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SPATIAL CHANGES IN THE PURSE-SEINERS' ACTIVITIES IN THE EASTERN ATLANTIC OCEAN FROM 1991 TO 1995

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SUMMARY

This document analyses the spatial changes observed in the different tropical purse seine fishing activities in the Atlantic Ocean from 1991 to 1995. Although the overall nominal fishing effort stayed stationary, the percentage of effort exerted in the Liberian area decreased and was relocated in the offshore Ghanaian-Ivory Coast area. As a result, the proportion in the catch of tunas larger than 30 kg was multiplied by five in this former area, which represented 50% of the total catch of this size category. The sharp decrease observed in the proportion of fishing effort allocated in the northern Liberian area did not produce a significant decrease in the percentage of the catch of tunas less than 10 kg (25% of the this size category continued to be caught, maybe due to the log fishing mode in this area). The estimated percentage of sets made on logs equipped with radio range beacons showed an increase from 12% to 34% in five years, whereas the percentage of sets made on all types of logs only increased by 5%. This suggests that logs without transmitter were progressively equipped with this device throughout the years. The spatial catch distribution of the small fishes was significantly correlated with the spatial distribution of the fishing effort but did not show a clear relationship with the spatial distribution of logs equipped with radio range beacons. The spatial-temporal stratum chosen by the European purse seine companies for the closure of log fishing operations corresponds to the major area and to the major season (from November to January) of the occurrence of log sets. This stratum represented approximately 36% of the amount of log sets made by the purse seiners in the Atlantic Ocean, and 25 to 30% of the total catch of fishes under 10 kg.

RÉSUMÉ

Ce document analyse les modifications spatiales survenues dans les diverses activités de pêche des thoniers senneurs tropicaux dans l'Atlantique Est entre 1991 et 1995. Bien que l'effort de pêche nominal soit resté stable, la proportion d'effort exercé dans la zone Libérienne a diminué au profit de la zone hauturière ivoiro-ghanéenne. Comme conséquence directe, le pourcentage de prises de thons de plus de 30 kg a été multiplié par cinq dans cette dernière zone qui concentre la moitié des captures de gros individus. La forte diminution de l'effort de pêche enregistrée dans le secteur nord du Libéria ne fait pas baisser de manière significative la proportion de thons de moins de dix kg qui y est pêchée (à raison de 25 % des prises, en relation peut-être avec la pêche sous objets flottants). Les estimations portant sur le pourcentage de coups de senne réalisés sur des épaves équipées d'émetteurs indiquent une hausse 12 % à 34 % en cinq ans. Toutefois, comme la proportion de coups de senne réalisés sur des épaves de toute nature ne s'est accrue que de 5 %, il est probable que les épaves sans émetteurs ont été équipées progressivement au cours de ces années. La distribution spatiale des captures de petits thons était significativement corrélée avec la distribution spatiale de l'effort mais ne montrait pas de claire relation avec celle des épaves équipées avec des transmetteurs. La strate spatio-temporelle de fermeture de la pêche sous objets flottants, choisie par les armements des thoniers senneurs européens, correspond bien à la période (novembre à janvier) et à la zone d'utilisation maximale de ce mode de pêche. Cette strate représente 36 % du total de coups de sennes faits sous objets flottants et 25 à 30 % des prises de thons de moins de 10 kg réalisées dans l'Atlantique.

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RESUMEN

El documento analiza los cambios espaciales observados en las diferentes actividades de pesca de los cerqueros tropicales en el Atlántico, de 1991 a 1995. Si bien el esfuerzo nominal de pesca global permaneció estable, el porcentaje del esfuerzo ejercido en la zona de Liberia descendió y se trasladó a la zona de alta mar de Ghana-Côte d'Ivoire. Por ello, la proporción en la captura de túnidos de más de 30 kg se multiplicó por cinco en esta zona, lo que representaba el 50% del total en esta categoría de talla. El marcado descenso observado en la proporción del esfuerzo de pesca ejercido en el norte de la zona de Liberia, no produjo un importante descenso en la pesca de túnidos inferiores a 10 kg (se sigue capturando un 25% de peces de esta talla, debido tal vez a la pesca con objetos flotantes). El porcentaje estimado de lances con objetos equipados con radio, mostraba un aumento del 12 al 34% en cinco años. Dado que el porcentaje de lances efectuados con todo tipo de objetos sólo aumentó en un 5%, es probable que los objetos sin transmisores fueron siendo equipados progresivamente durante esos años. La distribución espacial de la captura de peces pequeños estaba muy relacionada con la distribución espacial del esfuerzo de pesca, pero no mostraba una relación clara con la de los objetos equipados con radio. El estrato espacio-temporal escogido por los armadores de cerqueros europeos para la veda de las operaciones con objeto, corresponde a la principal zona y a la principal temporada (noviembre a enero) de esa actividad. Este estrato representaba aproximadamente el 36% de todos los lances con objeto realizados por los cerqueros en el Atlántico y del 25 al 30% de la captura total de peces de menos de 10 kg en dicho océano.

INTRODUCTION

The management of the tropical tuna mixed-species fishery involves different objectives, such as (a) the optimization of the fishing mortality rates on the target species, (b) the less damaging use of the epipelagic ecosystem (i.e., by limiting and controlling unnecessary incidental catches), and (c) the economical sustainability of the exploitation.

The main target species for the tropical tuna purse-seiner fishery in the Atlantic Ocean are the yellowfin (*Thunnus albacares*), and the skipjack (*Katsuwonnus pelamis*). In contrast, the bigeye tuna (*Thunnus obesus*) can be considered as a by-catch for this fishery. The recent development of the fishing operations on logs equipped with a transmitter (namely, radio range beacons) was incited by the necessity to exploit a new fraction of the stocks, previously unavailable (especially for exploiting the skipjack tuna). The resulting increase of the amount of sets made on logs can be justified in order to make the best use of a given species of tuna, but a non-controlled use of this fishing mode could lead to a wasteful exploitation of the other species.

As a general rule, optimizing the best use of the ressource can be seen such as maximizing yield per recruit (i.e., preventing growth overfishing), or as maximizing the surplus production (i.e., preventing recruitment overfishing). There is evidence that catches of yellowfin and bigeye tuna made under logs are composed in majority by small fishes. Consequently, an increase in the mortality rates of the juveniles of both species could lead to a growth overfishing. Depending upon the rates of exploitation of the different stocks of tropical tunas in the Atlantic Ocean, this negative impact could be combined with a recruitment overfishing. Such a situation could be found in the case of bigeye tuna because the total catch of this species increased by forty percent since the early 1990s (large bigeye tunas are targeted by the long-line fishery, as well as by some european baitboat fisheries).

The aim of this paper is to analyse the possible influence of the changes in the purse-seiners' activities in the recent increase in catches of juveniles.

MATERIALS AND METHODS

The Data

The data base was obtained from logbooks of the purse-seiners (mainly the F.I.S. and the Spanish fleets) operating in the Eastern Atlantic Ocean from 1991 to 1995. The reasons for limiting the scope of the study to these recent years is mainly due to the fact that the majority of vessels did not report the fishing mode associated with the set (e.g., non-associated schools, log schools, etc.,) before 1990.

The major results of the European research program about the sampling of the tropical tunas ("Tropical tunas sampling scheme analysis") will be used to rebuild the ICCAT's catch/effort surface data base (task II) as soon as possible. Keeping in mind that the species composition within each commercial size category probably will be modified, we preferred to use the size category of the fish rather than the species of tuna reported in logbooks. Moreover, we assumed that the purse-seiner fishermen's strategies (i.e., the spatial-temporal allocation of the fishing effort) were more related to the search of the schools composed by large fishes than to the search of a given species of tuna. This assumption was made because the price differential was bigger between size categories than between tuna species (at least for the surface fishery). In addition, it was evidenced that it was more appropriate to consider the association of tunas with the fishing modes on the basis of fish size than on tuna species. The size categories were chosen based on the classification used commercially: small < 10 kg, medium >= 10 to < 30 kg, large >= 30 kg.

Tuna fishermen know that swimming-surface tuna schools tend to concentrate under floating objects or under marine animals. In this part of the Atlantic Ocean, tuna schools are found with different types of associations (Stretta and Slepoukha 1986, Cayré et al. 1988). These associations were broken down into six main fishing modes:

- Sets associated with logs not equipped with radio range beacons,
- Sets associated with Fish Aggregating Devices, or with natural logs, equipped with transmitters,
- Non-associated schools (i.e., school sets),
- Sets associated with whales,
- Sets associated with whale-shark (*Rhiniodon typus*),
- Sets made on non-surface schools (i.e., schools detected by the sonar).

The sets reported with an unknown association were not retained in the analysis of the distribution of the fishing modes. Although that logs were classified as natural objects or as artificial ones in a previous study (Ariz et al. 1992), we preferred to classify them with respect to the presence/absence of a radio range beacons (because that has a direct influence on the searching time). Consequently, unclassified logs were redistributed in log sets equipped with a transmitter and log sets without this device, according to their respective proportions observed within each area.

Considering the possibility that any temporal change in the purse-seiners' activities could interact with a spatial effect, the overall fishing ground was divided into seven areas as follows (Fig. 1):

1) Cap Lopez 5° N. - 10° S. / 5° E - 15° E,
2) Ivory Coast-Ghana coastal 5° N - 0° N / 10° W. - 5° E,
3) Ivory Coast-Ghana offshore 0° S - 7° S / 10° W - 5° E,
4) North Liberia 5° N - 0° N / 30° W - 10° W,
5) South Liberia 0° N - 7° S / 30° W - 10° W,
6) Guinée 10° N - 5° N / 30° W - 10° W,
7) Senegal 20° N - 10° N / 25° W - 15° W.

Method

For detecting heterogenity in the percentage distribution of a given variable, during the period analysed, we used the Krumbein and Tukey analysis of variance (Krumbein and Tukey 1956, in Saila 1983). The aim of this method is to compare two periods of time and to determine whether there have been significant differences in the variable proportions between them. For instance to compare the proportions of each fishing modes among the areas between two periods, let

$$X_{ikm} = \mu + A_i + S_{ik} + T_m + AT_{im} + ST_{ikm}$$

where,

X_{ikm} = percentage observed at period i, fishing mode k and area m,
μ = mean of all percentages,
A_i = effect of the i th period thought to influence X_{ikm},
S_{ik} = effect of the k th fishing mode in period i thought to influence X_{ikm},
T_m = effect of the m th area thought to influence X_{ikm},
AT_{im} = first order interaction term between periods and areas,
ST_{ikm} = first order interaction term between fishing modes from each period and area within fishing mode.

In this type of analysis, only the interaction mean squares between areas and fishing modes (i.e., the sampling levels described by Saila 1983) are of interest. The F ratio of periods x areas to the fishing modes within periods x areas interaction is used to test the hypothesis that variability in area proportions between periods is not significantly greater than that within fishing modes at each periods.

Using the Saila's notation, let:

$$F = \frac{[\, SS4 / (I-1)\,(M-1)\,]}{[\, SS5 / I\,(K-1)\,(M-1)]}$$

with I = number of periods, M = number of areas, K = number of fishing modes.

$$SS4 = [(\Sigma_{IKM}\, X_{ikm})^2 / IKM] + [\Sigma_{IM} (\Sigma_K X_{ikm})^2 / K] - [\Sigma_I (\Sigma_{KM} X_{ikm})^2 / KM] - [\Sigma_M (\Sigma_{IK} X_{ikm})^2 / IK]$$

$$SS5 = [\Sigma_I (\Sigma_{KM} X_{ikm})^2 / KM] + [(\Sigma_{IKM}\, X_{ikm})^2] - [\Sigma_{IK} (\Sigma_M X_{ikm})^2 / M] - [\Sigma_{IM} (\Sigma_K X_{ikm})^2 / K]$$

In order to detect whether a change occurs in a given year, four sets of two periods were successively created as follow: 1991 vs 1992-1995; 1991-1992 vs 1993-1995, 1991-1993 vs 1994-1995, and 1991-1994 vs 1995. Considering that 4 comparative tests are made simultaneously, each individual F value is checked at the Bonferroni corrected α', where $\alpha' = \alpha/4$. The statistical procedure results in a decision to either reject the null hypothesis (H0) or not reject it. The statistical power of a test $(1-\beta)$ is the probability of correctly detecting a specified effect, if that effect exists. This parameter is a function of α (the probability for making a type I error, i.e., to reject H0 when it is true), the effect size and the sample size/sample variance. The easier way for controling β (the type II error, i.e., to not reject H0 when it is false) consists in accepting an increase in α, thus, an overall type I error of 0.10 was chosen.

RESULTS

Changes in the purse-seiners' activities throughout the years.

The results provided by the Krumbein and Tukey analysis of variance did not show significant changes in the spatial distribution of the fishing modes or in the spatial distribution of the catches of the commercial categories (Tab. 1). This type of analysis would not be powerful enough to detect gradual changes between years (i.e., the great variability observed between areas could mask these changes). The only significant temporal change (at a 0.1 level) was found in the distribution of commercial category catches between 1991 and 1995 (especially for the size categories 2 and 3, Tab. 2). The percentage in catch of medium fishes decreased in the coastal Ivory Coast-Ghanean area (from 21% to 13 %), but increased in the Guinean area (from 4 % to 22%). For the large fishes, the percentage in catch realized in the offshore Ivory Coast-Ghanean area was approximately multiplied by five (11% to 51 %). In other words, in 1995 half of the catches of large tunas were made in this area. In contrast, there was no apparent change in the spatial distribution in catch for the juveniles.

In spite of this apparent stability, gradual changes in some activities can be observed throughout those five years (Tab. 3 and 4). Although the overall nominal fishing effort developped by the purse-seiners in the Atlantic Ocean stayed stationary at 200,000 fishing days per year, its spatial distribution varied over the years (Tab. 3). The fishing effort was partially relocated from the Liberian areas (areas 4 and 5) to the Ivory Coast-Ghanean offshore area (area 3). Consequently, the sharp increase in catch of large fishes observed in this last area may be explained by (a) a related increase in fishing effort, and (b) by the fact that 40% of the non-associated school sets (the main fishing mode associated with large tunas) were made in this area (Tab. 4).

By contrast, the relocation of the nominal fishing effort did not produce significant changes in the spatial catch distribution of the small size category. Likewise, around 20% to 25% of fishes lower than ten kilograms continued to be caught by the purse-seiners in the Northern Liberian area, in spite of the reduction of the fishing effort (approximately, from 25 % to 13 %). This could be partialy explained by the relative importance of log sets made in this area (Tab. 4). The other major area for the production of small tunas was the coastal Ivory Coast-Ghanean area (Tab. 3).

Considering now the main fishing modes, it appeared that (Tab. 4);
- sets associated with logs not equipped with a transmitter were made in majority in the area 1 (Cap Lopez) and, in the recent years, in the area 2 (Ivory Coast-Ghanean coastal area);
- sets associated with logs equipped with radio range beacons were located in the area 2, in the area 4 (Northern Liberia) and, more recently, in the area 3 (Ivory Coast-Ghanean offshore area). This recent importance of the area 3 can likely be attributed more to an increase of the fishing effort in this area (Tab. 3) rather than in a change in the harvesting practices within this area.
- the greater percentage of school sets were made in the area 7 (Senegal), in the area 4 (until 1993), and in the area 3 (after 1993).
- sets associated with whales were made mainly in the areas 1, 2 and 3 (from Cap Lopez to Ivory Coast-Ghana);
- Ninety percent of sets associated with whale-shark were concentrated in the Cap Lopez area.

The use of log sets in the Atlantic Ocean concerned the introduction of radio range beacons to locate the logs as well as the extension of the fishing ground to the western offshore area (Ariz et al. 1992). Among the sets in which the fishing mode was clearly reported in the logbook, the use of logs equipped with a transmitter showed a strong seasonality (Fig. 2). This fishing mode was dominant during the months of November, December and January. The seasonal pattern of the use of logs not equipped was not so marked and its maximum was observed in late summer or at the beginning of fall.

During the recent years, the proportion of sets made under logs equipped with a transmitter has increased by 22 %, whereas the proportion of sets associated with all types of logs increased only by 5% (Tab. 5). This suggests that natural or artificial logs were progressively substitued by logs equipped with radio range beacons (another possibility could be an improvement of the report of this device in the logbooks). In spite of the increase in proportion of sets made under logs equipped with a trasmitter, there was no evidence of a correlated increase in catches of the small size category.

To compare the yearly spatial distributions of the catch size categories and the yearly spatial distributions of the different activities (e.g., between the subtable "Size category 1", in table 3, and the subtable "Logs with transmitter", in table 4), we used the Krumbein and Tukey' F statistic. Only the test between the distribution of the nominal fishing effort and the distribution of the catch of the first size category was not significant at a 0.05 level (Tab. 6). This suggests the existence of a strong proportionality between the catch of small tunas and the fishing effort exerted in a given area. At first glance this result is obvious, but it can be argued that it was not the case for the size categories 2 and 3. This does not mean that the spatial distribution in catches of these two categories were independent of the spatial distribution of the effort, but that they were also related to other factors.

To assess the proximity between each size category's subtable and the different activities' subtables, we used the absolute value of the F's statistic. The salient result concerned the apparent lack of relationship between the spatial distribution in catch of the small tunas and the spatial distribution of the sets equipped with radio range beacons (Fig. 3). The only direct relationship between the use of logs equipped with radio range beacons and the catch of small tunas was maybe observed in the Northern Liberian area. As mentioned, in this area the reduction of the fishing effort was not followed by a decrease in catch of juveniles, likely because around 30 % of the sets continued to be made made on logs equipped with a transmitter (Tab. 4). Another important point to keep in mind is the fact that in some areas small tuna schools were also found in school sets (e.g., the skipjack schools in the Senegalese area). On the other hand, the discrepency observed between the spatial catch distribution of the different size categories and the repartition of sets not equipped with a transmitter appeared coherent. The occurrence of those sets (likely, made under natural logs) depend on the relative proximity of the great western African rivers (for instance, the Zaire river in the case of the Cap Lopez area, etc,). The similitud observed in the spatial proportion of the catches of large tunas and the spatial proportion of sets made under logs, equipped with a transmitter, highlights the difficulty to manage this mixed-species fishery.

The development of the utilization of the sonar has been assumed to be as one of the causes that could explain the recent increase in bigeye catches. Although it was not easy to check this assumption from data collected in logbooks, it appeared, however, that only one percent of the tuna schools were detected with the aid of this fishing equipment. In the same way, the usefulness of the sonar during the setting operation can not be correctly assessed from logbook information.

The stratum chosen to the closure of the log fishery.

In order to reduce the fishing mortality exerted on the juveniles, a general agreement made by the Spanish and the French purse-seiner fishermen decided to create a spatial-temporal stratum where log sets will not be authorized. This stratum (called "area X" in the present analysis) will be effective from November 1997 to January 1998, within an area delimited from 5° N to 4° S and from 20° W to the African coasts in the East. How this stratum is important (a) with respect to the mixed-species management of tropical tunas (especially for reducing the mortality on the juveniles), and (b) in terms of the economical sustainability of this fishery, can be tentatively evaluated by comparing the proportion of the main activities developped by the purse-seiners during the recent years.

The spatial-temporal stratum chosen by the purse-seiner companies, for stopping fishing operations associated with logs, corresponds to the major area and to the major season of this fishing mode (Fig. 4). This stratum represented approximately 36 % of the amount of log sets made by the purse-seiner fishery in the Atlantic Ocean. Among the sets with an association clearly identified in the logbooks, the percentage of sets made on a log equipped with a transmitter increased from 26% in 1991 to 57 % in 1995 (Tab. 5).

Although only 21 % of the yearly purse-seiner fishing effort was allocated in this stratum, the percentage in catch of the fishes less than ten kg. varied from 25 % to 30 % (Tab. 7). At the same time, the percentage of large fishes caught in this stratum increased from 8 % to 22 %). As mentioned, it is likely that this change was related to the increase in percentage of the school sets (i.e., non-associated schools) realized within the "Ivory Coast-Ghanean offshore area" in 1994-1995. The proportion of the amount of logs sets made in the stratum X, with respect to the Atlantic Ocean, showed only a weak increase. However, although that the proportion of the nominal fishing effort exerted in this strata, with respect to the Atlantic Ocean, stayed constant (around 21 %, as mentioned), the proportion of all types of sets made in this stratum increased by 9 % (from 18 % to 27 %, Tab. 7).

CONCLUSION.

Judging from these percentages, there was no clear evidence that the significant increase in sets on logs equipped with a transmitter led to a correlated increase in the catches of the small size category (excepting maybe in some areas, as in the Northern Liberia).

This suggests the following assumptions:

- the total number of log sets increased slowly, because the logs equipped with radio range beacons could have partially substituted the logs not equipped. It can be noted, nevertheless, that in such a situation the searching time to locate a log would be reduced (i.e., resulting in an increasing fishing power of the vessels);

- the changes in the spatial distribution of the fishing effort could be as many important as the use of logs equipped with a transmitter to explain the increase in the catches of juveniles (i.e., the relocation of the fishing effort in areas where large yellowfins as well as juveniles of tunas are abundant);

- In the present analysis, the apparent lack of relationship between the spatial distribution of the catch of the small tunas and the spatial distribution of sets made under logs equipped with transmitter (maybe with the exception of the Northern Liberian area) could be due to some causes. For instance, (a) the fact that the small size commercial category could be not representative of the true proportion of juveniles (i.e., the proportion of fishes less than 3 kg), and (b) by the time scale used in the present analysis (i.e, a quarterly scale could be more appropriate);

- the increase in the catch of juveniles for a given species (e.g., bigeye) could be masked by the decrease in catch of juveniles for the others (e.g., skipjack and yellowfin);

It is not easy to draw a clear conclusion from these results. Some questions remained without answers. Why was there not clear causal influence between the increase of sets on logs equipped with a transmitter and the catches of juveniles, as it is usually suspected, or why did an important percentage of fishes under ten kilograms continue to be caught in the northern Liberian area (i.e., was the log fishing mode only the explanation of that) ?

From a rational point of view, it is obvious that in order to reduce the mortality of juveniles, as well as to limit incidental catches, the purse-seiner fishery must control the amount of sets on logs, especially sets on logs equipped with a transmitter (including the use of supplies). Nevertheless, to be effective in such a regulation, it is important to consider that for the purse-seiner fishery the major interests of the fishing operation on logs are (a) the reduction of the daily variability in catch rates (sets on logs have a good probability of success and, on average, produce bigger catch per set than school sets), and (b) the increase in catchability when environmental conditions are bad (e.g., the deepening of the thermocline such as in 1984, etc.,). It is interesting to point out that when the different stocks were moderately exploited, such as in the 1980s, an increase of the log fishery was not considered to produce negative change in the yield per recruit of the three main species of tropical tunas (Ariz et al. 1992).

With the above considerations in mind, we suggest than different managements scenari could be attempted. Instead of prohibiting the use of logs, an alternative could be a year-to-year authorization of this fishing mode depending upon some conditions (e.g., the type of the logs, the size of the stocks and the environmental factors). This type of harvest srategy could contribute to a better management of the epipelagic ecosystem and would take into account the interests of the fishermen.

Although this paper was focused on the effect of the log sets on the mortality of juveniles, it is evident that, to be effective, regulations must be shared between the different fishing gears exploiting the tropical tunas. If reducing growth overfishing must be encouraged, reducing total catches must be also considered as an objective. For instance, in the case of the bigeye tuna, it is important to bear in mind that purse-seiners' catches represent only 21 % of the total catch. The major catches of this species are made by long-liners (57%) and by baitboats (22 %).

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Table 1. Results of the Krumbein and Tukey analysis of variance used to assess change in the spatial distribution of the variables of interest between two periods of time. The F values for the simultaneous tests were checked at the Bonferoni corrected level ($\alpha' = 0.025$). The individual F for the comparison between 1991 and 1995 was checked for $\alpha = 0.10$. NS = non significant; * = significant at the 0.10 level.

Spatial change in	Periods	F observed	
Fishing modes	91 / 92-95	0.314	NS
	91-92 / 93-95	0.647	NS
	91-93 / 94-95	0.673	NS
	91-94 / 95	0.468	NS
	91 - 95	0.875	NS
Size categories catch	91 / 92-95	0.981	NS
	91-92 / 93-95	1.373	NS
	91-93 / 94-95	1.696	NS
	91-94 / 95	1.337	NS
	91 - 95	2.180	*

Table 2. Comparison of the percentage spatial distribution of the three commercial size categories of tunas caught by the purse-seiners in 1991 and in 1995.

Year	Area	Cat 1	Cat 2	Cat 3
91	Cap Lopez	9.78	17.76	3.34
	IC-Ghana coastal	21.05	20.53	18.01
	IC-Ghana offshore	6.40	8.57	10.79
	North Liberia	26.33	15.11	29.61
	South Liberia	12.44	15.35	32.20
	Guinea	4.04	4.45	4.48
	Senegal	19.96	18.22	1.57
95	Cap Lopez	6.93	14.61	4.27
	IC-Ghana coastal	21.13	12.97	17.61
	IC-Ghana offshore	14.98	12.14	51.20
	North Liberia	23.56	13.15	7.79
	South Liberia	5.86	9.93	3.71
	Guinea	9.54	21.95	13.11
	Senegal	18,00	15,25	2,29

Table 3. Changes in the percentage spatial distribution of some fishery patterns for the purse-seiner fishery in the Atlantic Ocean from 1991 to 1995.

	Area	91	92	93	94	95
Nominal effort	Cap Lopez	9.59	8.30	7.13	6.99	7.92
	IC-Ghana coastal	23.66	26.97	29.03	20.78	21.91
	IC-Ghana offshore	8.29	12.05	10.56	19.68	21.88
	North Liberia	23.72	28.69	20.25	11.78	13.59
	South Liberia	11.81	10.06	6.95	8.07	4.79
	Guinea	5.31	3.38	3.85	7.76	9.91
	Senegal	17.63	10.54	22.22	24.96	20.00
Size category 1 < 10 kg	Cap Lopez	9.78	7.44	8.72	6.73	6.93
	IC-Ghana coastal	21.05	29.10	24.04	24.62	21.13
	IC-Ghana offshore	6.40	8.22	8.05	11.33	14.98
	North Liberia	26.33	29.57	24.34	20.08	23.56
	South Liberia	12.44	11.23	10.42	8.43	5.86
	Guinea	4.04	3.57	4.55	8.90	9.54
	Senegal	19.96	10.88	19.88	19.90	18.00
Size category 2 10 - 30 kg	Cap Lopez	17.76	22.80	16.92	15.77	14.61
	IC-Ghana coastal	20.53	19.58	24.26	22.76	12.97
	IC-Ghana offshore	8.57	8.59	15.15	13.32	12.14
	North Liberia	15.11	27.24	17.86	12.90	13.15
	South Liberia	15.35	10.50	9.43	13.20	9.93
	Guinea	4.45	4.21	3.84	11.96	21.95
	Senegal	18.22	7.07	12.55	10.09	15.25
Size category 3 >= 30 kg	Cap Lopez	3.34	4.49	6.89	4.27	4.27
	IC-Ghana coastal	18.01	24.86	36.56	11.54	17.61
	IC-Ghana offshore	10.79	20.54	18.86	43.47	51.20
	North Liberia	29.61	32.37	25.88	6.07	7.79
	South Liberia	32.20	14.12	8.98	20.00	3.71
	Guinea	4.48	1.09	0.86	10.99	13.11
	Senegal	1.57	2.55	1.95	3.66	2.29

Table 4. Changes in the percentage spatial distribution of the main fishing modes for the purse-seiner fishery in the Atlantic Ocean from 1991 to 1995.

	area	91	92	93	94	95
Logs not equipped	Cap Lopez	56.74	46.96	37.74	47.64	36.33
	IC-Ghana coastal	19.75	15.47	19.97	29.30	27.54
	IC-Ghana offshore	3.13	8.84	6.13	13.80	12.30
	North Liberia	10.97	15.19	21.54	3.78	7.62
	South Liberia	3.45	6.08	6.13	2.08	1.56
	Guinea	3.29	1.10	6.76	0.95	8.40
	Senegal	2.66	6.35	1.73	2.46	6.25
Logs with a transmitter	Cap Lopez	3.04	2.56	2.29	2.30	1.67
	IC-Ghana coastal	21.89	27.94	26.96	27.24	30.60
	IC-Ghana offshore	8.20	7.37	10.29	15.70	18.88
	North Liberia	34.84	42.47	33.86	27.13	29.05
	South Liberia	16.18	13.45	15.20	14.06	7.99
	Guinea	12.28	3.84	7.03	9.68	8.74
	Senegal	3.56	2.36	4.37	3.91	3.07
School sets	Cap Lopez	13.87	10.86	10.63	9.43	9.29
	IC-Ghana coastal	13.70	20.48	19.86	7.27	13.79
	IC-Ghana offshore	8.67	12.86	9.02	29.94	39.80
	North Liberia	21.09	30.25	24.78	6.06	6.86
	South Liberia	16.53	10.71	4.56	10.78	2.34
	Guinea	2.68	2.33	1.16	4.43	9.66
	Senegal	23.46	12.52	29.99	32.08	18.27
Whales	Cap Lopez	25.94	50.32	30.71	33.16	38.43
	IC-Ghana coastal	29.93	25.16	34.65	8.42	24.25
	IC-Ghana offshore	2.74	13.38	18.90	34.21	22.39
	North Liberia	11.72	8.28	4.72	6.84	6.34
	South Liberia	1.50	0.64	1.18	1.05	1.49
	Guinea	2.74	2.23	0.00	6.32	2.61
	Senegal	25.44	0.00	9.84	10.00	4.48
Whale-sharks	Cap Lopez	88.75	89.81	85.19	96.08	95.07
	IC-Ghana coastal	1.25	2.78	0.00	0.00	0.60
	IC-Ghana offshore	1.25	6.48	2.78	2.94	2.09
	North Liberia	5.00	0.00	0.00	0.00	0.45
	South Liberia	0.00	0.00	0.00	0.00	0.00
	Guinea	0.00	0.00	0.00	0.00	1.49
	Senegal	3.75	0.93	12.04	0.98	0.30

Table 5. Yearly changes in the proportion of log sets with respect to the total sets (reported with an association) in logbooks.

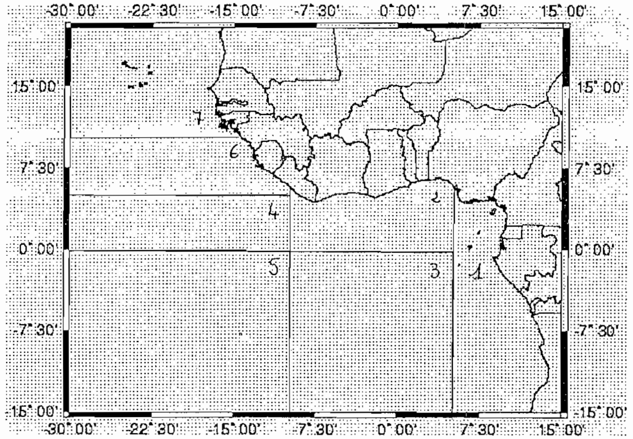
	Atlantic Ocean		Stratum X	
	Logs with tr.	Total logs	Logs with tr.	Total logs
91	11.57	38.51	26.10	71.68
92	18.80	39.63	27.20	57.35
93	13.72	38.98	27.58	64.91
94	25.73	40.48	42.44	56.02
95	34.25	43.80	56.92	65.41

Table 6. Results of the Krumbein and Tukey analysis of variance used to compare the percentage spatial catch distributions of the commercial categories and different purse-seiner's distribution activities. For a F (6,48): NS = non significant; * = significant at the 0.10 level; ** = significant at the 0.05 level; *** = significant at the 0.01 level.

Catch distribution	Activity	F observed	
Size category 1	Effort	1.208	NS
	Logs non eq.	25.855	***
	Logs with tr.	14.163	***
	School sets	2.495	**
Size category 2	Effort	3.052	**
	Logs non eq.	10.068	***
	Logs with tr.	14.163	***
	School sets	2.290	*
Size category 3	Effort	4.257	***
	Logs non eq.	11.790	***
	Logs with tr.	2.976	**
	School sets	3.843	***

Table 7. Yearly changes in proportion of sets made in the stratum X with respect to the total Atlantic Ocean.

Year	All sets known	Logs not eq.	Logs with tra.	All Logs	Catch Cat. 1	Catch Cat. 2	Catch Cat. 3	Effort
91	18.16	6.01	40.98	33.80	30.69	16.65	8.22	20.31
92	22.10	23.89	31.99	31.98	26.04	13.84	19.12	20.99
93	21.99	22.00	44.21	36.62	26.43	20.64	13.20	21.66
94	25.76	10.22	42.48	35.64	24.77	17.38	22.05	20.97
95	26.82	12.61	44.58	40.06	31.04	16.48	21.87	21.75



1) Cap Lopez
2) Ivory Coast-Ghana coastal
3) Ivory Coast-Ghana offshore
4) North Liberia
5) South Liberia
6) Guinée
7) Senegal

Figure 1. Map showing the different areas used in this study.

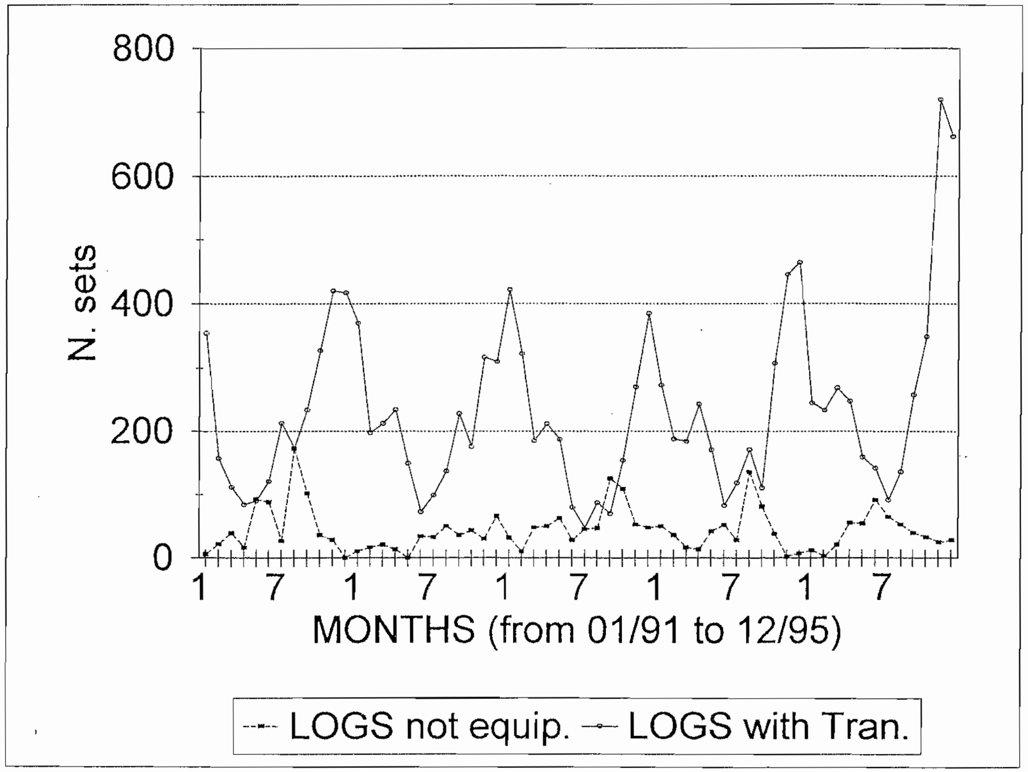


Figure 2. Monthly evolution of the number of sets made under logs (logs not equipped with radio range beacons and logs equipped) for the purse-seiner fishery from 1991 to 1995 (when the fishing mode was clearly identified in logbooks).

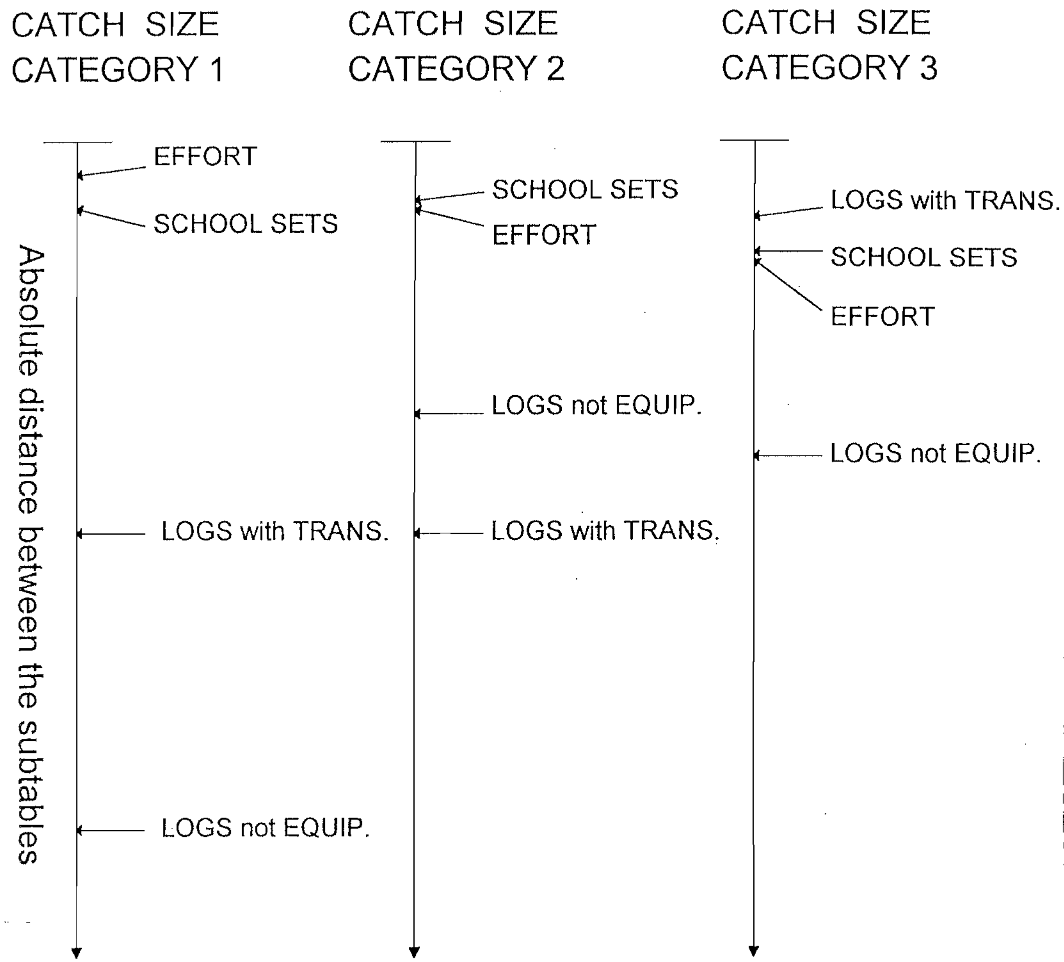


Figure 3. Schematic representation of the proximity between the spatial distribution of the catches of the commercial categories and some purse-seiners' distribution activities (based on the absolute value of the Krumbein and Tukey's F statistic in Table 6).

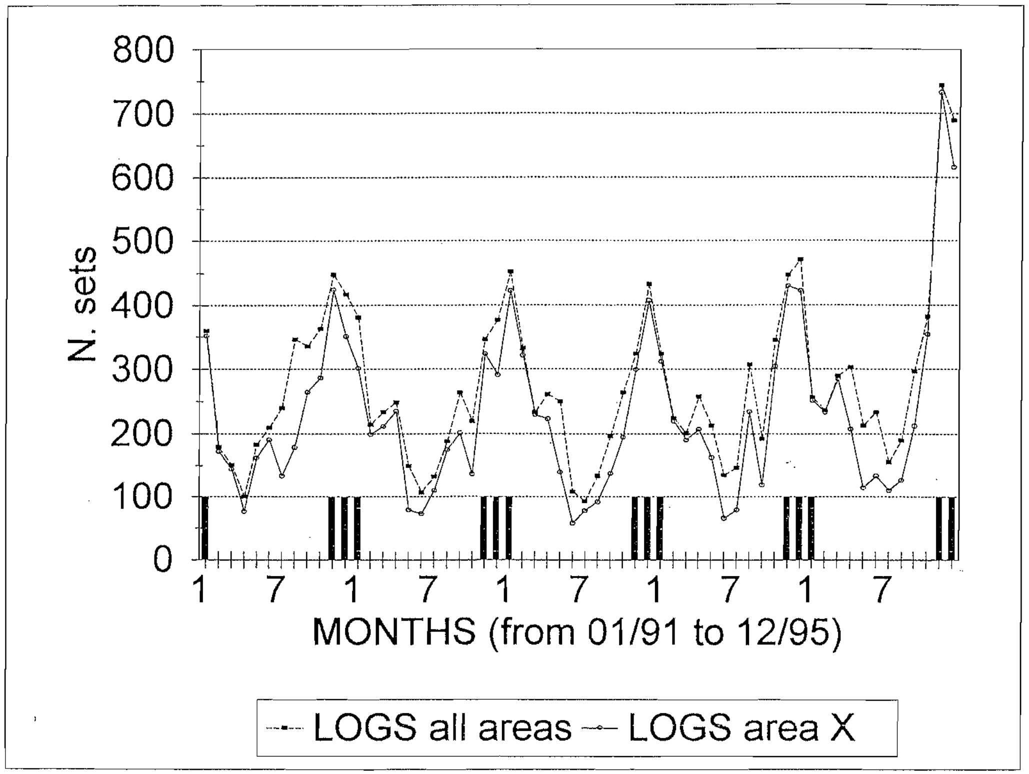


Figure 4. Monthly evolution of the number of sets made under all types of logs in the stratum X and in the whole Atlantic Ocean for the purse-seiner fishery from 1991 to 1995 (when the fishing mode was clealy identified in logbooks). The months of November, December and January, corresponding to the closure of the log fishery, are represented with bars.