampling file showing the percentages of small bigeye can also be associated to the average FAD catches by 1° squares, allowing to show the areas where the highest or lowest proportion of small bigeye have been identified in the samples during the sampled period. Such result is shown by figure 20, on a map showing the most important and less important percentiles of the small bigeye percentages in weight in the total catches. The red and orange areas where the highest percentages of small bigeye have been taken. The geographical homogeneity of this distribution appears to be quite poor in many areas, but some of the areas shown by this map may be indicative to do more in depth study better when considering closed areas, when targeting a protection of small bigeye.

3-5- Species composition of peculiar associations: sea mount, whale and whale sharks

A limited sampling has been collected on tunas schools fished in these 3 types of association, and despite of these small samples (and the risk that some of the samples may be mixed and then "polluted" by sets from another origin), they are worth to study.

Whale sharks: 37 samples have been identified as being taken on tunas caught associated to whale sharks. Catches from these samples show a species and size composition that is very similar to free schools (see figure 2a and 17, left). However, there is a quite high diversity of the species mixture that has been observed in these samples, most often with a mixture of the various species, but also sometimes with a single species (yellowfin, skipjack or albacore: in 11% of the samples, figure 17, right).

Whales (and other large mammals): 56 samples have been identified as being taken on tunas caught in associated to whales or cachalot. Catches from these samples show a species and size composition that is very similar to those of whale sharks and free schools samples (see figure 2a and 18, left). However, there is a quite high diversity of the species mixtures observed in these samples, most often with a mixture of the various species 70% of samples), but also sometimes with a single species (pure yellowfin 18% and pure skipjack 12% of the samples, figure 18, right). This species composition of the samples appear to be very similar to the various sets observed by scientists on the Soviet purse seine fleet during the late eighties (Romanov com.pers.).

"Coco de mer" sea mount , or Travin Sea mount (legal name): 137 samples have been identified as being taken on tunas caught associated to this sea mount that is located close to the Equator at 56°E, this sea mount being a "hot spot" fishing area[8] discovered by tuna fishermen in 1984 and where large quantities of tunas (a total of more than 100,000 tons) have been caught since. Tuna catches on this spot has been classified as being similar to FADs associated catches (Petit 1998? mettre ds biblio), and the frequency of schools types sampled from the sea mount confirms widely this conclusion: figure 19 right shows that most sampled sets contains the 3 tropical species (74%), the second most important category showing a mixture of yellowfin and skipjack without bigeye (11% of the samples). However it should be noted that large yellowfin (over 10kg) are often caught on the Coco de Mer (68%

[8] Coco de mer/Travin Sea Mount is a sea mount that has been producing the highest tuna catches ever observed world wide on a sea mount, and by far.

of the sampled catches) when this category tend to be a minor one, 14% in weight of the FAD catches, in the average FAD samples (see figure 2). On the other hand, skipjack catches are less frequent on this sea mount (40%) than in the whole FAD fishery (64%).

4-Discussion

The multi species sampling scheme allows to estimate the species composition of the fraction of tuna schools caught by given sets or by several consecutive sets done in the same strata. This information does not correspond to the real species composition of perfectly well identified tuna schools, but this biological information is probably very close to be representative of the real species composition of the various types of tuna schools caught each year in each time and area strata. The result of this sampling, sizes and species composition, done in the ports and most often in good conditions by well trained technicians and scientists, is probably highly reliable (and probably much better than a species composition estimated at sea by an observer, due to the very fast handling procedure during the set). The exact relationship between the species composition of each individual school and each of these samples remain of course quite uncertain for various reasons, for instance due to the mixing of heterogeneous sets in the sampled wells, to potential bias in the sampling operation, or to the misidentification of school types in the log book (although it can be concluded that this type of misidentification is rare due to the typical sizes and species compositions observed in most sampled schools). At least, it can be considered that these very detailed informations on the sizes and species composition of the samples are very interesting to analyse.

Another interesting point to note is the differences in the species composition by 1° squares of the basic samples and the corrected species composition of the catches by 1° squares as it has been estimated by the present data processing: these 2 types of results shown by figures 10-15 tend to be quite consistent in most cases, but it also appears that there is a much larger spatial variability in the samples than in the corrected statistics. The species composition estimated after data processing may in fact be statistically correct at the average level of the Indian Ocean, but it would be interesting to re-examine the present working hypothesis that the species composition is constant (within each size group) during entire quarters and in wide geographical areas. At least the various geographical heterogeneity that are apparent in the basic SPECIES sampling file should be further analyzed. This problem is for instance well shown on figure 7: in the Somalia area the FAD associated catches are showing a severe decline in bigeye percentages at northern latitude (and nearly no bigeye north of 9°N), when the basic data processing assumes that the species composition is constant in the area. This result should then encourage scientists to stratify this Somalia area in 2 northern and southern components (with a frontier at 8 or 9°N) and to extend the area from 12°N to 15°N (as this area is clearly an extension of the main FAD fishery operating in the Somalia area).

One of the main results of this first study is to show the major consistency of the species composition of the FAD associated catches during a long period and in wide areas: these catches can be classified in only 2 major groups (yellowfin+skipjack+bigeye or the same association but without bigeye) and this association pattern has been permanently observed in the FAD fishery during the last 17 years, and in all the fishing areas. Keeping in mind that this FAD fishing zone covers a wide range of heterogeneous ecosystems, it would means that the effects of the FAD in selecting and aggregating a given range of associated species is very strong, and widely dominant over the environmental heterogeneity observed in this wide area. However, the analysis of the 1° squares average composition of sampled catches (figure 11) could indicate that there is some variability of the species composition within the FAD catches, for instance in the Somalia area as well as in the Mozambique Channel.

On the other side, the species composition of free schools shows a much greater spatial and temporal heterogeneity, showing different species composition between the various main fishing areas. Major differences are for instance for most years observed in the species composition in the Mozambique Channel and in the Somalia areas, compared to the major fishing zone located between the Equator and 12°South that are showing a more consistent species composition (figure 13). In this case, the environmental heterogeneity of each ecosystem plays an important role in conditioning the species composition of the tuna schools. Furthermore, the fact that there is also a large variability of species composition within each ecosystem and area may be also due to other sources of local environmental variability, for instance linked to the bathymetry, the currents, island or sea mounts effects, etc. This apparent large geographical variability of the species composition would need to be further study and understand.

5-Conclusion

This new scientific overview of the sampled species composition of purse seine landings in the Indian Ocean was an interesting first step in order to understand better the potential time and area structure and changes of the species composition of tuna schools, free and associated to FADs. These first results are already quite new and very encouraging, and there has been a major scientific interest to conduct such study since the beginning (c'est 82, et l'étude depuis 90 …) of the purse seine fishery in the Indian Ocean, and to conduct a complete statistical analysis of this large and valuable scientific data set. The results of such study could have a double interest:

(1) at a biological and behavioural levels, allowing to better identify and analyse the potential changes in the species and size composition of tuna schools, and possibly in given strata (such as in Fonteneau et al. 2000), for instance under the increase pressure by fisheries and the subsequent decline in the biomasses of all stocks since the early eighties or following changes in the environment or in the ecosystem.

(2) at the level of fish stock management and conservation: the mixing of species and sizes observed in a given schools is clearly a parameter of great importance that should be well taken into account in the management of tuna stocks, for instance allowing to limit fishing activities in areas where given species and sizes are more frequently caught (for instance small bigeye).

Such analysis should also be done by comparing the size and species sampling done in the Atlantic and in the Indian ocean, two oceans where the same type of multi-species sampling has been permanently conducted on the landings of all the EU purse seiners since 1980 (Atlantic) and 1983 (Indian Ocean). The same comparison should also be interesting to conduct in the Eastern (IATTC area and its systematic sampling since the year 2000) and in the Western Pacific where various similar size and species samplings have been also successfully conducted (Coan 2002)

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Litterature

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Table 1: Check list of the 26 parameters recorded in the « SPECIES » file, and obtained from the basic multispecies sampling file of size samples

Variable	Type
1	Ident sample
2	ocean
3	sampling port
4	Country
5	Gear
6	year
7	Month
8	Day
9	1° Area
10	ET Area
11	Type of school
12	weight of sampled total catch
13	weight of sampled yellowfin catch
14	weight of sampled skipjack catch
15	weight of sampled bigeye catch
16	weight of sampled albacore catches
17	weight of sampled auxis catches
18	weight of sampled Euthynnus catches
19	weight of sampled small yellowfin catch (<10kg)
20	weight of sampled large yellowfin catch (>10kg)
21	weight of sampled small skipjack catch (<2.5kg)
22	weight of sampled large skipjack catch (>2.5kg)
23	weight of sampled small bigeye catch (<10kg)
24	weight of sampled large bigeye catch (>10kg)
25	Max distance between sampled sets
26	Max numbers of days between sampled sets

Table 2: Yearly numbers of samples kept in the present analysis,

Year	Free schools	FAD	Total
1990	217	188	405
1991	96	127	223
1992	99	127	226
1993	148	149	297
1994	137	285	422
1995	115	449	564
1996	149	258	407
1997	122	252	374
1998	1	42	43
1999	9	14	23
2000	52	113	165
2001	293	396	689
2002	238	567	805
2003	512	510	1022
2004	447	515	962
2005	694	627	1321
2006	484	821	1305
Total	3813	5440	9253

Table 3:Number and frequency of the 8 types of species associations identified in the free schools (left) and in the FAD samples (right) during the studied period 1991-2006 (classified by decreasing %)

School type	Free schools	FAD
YFT+SKJ+BET	206	3898
YFT	1896	137
SKJ	453	106
YFT+SKJ	365	1199
YFT+BET	521	19
YFT+ALB	189	5
YFT+BET+ALB	135	1
others	48	75

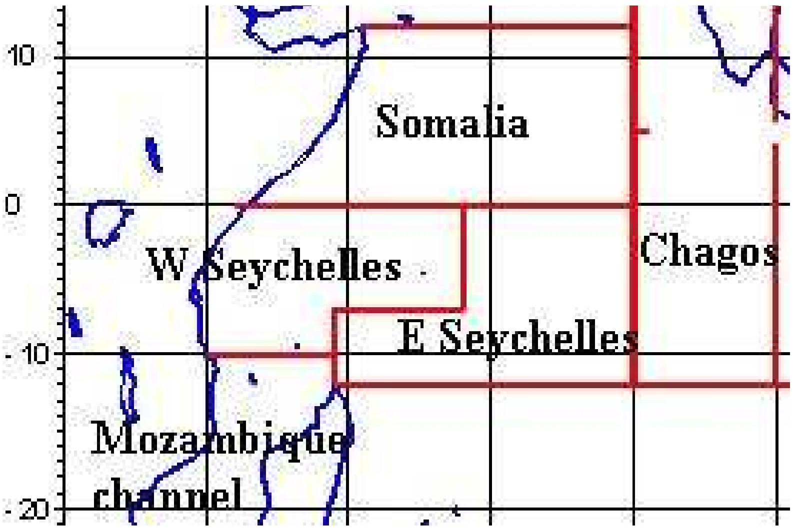
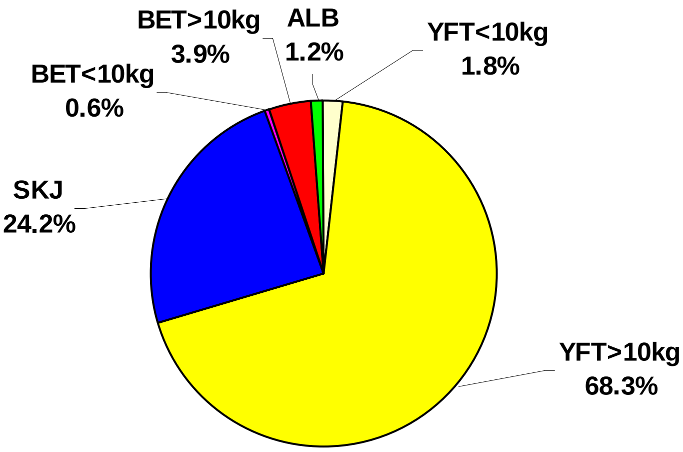


Figure 1: The 5 main areas used in the correcton of species composition of purse seine catches and in the analysis of the sample species composition



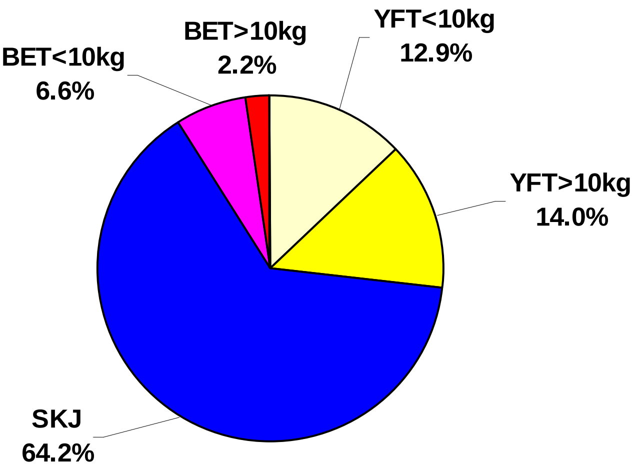


Figure 2a: free schools samples **Figure 2b: FAD samples**

Figure 2: Average species composition of the purse seine catches fishing in the Western Indian ocean for the free schools catches (left, figure 2a) and the FAD associated catches (right, figure 2b) (average period 1990-2006, after correction of the species composition). This species composition is given by size categories (+ and – 10kg for yellowfin and bigeye, all skipjack being smaller than 10kg and all albacore larger than 10kg)

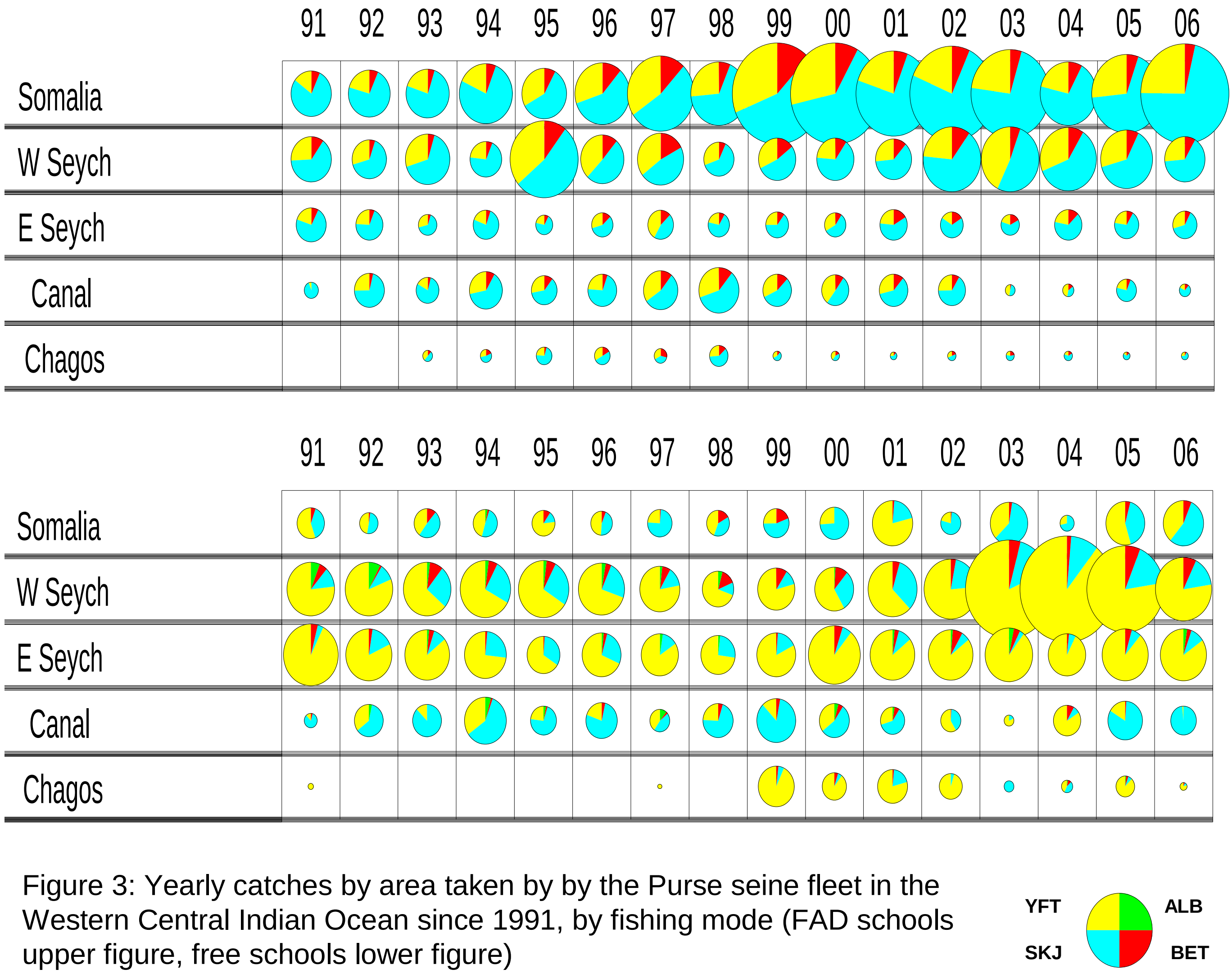


Figure 3: Yearly catches by area taken by by the Purse seine fleet in the Western Central Indian Ocean since 1991, by fishing mode (FAD schools upper figure, free schools lower figure)

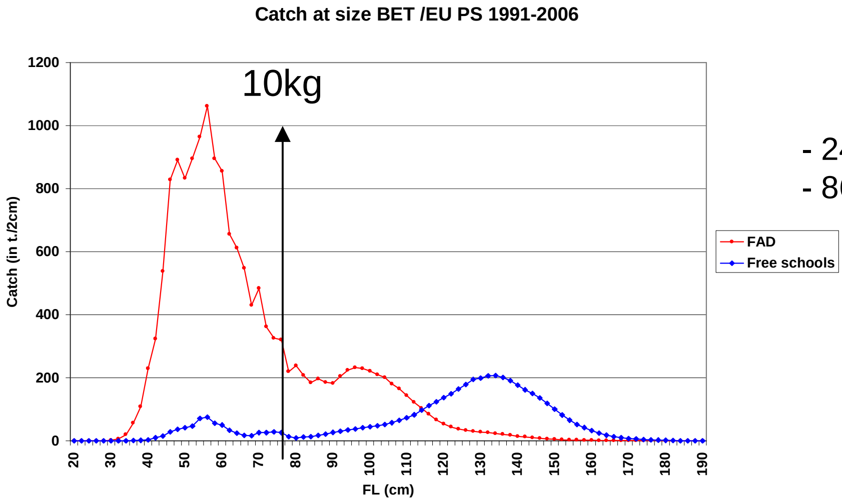


Figure 4a: Bigeye
- 24% of large BET in FAD schools
- 86% of large BET in free schools

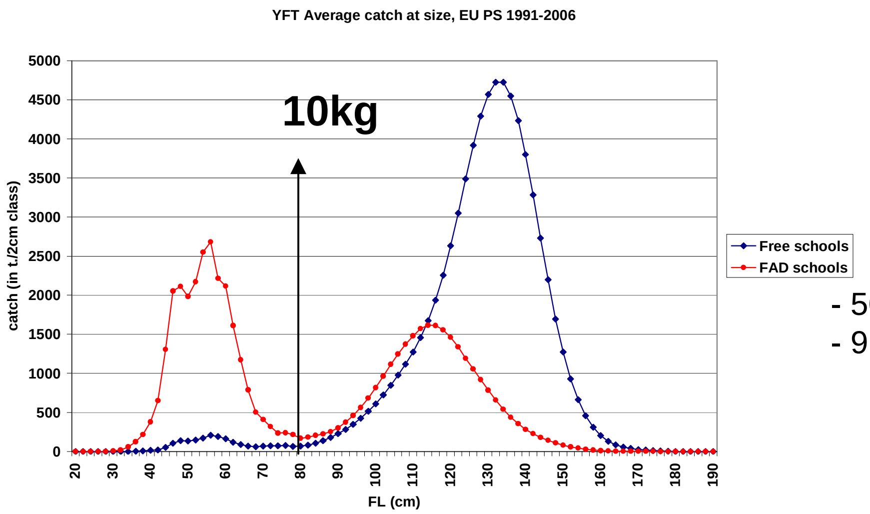
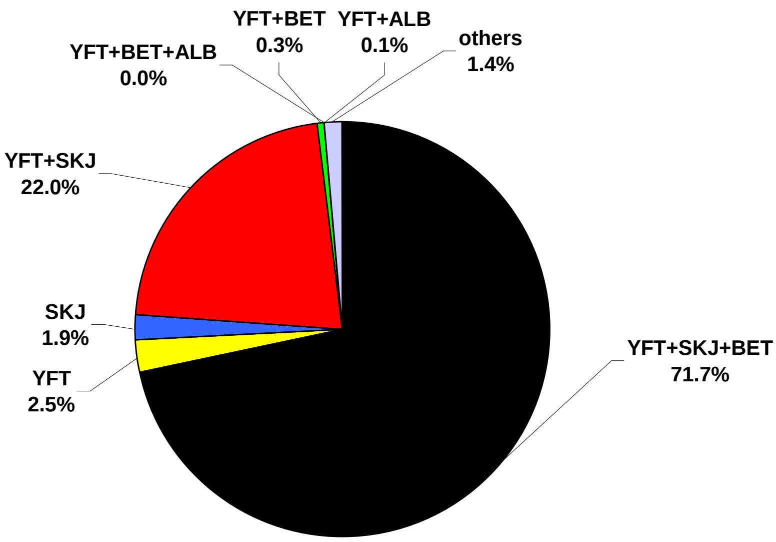


Figure 4b: Yellowfin
- 50% of large YFT in FAD schools
- 97% of large YFT in free schools

Figure 4: Average catch at size in weight taken by the EU purse seine fishery in the Indian Ocean during the period 1990-2006, by species (bigeye upper figure 4a, yellowfin lower figure 4b) and by fishing mode



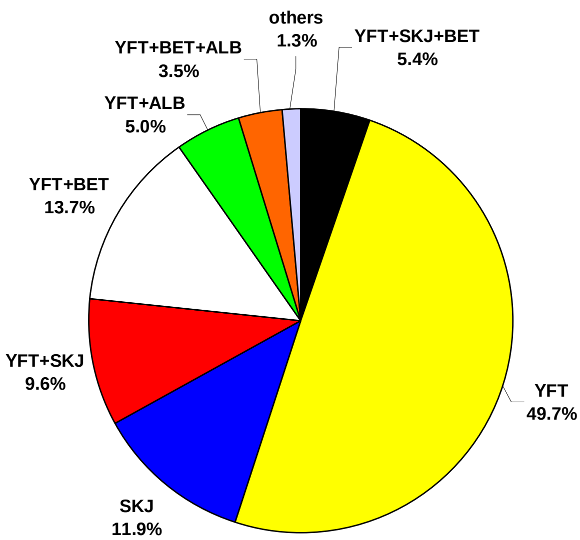


Figure 5: Average frequency of the various types of species composition observed in the Indian Ocean selected species samples (1990-2006) of the FAD (5a) and free schools (5b) samples

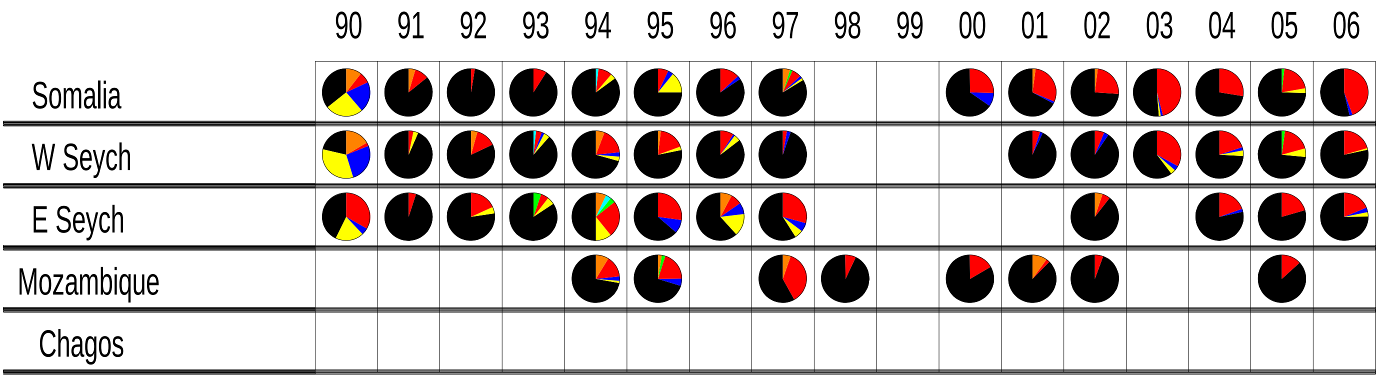


Figure 6a: FAD schools samples

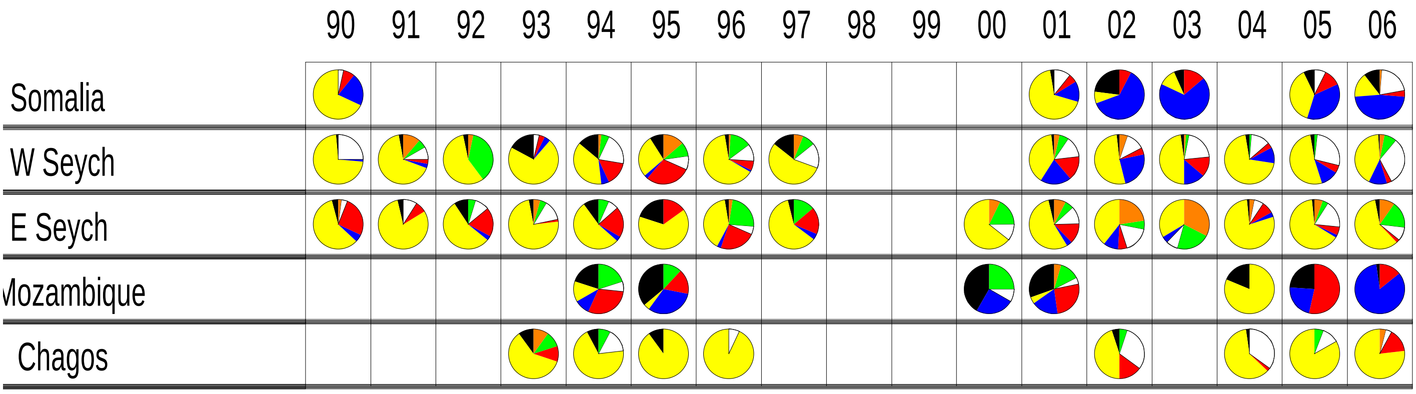


Figure 6b: free schools samples

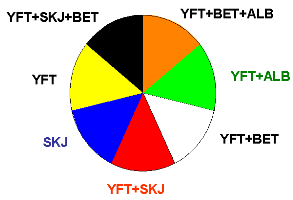


Figure 6: Frequency of species composition observed In the FADs schools samples (upper figure 6a), expressed in % (only for strata with more than 10 samples each year) and same result for the free schools samples (lower figure 6b).

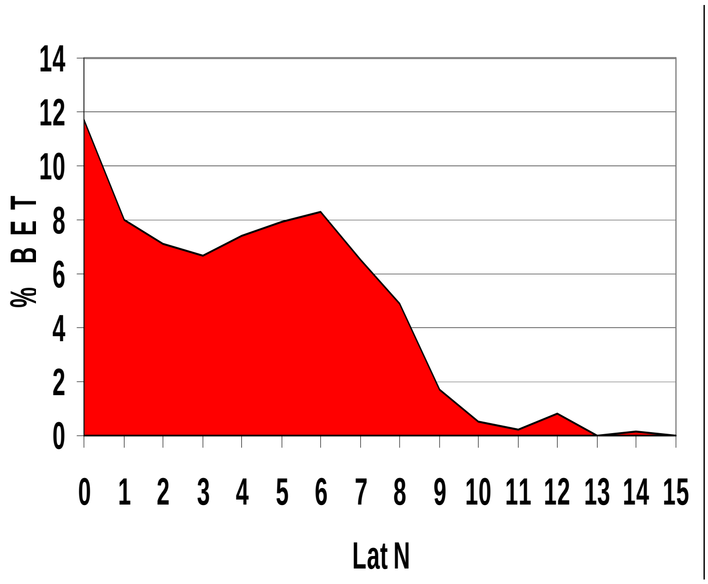


Figure 7: Percentage of bigeye (in % of weight) in the Somalia area on FAD schools as a function of latitude (north of Equator)

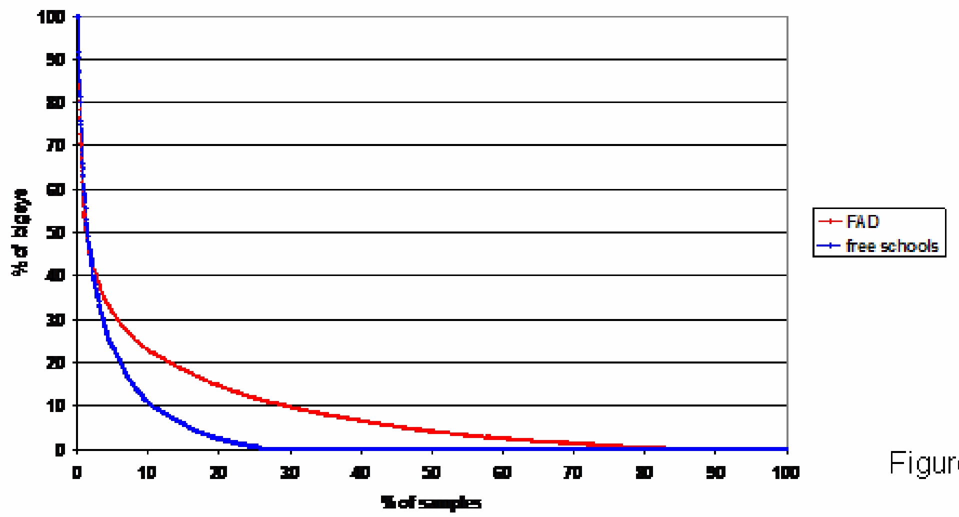


Figure 8a : Bigeye

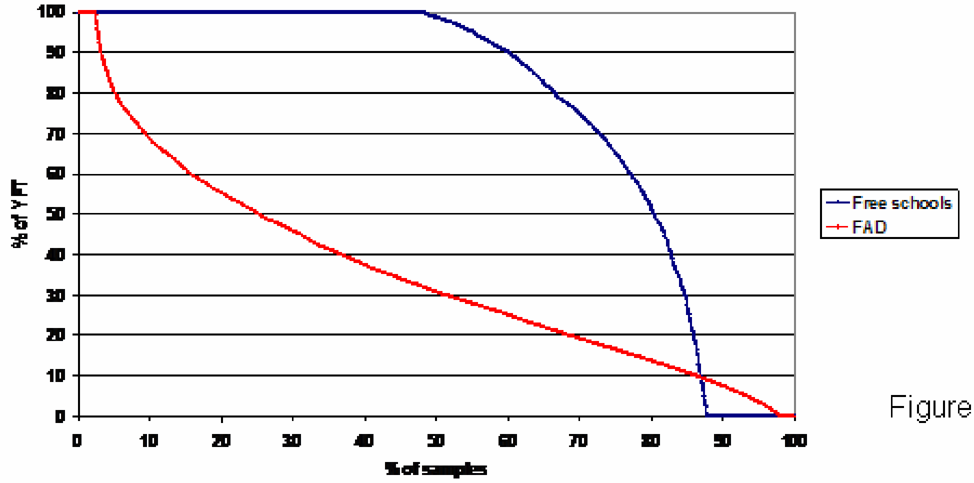


Figure 8b Yellowfin

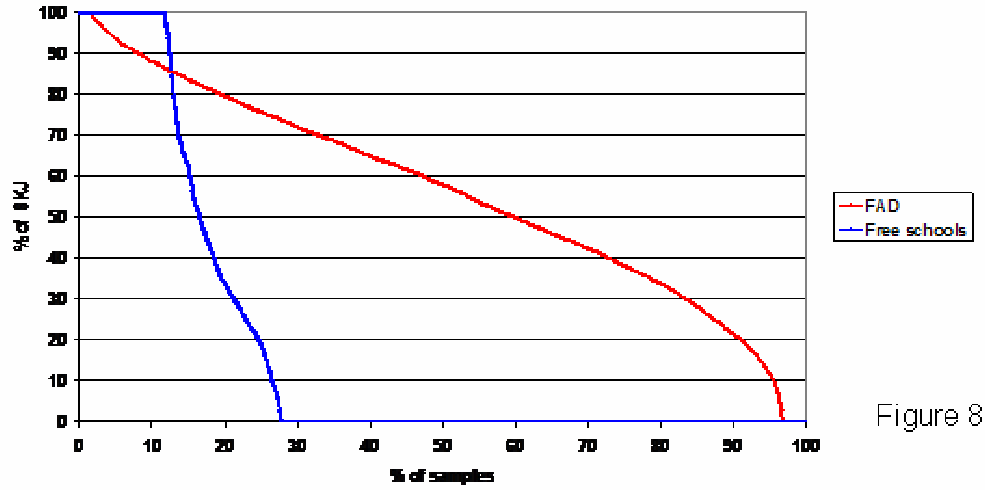


Figure 8c: Skipjack

Figure 8: Percentages (in weight) of bigeye (figure 8a), yellowfin (figure 8B) and skipjack (figure 8c) in the FAD and in the free schools samples, classified by decreasing importance, observed in the Indian Ocean during the period 1990-2006 (the 5440 FAD and 3813 free schools samples being classified in the same scale of percentages)

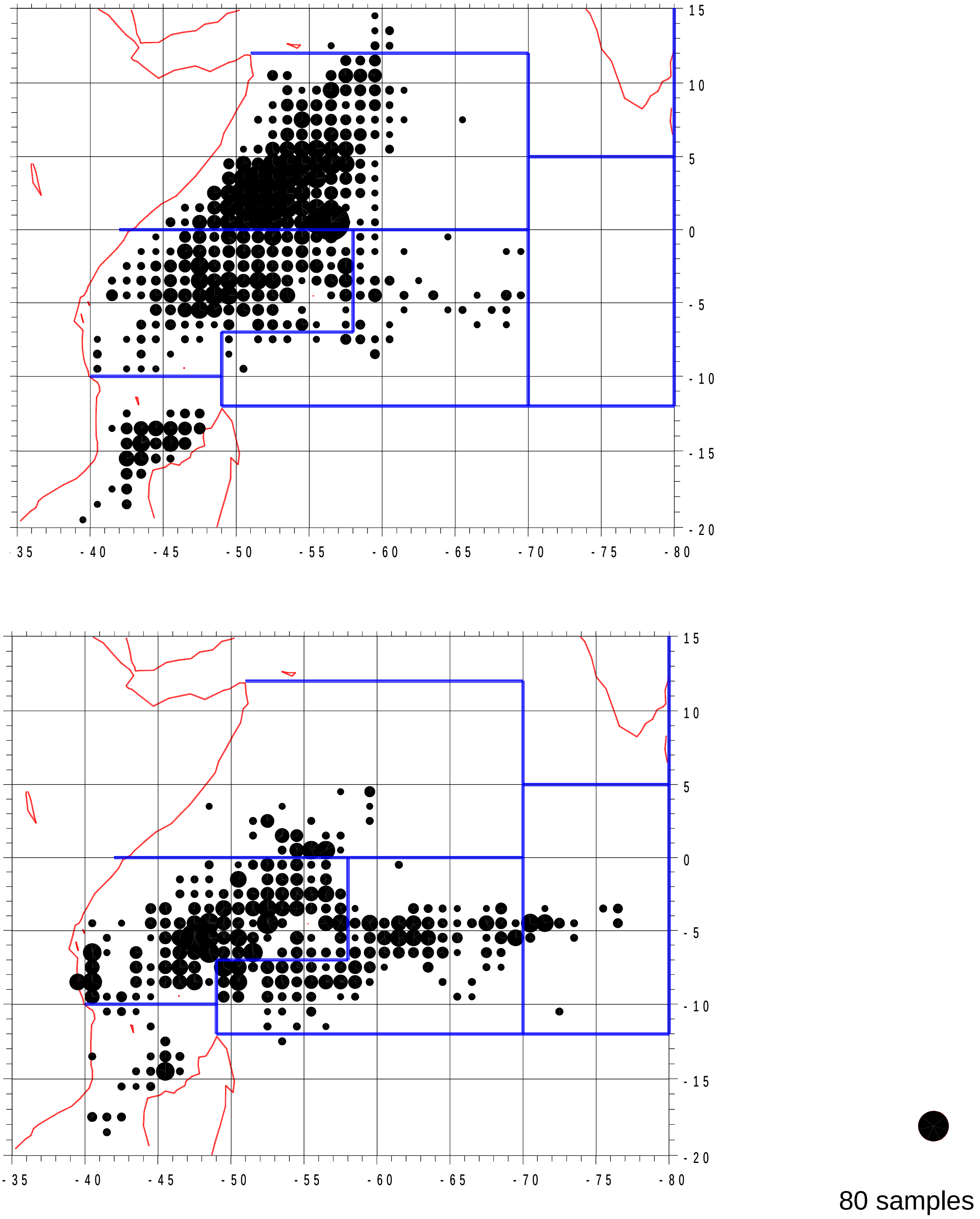


Figure 9: Total numbers of FAD associated and free schools samples by 1°squares available in the analysis during the 1990-2006 period (8a: FADs upper figure, 8b: free schools, lower figure)

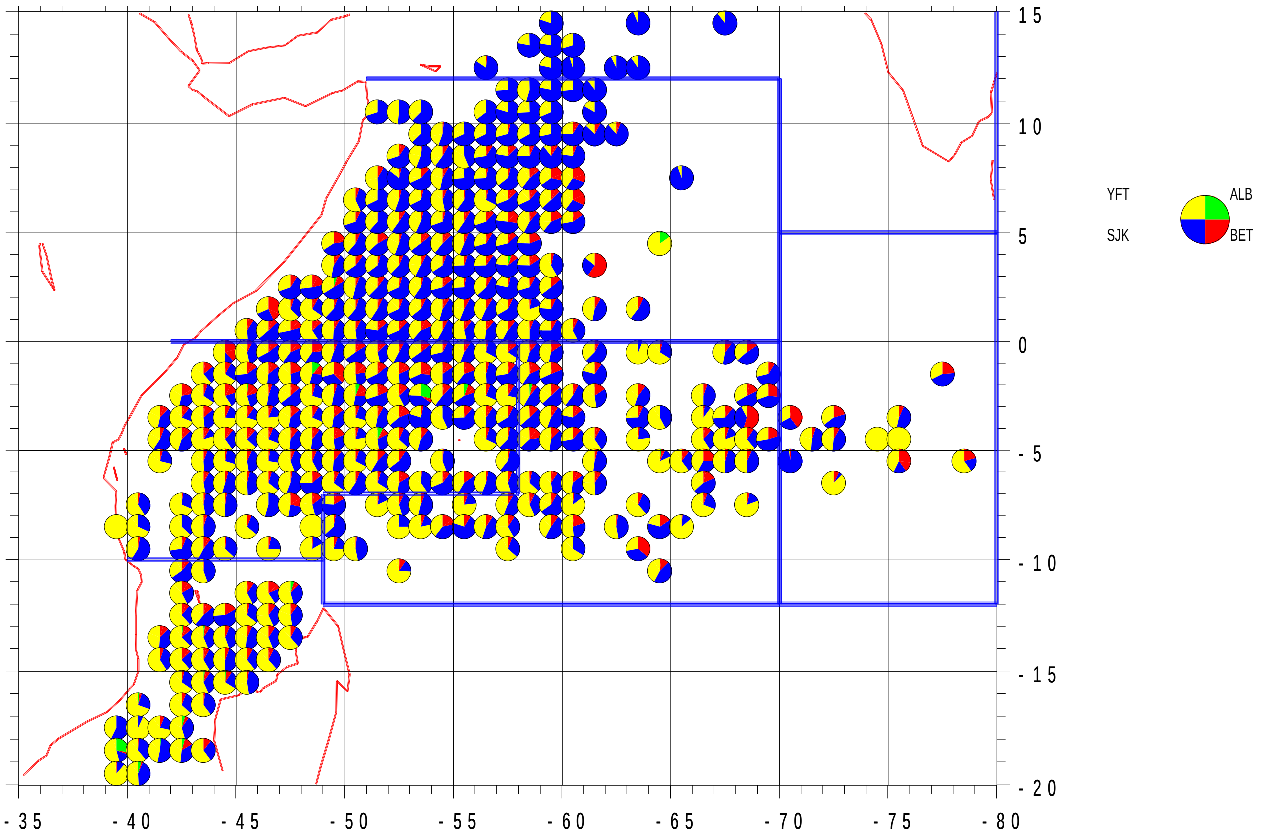


Figure 10: Average species composition by 1° squares of the sampled FAD associated catches during the whole period 1990-2006 (in %) (sample > 1t.)

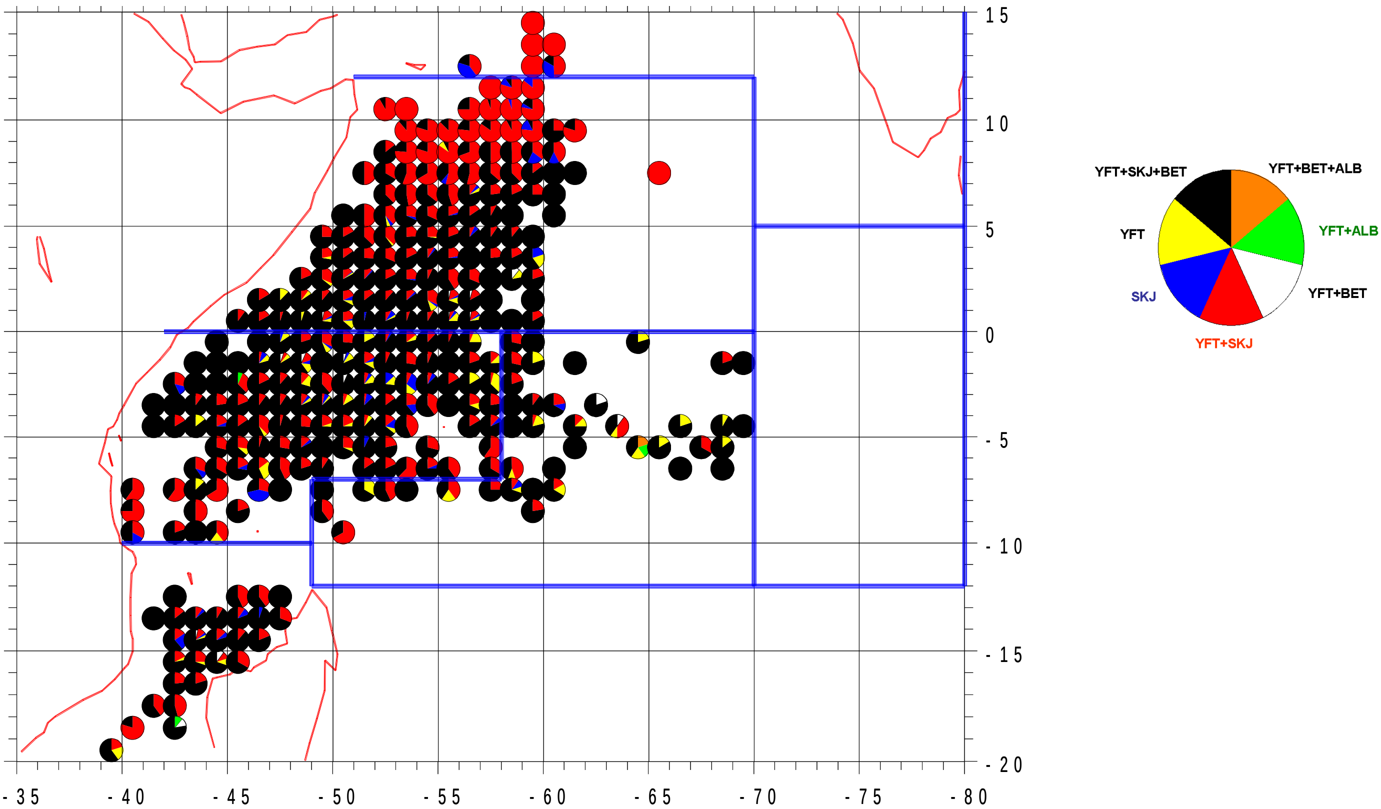


Figure 11: Frequency of the main types of species composition observed in the FAD samples during the period 1990-2006 (in %) (only more than 5 samples/1°)

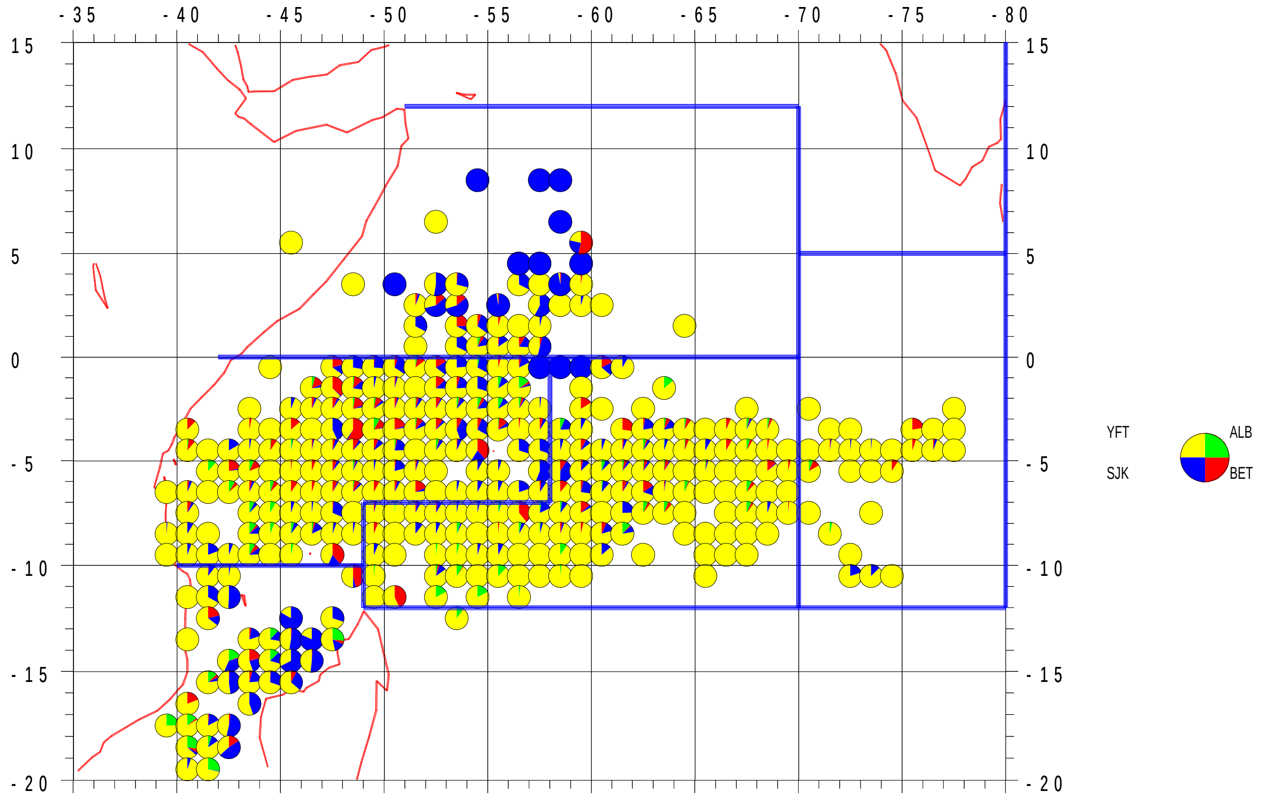


Figure 12: Average species composition by 1° squares of the free schools sampled catches during the whole period 1990-2006(in %) (sample > 5t.) and species composition areas

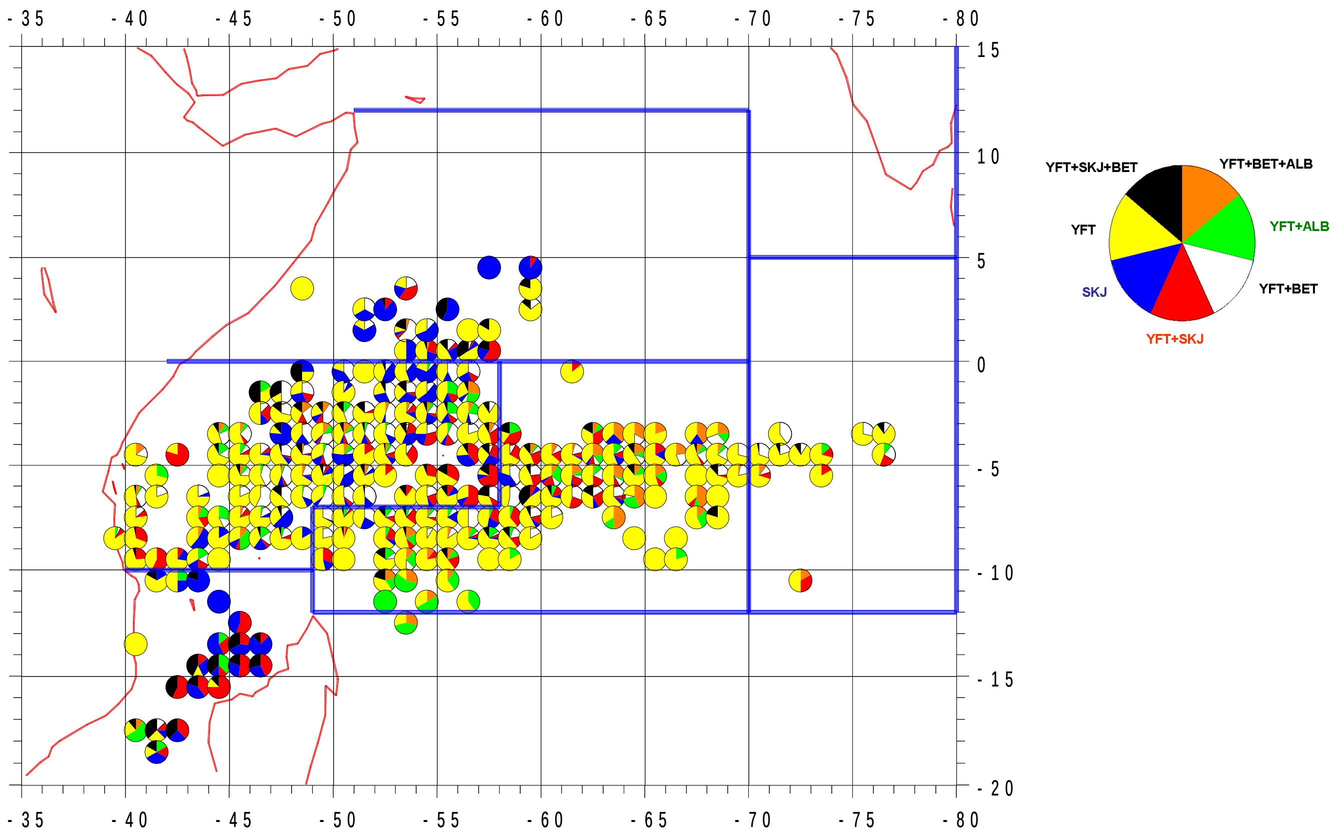


Figure 13: Frequency of the main types of species composition observed in the free schools sampled catches during the period 1990-2006 (in %) (only more than 5 samples/1°)

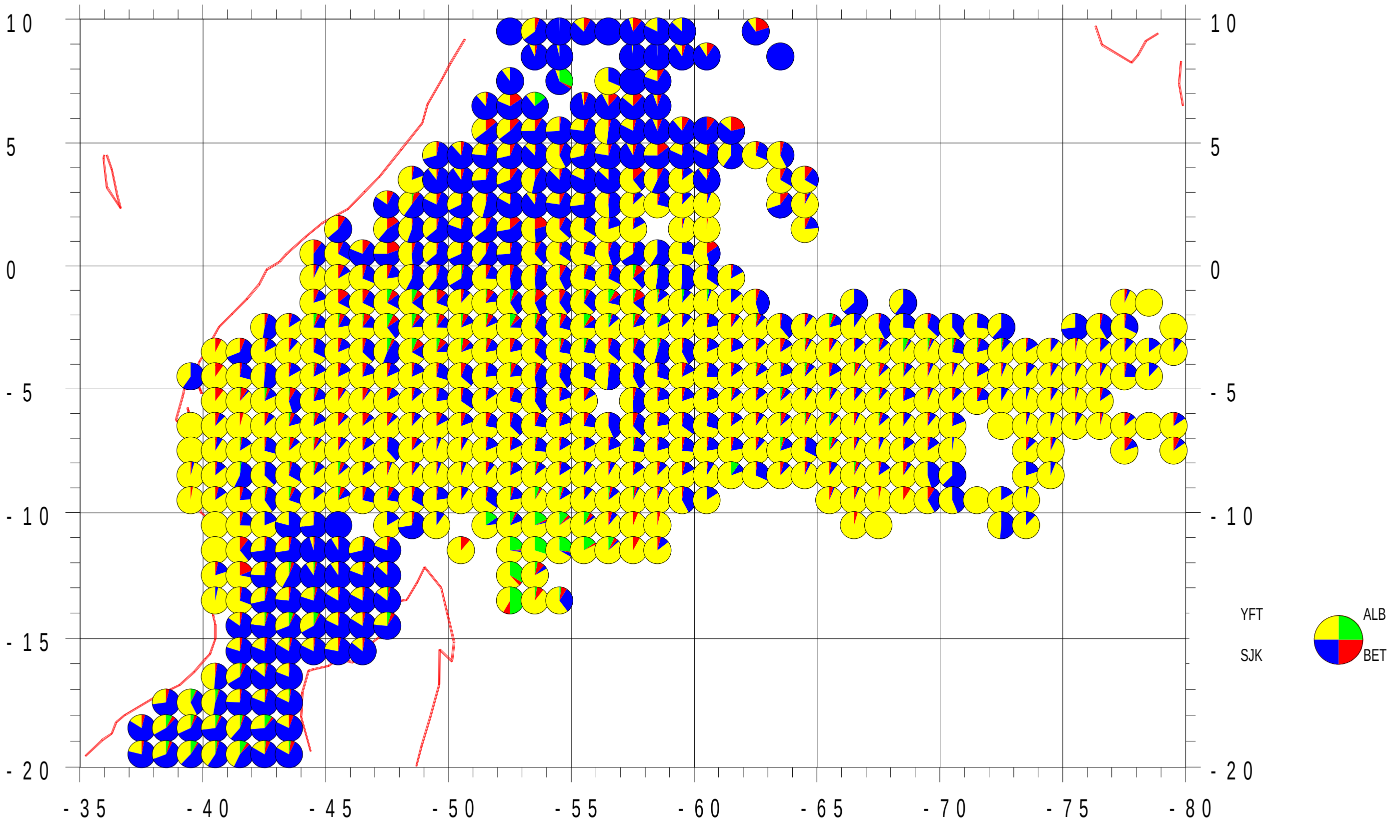


Figure 14: Average species composition of free schools catches by purse seiners during the period 1990-2006 (in %) as estimated after the area/quarter species correction

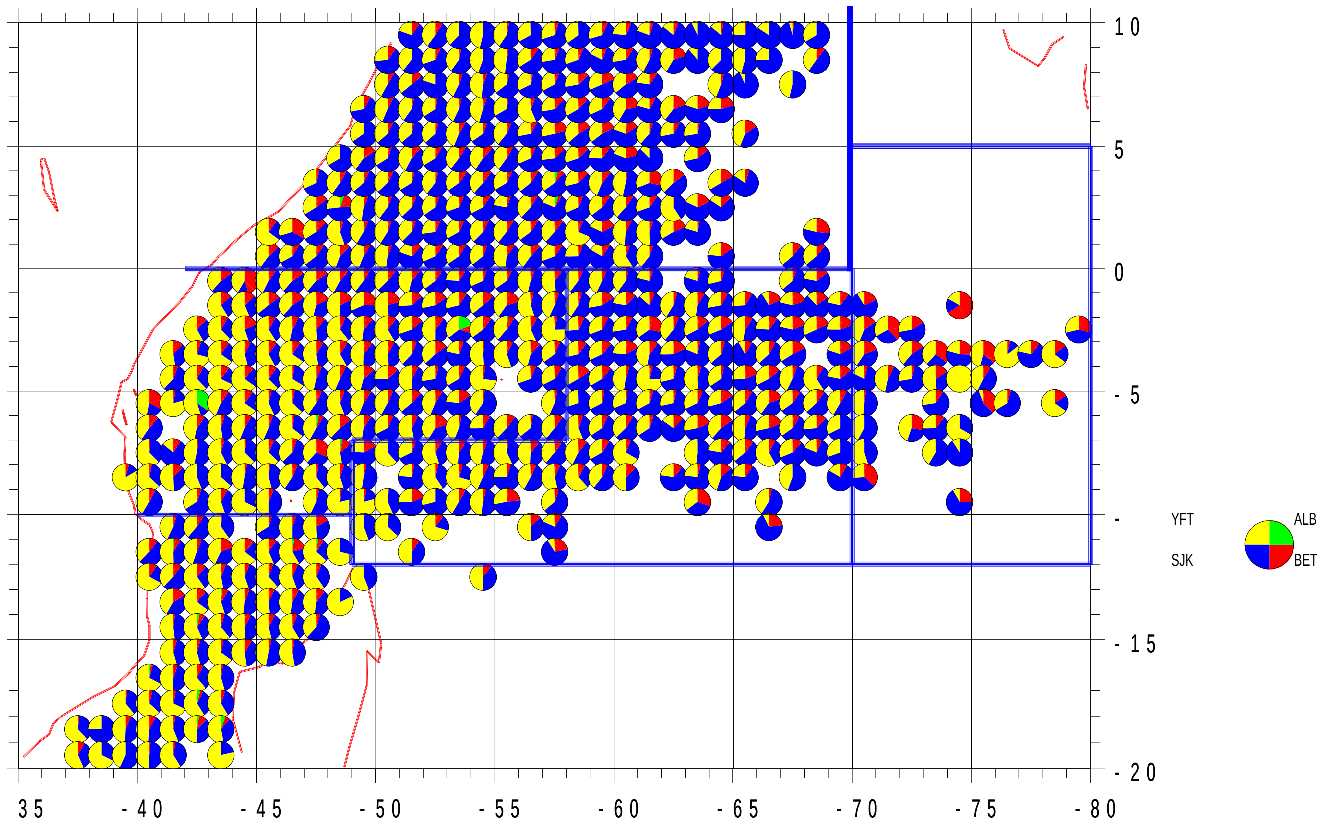


Figure 15: Average species composition of FAD schools catches by purse seiners during the period 1990-2006 (in %) as estimated after the area/quarter species correction

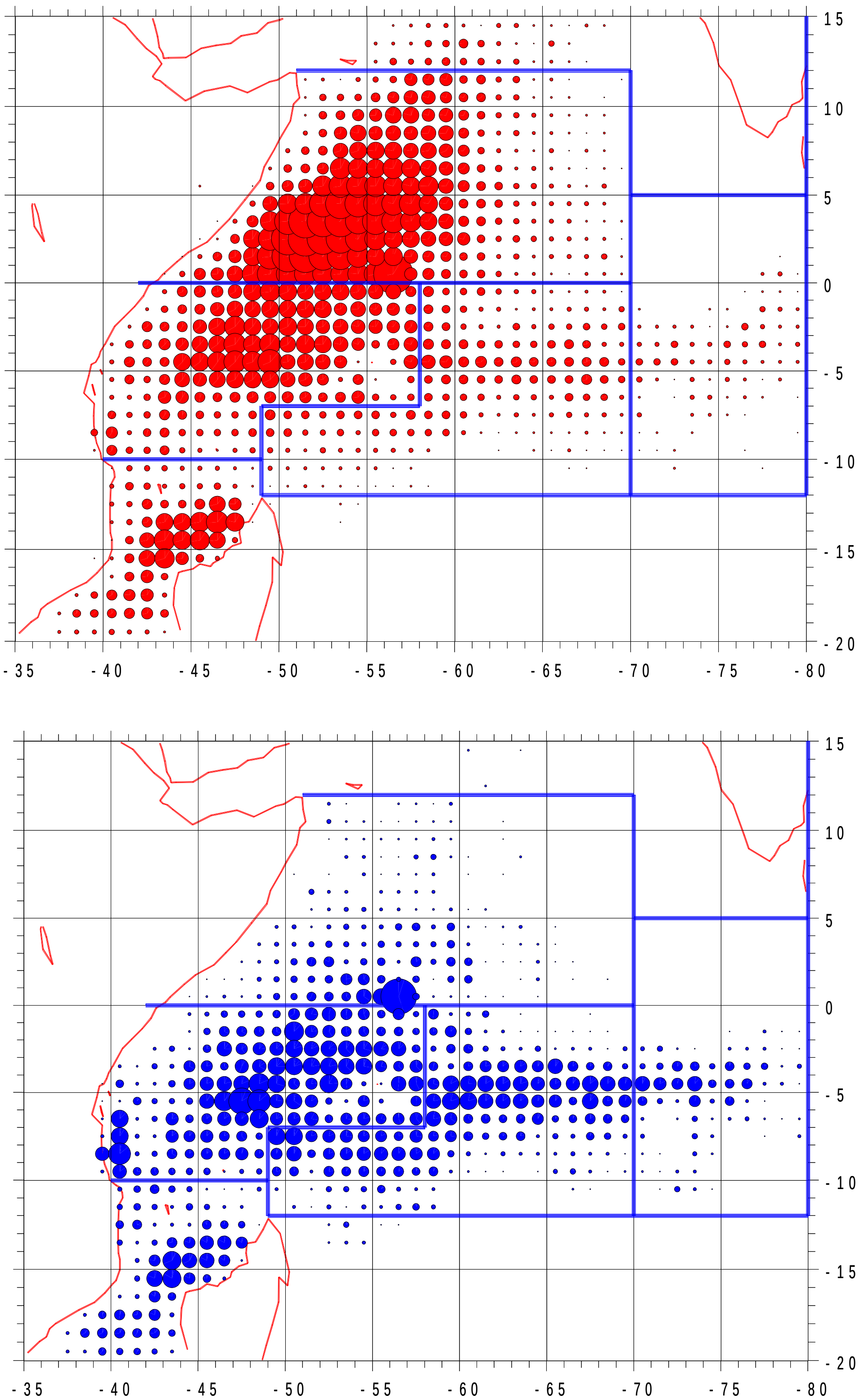


Figure 16: Average catches taken by the purse seine fisheries during the period 1990-2006, On FADs (upper figure 15a) and on free schools (lower figure 15b)

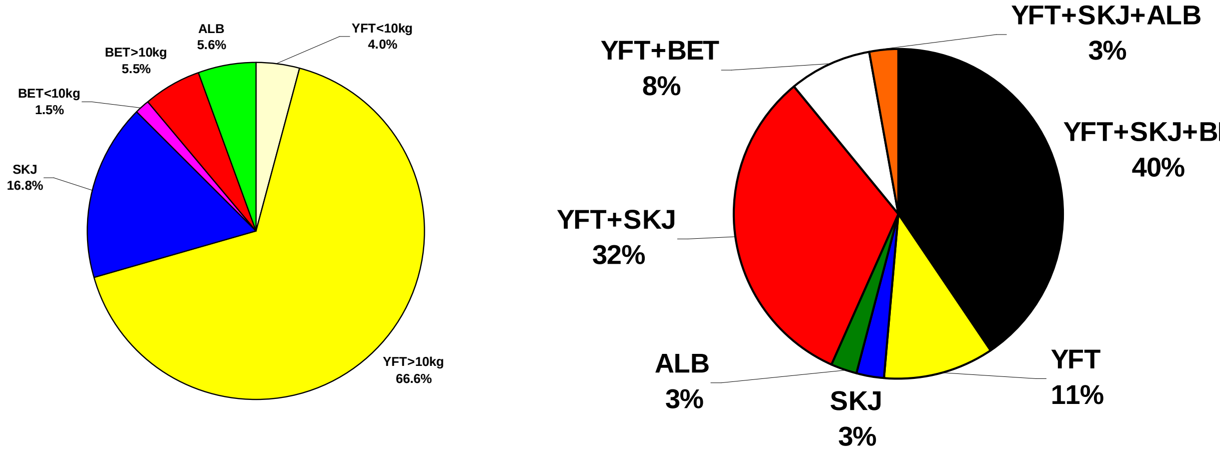


Figure 17: Frequency of the various types of species composition observed in the Indian Ocean whale sharks 37 samples (1990-2006)

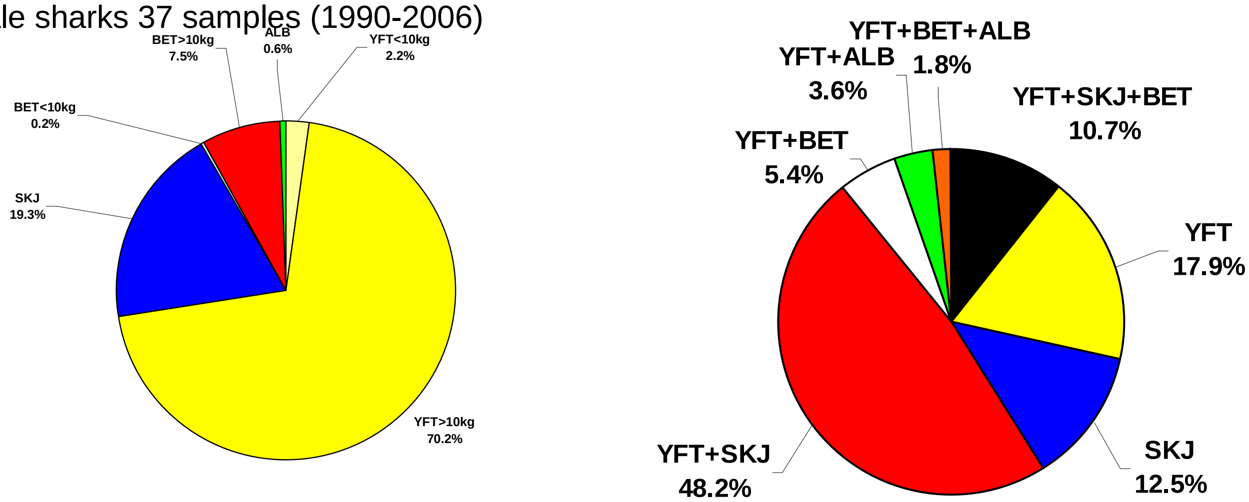


Figure 18: Frequency of the various types of species composition observed in the Indian Ocean 56 samples of tunas caught associated to whales (1990-2006)

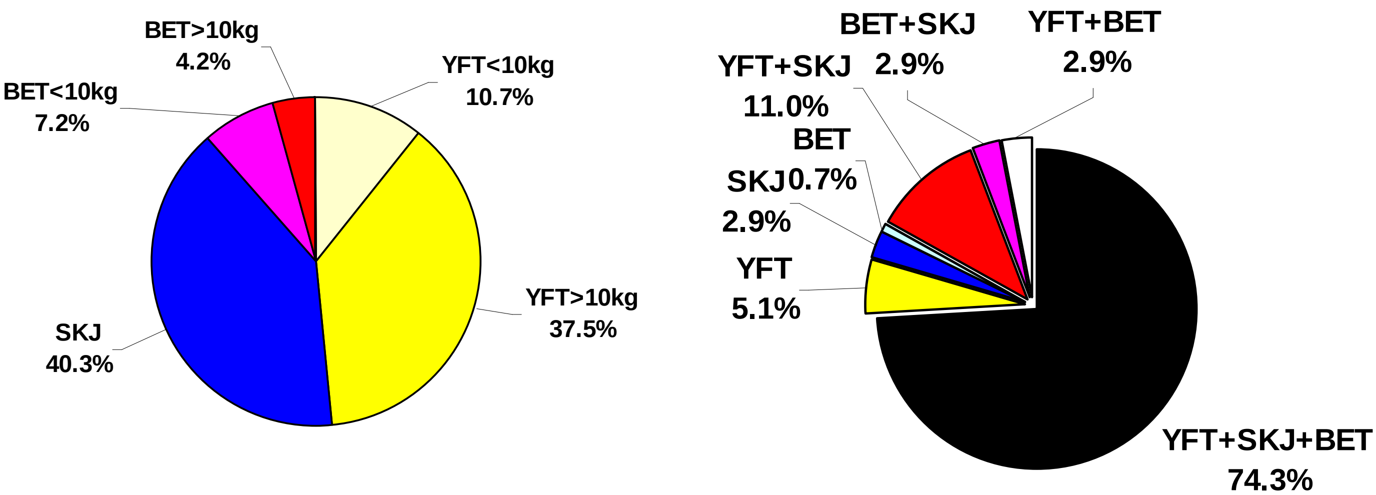


Figure 19: Frequency of the various types of species composition observed in the Indian Ocean 137 samples of tunas caught associated to Coco de Mer (1990-2006)

NB: *Species composition of figures 17 to 19 are calculated as the unweighted totals of the specific weights of the samples. The real species composition of the weighted catches would be more representative of the real species composition of these catches*

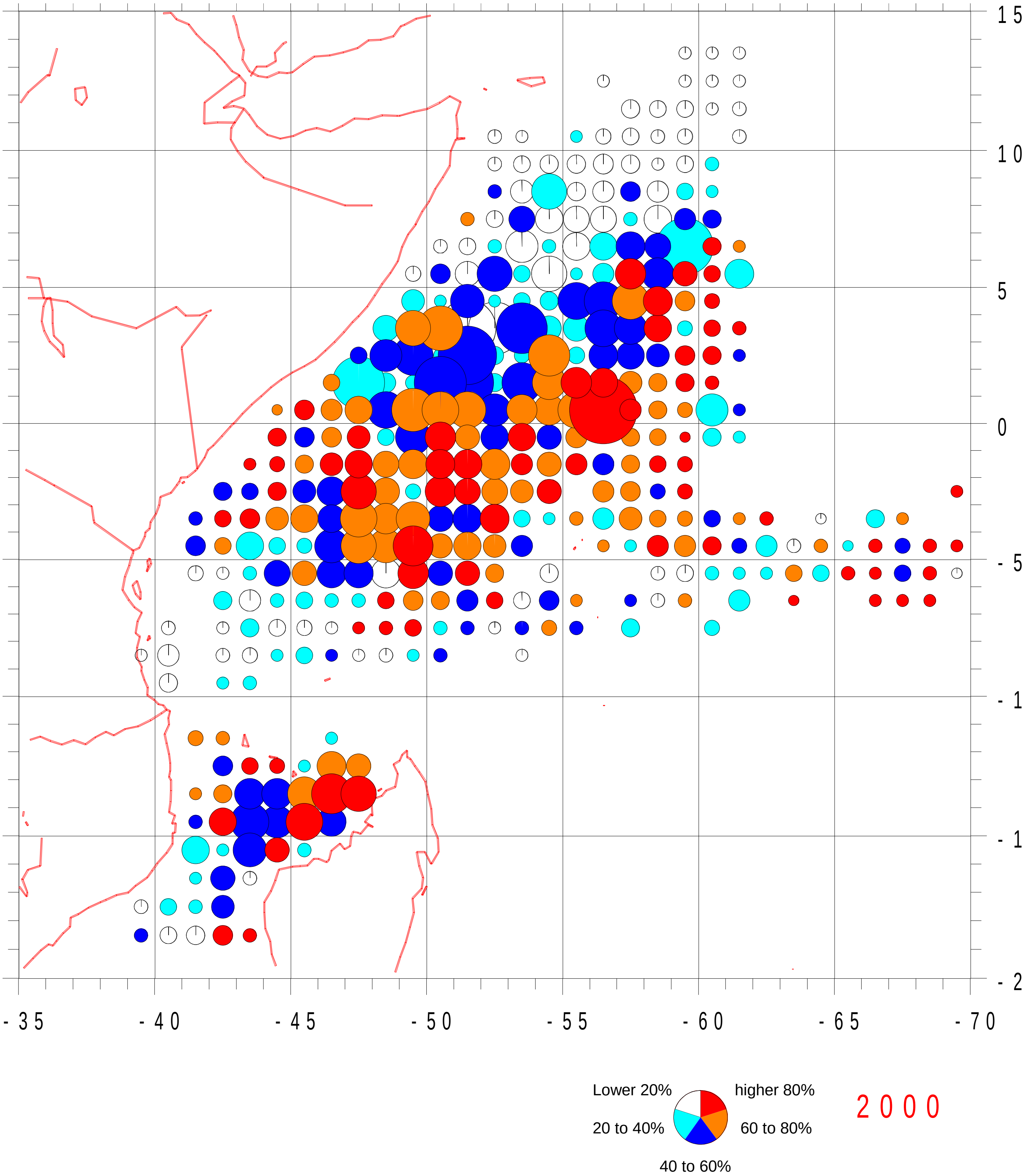
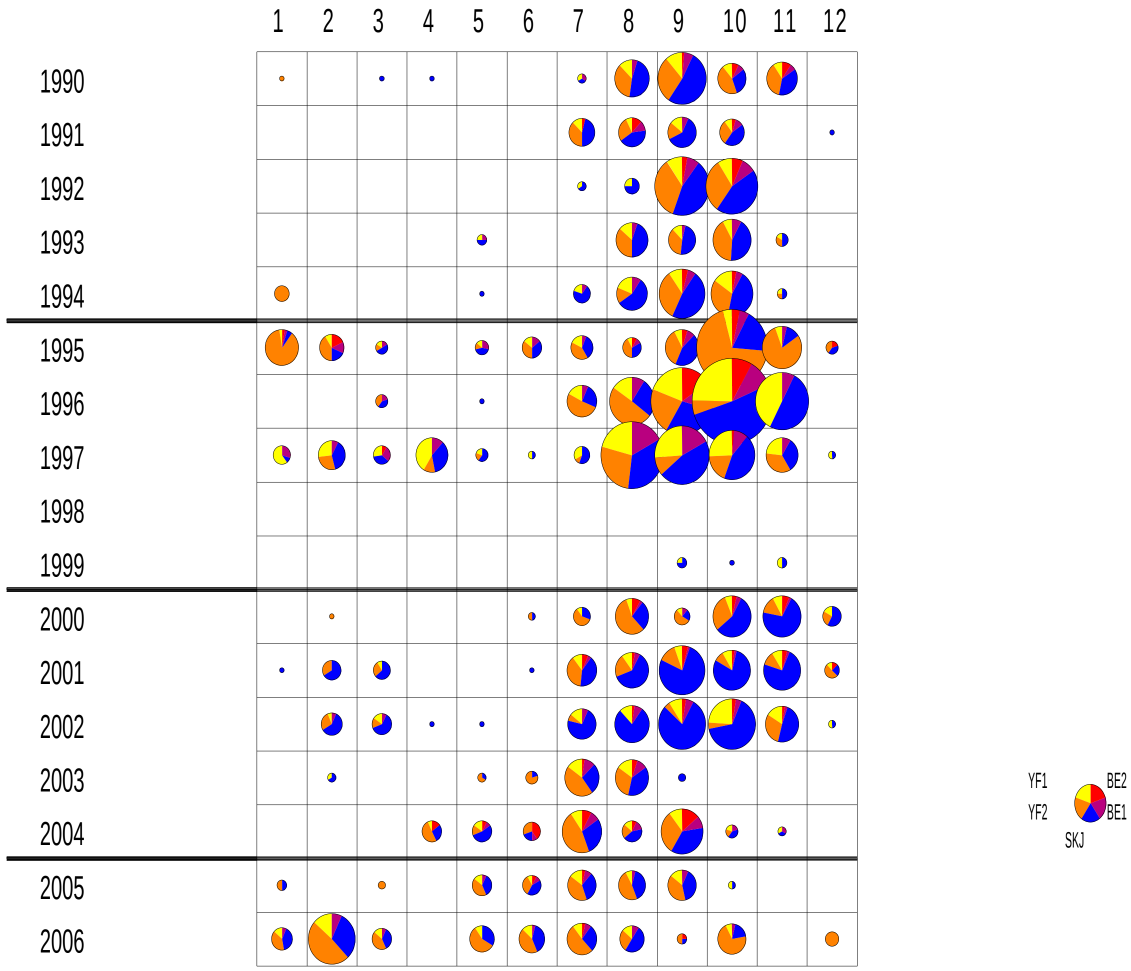


Figure 20: Average tuna catches taken on FADs by the purse seine fishery during the 1991-2004 period, and relative amount of small bigeye, shown by the percentiles of small BET (<10kg) sampled in the total catches in each 1° square during th e period. This amount is shown by the color of each circle: white the 20 lowest % of BET (ave.1.1% of BET), light blue between 20 and 40% ave.=3.9%), dark blue 40 to 60% (Ave.6.1%), orange 60 to 80% (ave. 8.1%) and red more than 80% of the most abundant percentages of small bigeye (ave.12.3%).



YF1=YFT<10kg
YF2=YFT >10kg
BE1=BET<10kg
BE2=BET>10kg

Figure 21: Monthly species and size composition of the sampled catches associated to FADs in the West Seychelles area

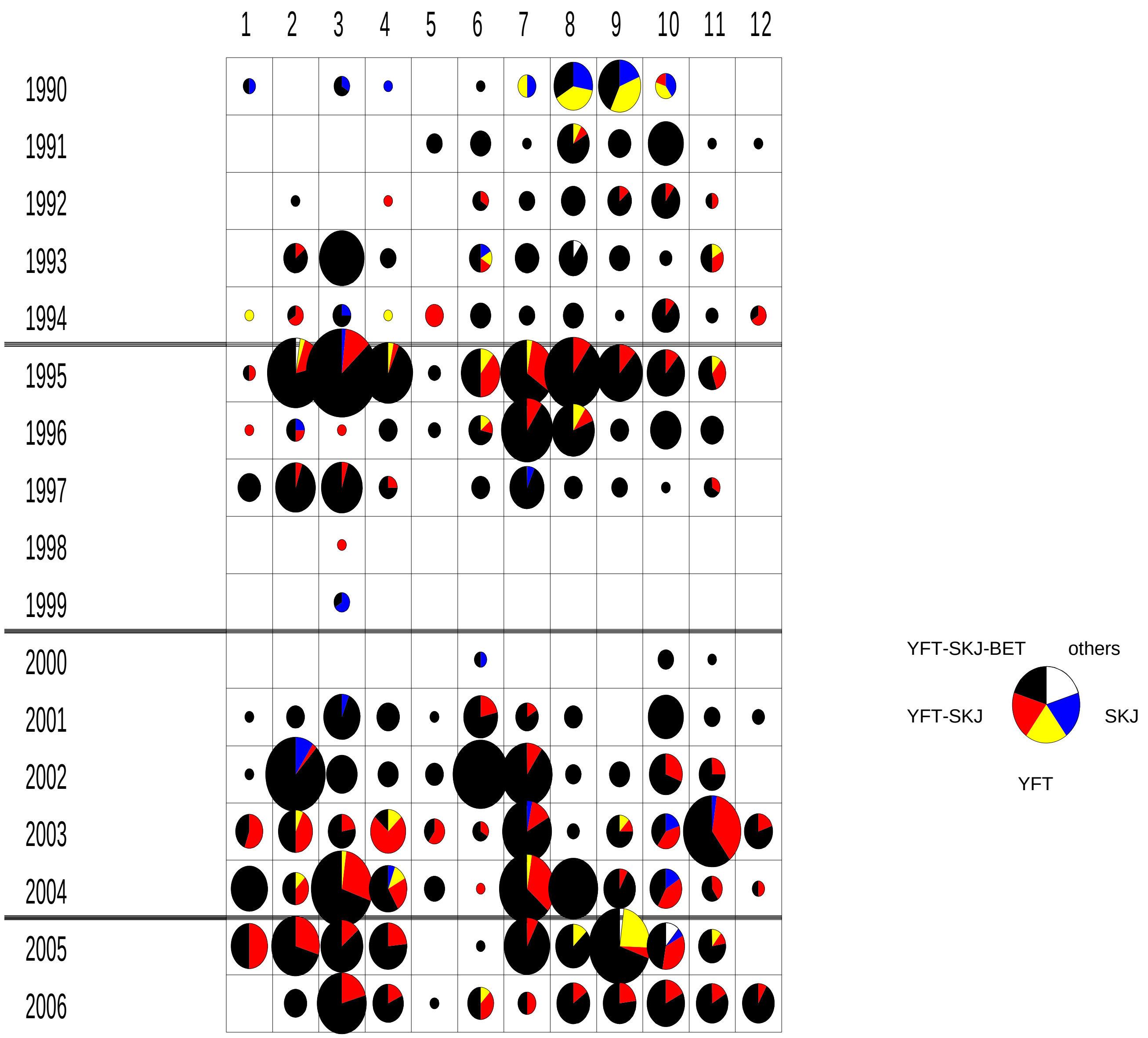


Figure 22: Frequency of the monthly types of schools sampled on FADs in the West Seychelles area