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SPACE-TIME PATTERNS IN THE FRENCH AND SPANISH PURSE SEINE FISHERY FOR YELLOWFIN TUNA IN THE EASTERN ATLANTIC

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SUMMARY

Examination of space-time patterns to yellowfin tuna fishing by FISM and Spanish large seiners revealed seasonal patterns, but no clear disruption of pattern that could explain the large increase in catch by the Spanish fleet and the large increase in overall effective effort. However, there was evidence that Spanish seiners were fishing on smaller fish in 1981. Based on evidence presently at hand, the status of the yellowfin stock of the eastern Atlantic relative to maximum sustainable yield is uncertain. The need for careful monitoring is underscored by these recent developments.

RESUME

L'examen des modes spatio-temporels de la pêche à l'albacore par les grands senneurs FISM et espagnols a permis de discerner des modes saisonniers, mais aucune solution brusque de continuité susceptible d'expliquer la forte augmentation des prises de la flottille espagnole et le fort accroissement de l'effort effectif global. L'évidence indique néanmoins que les senneurs espagnols pêchaient de plus petits poissons en 1981. Selon les éléments de preuve actuellement disponibles, l'état du stock d'albacore de l'Atlantique est est incertain quant à son rendement maximum équilibré. Les récentes découvertes soulignent le besoin de suivre la question de près.

RESUMEN

El examen de las pautas espacio-temporales de la pesca de rabil efectuada por FISM y los grandes cerqueros españoles, reveló que existían pautas estacionales, pero no una clara ruptura de dicha pauta que explicase el gran incremento en la captura de la flota española y en el esfuerzo efectivo global. Sin embargo, existía evidencia de que los cerqueros españoles en 1981 pescaban peces más pequeños. En base a la evidencia actual, la condición del stock de rabil del Atlántico oriental con respecto al rendimiento máximo sostenible, es incierta. Estos últimos acontecimientos subrayan la necesidad de una cuidadosa vigilancia.

INTRODUCTION

In 1981 Spanish purse seine catches of yellowfin tuna (Thunnus albacares) increased to 50,000 mt, 49% over that of 1980 (ICCAT 1983). This contributed to an increase of 15% in the overall yellowfin catch of the eastern Atlantic and a remarkable 50% increase in the calculated effective fishing effort. The total effective fishing effort is calculated using the French (FISM=France, Ivory Coast, Senegal and Morocco) catch per unit effort (CPUE) index, which is the average CPUE per 1° square and 15 days of fishing of the FISM fleet (Fonteneau and Cayre 1983). This procedure assumes the FISM CPUE is a consistant index of relative population size over the entire eastern Atlantic fishery. Even though the 1981 total catch did not rise greatly, the jump in effective effort has much effect on the interpretation of catch-effort curves relative to the assessment of the eastern Atlantic yellowfin stock. Thus, Fonteneau and Diouf (1983) suggested that present fishing effort may greatly exceed that for obtaining maximum sustainable yield (MSY), with present catches possibly much above equilibrium catches.

If this strong increase in effective effort from 1980 to 1981 is real, it is unprecedented in the fishery. The FISM CPUE index for 1981 was 1.33 mt/day, 22% of that in 1969. If this relatively low catch rate is representative of the fishing grounds, it seems unlikely it would provide sufficient inducement to generate within one year a 50% increase in fishing effort to yield only a 15% increase in yield. The 1979 and 1980 CPUE's were somewhat higher, ca. 30% of the 1969 value, but no large increase in effort occurred then. If the Spanish fleet enjoyed a higher catch rate to induce its own 49% increase in catch, then this would suggest that the FISM CPUE, which showed no increase in 1981, is not representative of the overall fishing grounds.

The most likely reason the FISM CPUE index might not represent the overall stock density is that there has developed a sufficient space-time mismatch among FISM and other fleets so that the FISM CPUE no longer consistantly tracks the changes in the entire population, and the fish do not mix over the grounds fast enough to overcome this effect. This can be appreciated by realizing that total catch divided by a CPUE index to obtain effective effort is most appropriate when the catch and effort involved are both generated simultaneously by the same fishing operations. This paper examines the space-time patterns of the FISM and Spanish purse seiners to see if there are differences that might lead to nonrepresentativeness of the FISM CPUE. Such errors may be a matter of precision rather than bias. It should be noted that the multiplication factor for obtaining effective effort from CPUE and total catch is 1/CPUE, so that for a given catch and percent error in CPUE, the deviations among possible values of effective effort increase rapidly as CPUE decreases.

METHODS

The eastern Atlantic was divided into six subareas (Figure 1), and the yellowfin statistics, by annual quarter, of catch, effort, and CPUE from large purse seiners (PSG) were examined in each. The years 1978 to 1981 were studied, comparing the FISM and Spanish fleets. In recent years, most FISM caught yellowfin have been taken by PSG seiners (Fonteneau and Cayre 1983). Catches per 1° square per quarter that exceeded 50 mt were plotted to discern the changes in fishing pattern through time. Additionally, changes in size of fish caught among the two fleets were examined. These data were tabulated from ICCAT Data Records. Finally a production model analysis of the 1970-1981 catch-effort data was conducted, using PRODFIT (Fox 1975).

RESULTS

It was found that areas III and VI were not important relative to the total catches for both fleets. Therefore, only the trends in areas I, II, IV, and V will be further discussed. Notice that areas I and II comprise the traditional coastal areas from which the FISM CPUE index of the coastal zone is generated (see Fonteneau and Diouf 1983). An overview of the space-time trends in the FISM and Spanish fisheries is presented in Table 1. For clarity, only the important quarters of the year by area and year, for catch and effort, are presented, without the statistics. It was found that the biggest change in fishing occurred in 1981 (Table 1, Comments). It may be noted that areas I and II are primarily summer (quarters 2 and 3) fishing grounds in nearshore waters and areas IV and V are primarily fall-winter grounds offshore (quarters 4 and 1). This is also shown in Figures 2 and 3 which map the 1978-81 seasonal pattern to catches greater than 50 mt per 1° square and quarter.

As noted above and in Table 1, the main change in fishing occurred in 1981. In area I, the Spanish fleet increased its catch and effort during quarter 3 compared to 1980. Its average catch per 1° square was also higher. In area II, Spain had an overall good year with higher than average catches and average catches per 1° square, while FISM had a relatively poor year. In area IV, Spain increased its catches strongly during quarter 1 and extended good catches into quarter 2, though total catches were still less than that of FISM. In area V, Spain had very strong catches during the first quarter and its catches and catch rate were larger than that of FISM, as is usually true for this area. These 1980-81 statistics and changes are summarized in Tables 2 and 3. Table 3 gives the overall annual 1981:1980 ratios of catch, effort, and CPUE by area and fleet.

It can be seen that in 1981 FISM increased total annual fishing effort in areas IV and V while Spain increased effort in areas II, IV, and V. FISM appeared to de-emphasize area II, while Spain emphasized area IV, even though its catches in that area are usually less than that of FISM, as was the case in 1981.

The large increase in Spanish catches in 1981 also appeared to be associated with a decrease in size of fish caught. Length-frequency data from Data Records 20 and 21 (ICCAT, 1979, 1980) were used to examine the catch composition. This is summarized in Table 4 which gives for 1980 and 1981 for the FISM and Spanish fleets the cumulative fraction of the total catch by number up to 50, 60, 70, and 80 cm fork length. The largest change occurred in the Spanish catch in ICCAT area SBY2 where e.g. fish $\leq$ 50 cm accounted for 22% of the catch in numbers in 1980, but 67% in 1981. SBY2 had a similar though less marked trend. These ICCAT areas cover the main fishing grounds of areas I, II, IV, and V of this study. The FISM catch, designated only as from the eastern tropical Atlantic (ETRO) did not show a decrease in size. Because these data are raised from length samples to the total catches, errors may be multiplied. However, comparing these cumulative fractions between 1980 and 1981, there can be little doubt that a shift to smaller fish occurred in the Spanish, but not the FISM, catch. This was also pointed out by Pallares et al. (1983). They presented data showing an increase of age 1 fish in the Spanish catch from 79% in 1980 to 86% by number in 1981, representing a very large increase in small fish caught.

EFFECTS ON THE YIELD CURVE

A production model curve was fitted to the yellowfin catch and effort data from the eastern Atlantic. The catches (total surface plus longline, ICCAT 1983) show a drop in 1982 from 123.1 to 111.4 thousand MT (1982 value is preliminary). The CPUE indexes used to estimate effective effort are from Fonteneau and Cayre (1983); these indexes have continued to decline (Table 5), and the coastal index was estimated to be 1.16 in 1982 (ICCAT Report 1983). Since their CPUE indexes, for the traditional coastal zone and for the overall eastern Atlantic, are very similar, an arithmetic average of the two was used in this paper.

The production curve was fitted to these data for the years 1970 to 1981, using the Fox PRODFIT, (1975) procedure with shape parameter m=1. Effort equal to the average effort during the previous 3 years was used to approximate equilibrium conditions in fitting the curve. Some reasons why m=1 should be a good estimate of the true relationship of CPUE or equilibrium catch to effort were given by Au (1982). Because of the possibility of error in the data, particularly in effective effort, the above procedure was additionally modified to include errors of 5 percent in the catch and effort values. The procedure used a Monte Carlo process to generate a series of random catch-effort vectors with the errors uniformly distributed. Thus large and small errors were made equally likely so that the maximum effect of errors on production estimates could be examined.

The results are summarized in Table 5. MSY and optimal fishing effort averaged 110×10^3 MT and 67×10^3 days fishing, 3% and 7% lower respectively than previous estimates (Au, 1983). This was because an additive error model was used (Fox 1975); the multiplicative error model could not be used because it weights the 1981 anomalous data point strongly enough that non-negative slopes are acquired, in some cases, to the regressions of CPUE on effort. Similarly, even with the additive error model, PRODFIT would not continue if a 10% error in catch and effort were invoked.

These results provide a yield model similar to those previously generated. The calculations underscore that the 1981 data point is anomalous. If the 1982 data point is similar to that of 1981 and both are considered valid, the production curve will be significantly altered toward a higher MSY at a higher level of fishing effort. The 1982 production curve (ICCAT Report 1983) was also computed from the 1970-1981 data; because of effort averaging of observations that were equally weighted, the effect of the anomalous 1981 data point was reduced in that exercise.

DISCUSSION

There are differences in the fishing patterns of FISM and Spanish fleets, but these differences do not appear to deviate significantly from the general fishing pattern of each fleet. Both fleets show seasonal changes: offshore during the fall and spring and nearshore during the spring and summer. These movements may be related to weather as they are on the eastern Pacific tuna grounds. In the eastern Atlantic, the offshore fishery may develop as the strong southerly winds of the summer monsoon decline in areas IV and V. It is interesting to note too that on these offshore grounds, fishing is better north and south of the equator, just as is the case in the eastern Pacific.

The large increase in Spanish catch in 1981 was due to increases in areas II, IV, and V which accounted for 99% of the increase in the 4 areas considered. The largest increase was in area V (40%). Meanwhile, the FISM fleet decreased its total annual catches by 14% due to a 59% decrease in area II. It appeared that both fleets were emphasizing the offshore areas in 1981, and Spain may intend to emphasize most strongly area V where its catches are often better than that of FISM. It may be noted that the main area of offshore fishing south of the equator is in area V for Spain while it is in area IV for FISM (Figures 2 and 3).

These differences in catches by area and fleet do not in themselves provide a good explanation for the large increase in the 1981 effective fishing effort. If the FISM CPUE index is inaccurate in 1981, it could be due to a change in pattern of fishing within the fleets such that the consistency of the FISM CPUE is disrupted when applied to the entire fishery. The changes described above seem more a matter of changed emphasis within the fishing pattern of each fleet. Moreover, the general pattern is similar between fleets (Figures 3 and 4). Thus, a mismatch between the overall FISM CPUE and that experienced by the Spanish is not obvious. An underestimate of CPUE in 1981 to produce an overestimate of effective effort may therefore simply be a matter of imprecision. On the other hand, there was a significant increase in small fish taken by the Spanish, but not the FISM. Perhaps this means the Spanish fleet is emphasizing fishing on a different segment of the stock, a segment not strongly exploited by the FISM fleet. If so the effect would be similar to expanding the fishery onto new grounds or stocks.

If expansion of exploitation onto underexploited segments of the stock is occurring, a new limb to the production curve will be generated. Production curves should be viewed as a series of successive curves, each characterized by a lower catch rate (i.e. CPUE), that reflect the expansion of a fishery from smaller, highly productive portions of a stock to more extensive, lower productive or less available portions. Since the fishing rate (CPUE) would be expected to drop off more rapidly on the former portions and less rapidly on the latter portions of the stock, the trend of CPUE with effort would decline with upward curvature. This is just another reason for considering that production curves with shape parameter m=1 are reasonable for all but the most simple, homogeneous populations. If that is the case, the eastern Atlantic yellowfin population is still underexploited.

From the evidence presented, it must be concluded that the eastern Atlantic yellowfin tuna population is presently being fished near MSY, with some possibilities for expansion that may now be occurring. But it should be noted that total catches are no longer increasing rapidly (see Table 5). If expansion is occurring, the stock should be "healthy." If not, the FISM CPUE for 1981 is probably underestimated. A small underestimate can give rise to a large increase in calculated effective effort. Thus, a 10% error in CPUE when it was 6.17 (in 1969) produces a range of 0.03 in the catch-multiplication factor (1/CPUE), but when the CPUE is 1.33 (in 1981), this range is .15, a fivefold increase. In any case, present catches may not be greatly above equilibrium catches. Nevertheless, one must agree with Fonteneau and Diouf

(1983) that the population must be carefully monitored. This is especially so because the fishing patterns of the fleets do not indicate that any substantial offshore extension of fishing will occur.

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Table 1. Overview of space-time patterns of yellowfin tuna fishery, France (FISM) vs. Spain, in years 1978-1981.

Area	Year	Fleet	Important* quarter for catches	Comment
I	1978	FIS	2	Catches mainly in quarter 2, but quarter 3 also important to Spain; large Spanish catches in quarter 3 in 1981.
		SP	2 3	
	1979	FIS	2	
		SP	2 3	
	1980	FIS	1 2	
		SP	1 2 3	
	1981	FIS	2 3	
		SP	2 3	
II	1978	FIS	2 3	Good catches in quarters 2, 3; best usually in quarter 3. Quarters 2, 3, important off Cape Lopez; quarters 3, 4 important off Cape Three Points; Spain had good catches during all quarters of 1981 but especially quarters 2, 4. FISM had relatively poor catches in 1981.
		SP	2 3	
	1979	FIS	2 3	
		SP	2 3	
	1980	FIS	2 3 4	
		SP	2 3 4	
	1981	FIS	1 2 3	
		SP	1 2 3 4	
IV	1978	FIS	1 4	Quarters 4, 1 most important. FISM catches are typically much stronger than that of Spanish in this area. This was also true in 1981, though Spanish statistics showed high CPUE's during quarters 1 and 2.
		SP	1 2 4	
	1979	FIS	1 2 4	
		SP	1 4	
	1980	FIS	1 2 4	
		SP	1 4	
	1981	FIS	1 2 4	
		SP	1 2 4	
V	1978	FIS	1 4	Catches primarily in quarters 4, 1, but especially 4. Spain often has better catches in this area that FISM. In 1981, Spain surpassed FISM in all quarters but especially in quarter 1.
		SP	4	
	1979	FIS	1	
		SP	1 4	
	1980	FIS	3 4	
		SP	1 4	
	1981	FIS	1 4	
		SP	1 4	

*based upon relative strength of quarterly catches and effort

Table 2. Catch, effort, and CPUE statistics of French (FISM) and Spanish (SP) fleets by area and quarter for years 1980 and 1981.

Area	Year	Qtr.	Catch[1]		Effort[2]		CPUE[3]	
			FISM	SP	FISM	SP	FISM	SP
I	1980	1	2082	3500	641.4	634.1	1.6	3.3
		2	2029	2394	1023.0	1166.8	1.3	1.0
		3	0	2640	21.1	1389.6	0.0	0.9
		4	830	152	320.1	202.7	1.0	0.4
		Tot.	4941	8686	4805.6	3393.2	1.4	1.9
	1981	1	1836	340	372.8	133.8	1.7	0.7
		2	2856	1551	1033.7	630.6	1.4	1.3
		3	1070	5743	1155.3	1088.2	1.9	3.0
		4	1144	1260	649.5	422.5	0.8	1.3
		Tot.	6906	8894	3211.3	2275.1	1.4	2.4
II	1980	1	4505	1152	1056.5	337.5	2.4	1.5
		2	2161	2490	1255.6	797.8	1.0	2.3
		3	13377	2809	2844.5	716.1	2.9	3.1
		4	5653	4834	1076.3	848.7	3.6	3.4
		Tot.	25696	11285	6232.9	2700.1	2.8	2.9
	1981	1	2813	4156	695.3	580.2	2.0	2.9
		2	3034	5381	1670.4	1189.5	1.0	2.6
		3	3034	3267	2274.0	1197.4	0.9	1.5
		4	1619	4770	832.5	1367.2	0.6	2.5
		Tot.	10500	17574	5472.2	4334.3	1.2	2.4
IV	1980	1	3939	1446	947.3	361.7	1.9	2.5
		2	2138	41	565.1	12.0	1.7	2.0
		3	0	0		4.0	0	0
		4	4490	209	1037.1	93.0	2.9	1.2
		Tot.	10567	1696	2549.5	470.7	2.2	2.3
	1981	1	4083	4158	927.5	279.8	1.8	6.8
		2	6082	4510	530.9	355.0	4.5	11.2
		3	5	0	39.8	2.4	.2	0.0
		4	3545	1573	1632.1	258.2	1.3	1.3
		Tot.	13715	10241	3130.3	895.4	2.9	7.9
V	1980	1	315	2203	278.0	656.5	0.6	1.3
		2	149	112	212.2	56.0	0.2	1.9
		3	4267	217	310.4	11.8	5.8	11.9
		4	2637	4134	594.7	807.5	2.1	2.6
		Tot.	7368	6666	1395.3	1531.8	4.1	2.5
	1981	1	9274	14359	1369.5	1311.7	4.5	4.9
		2	5	402	105.9	112.1	0.0	0.8
		3	10	166	157.3	109.3	0.0	1.8
		4	1477	1608	306.8	672.7	1.8	1.5
		Tot.	10766	16535	1939.5	2205.8	4.1	4.4

[1] metric tons
[2] days fished
[3] figure in total columns is mean CPUE with quarters weighted by catch

Table 3. 1981:1980 ratios of total catch, effort, and mean CPUE, by area and fleet.

		FISM			SPAIN	
Area	Catch	f	CPUE	Catch	f	CPUE
I	1.40	.67	1.05	1.02	.67	1.25
II	.41	.88	.42	1.56	1.61	.84
IV	1.30	1.23	1.30	6.04	1.90	3.39
V	1.46	1.39	1.00	2.48	1.44	1.80

Table 4. Cumulative fractions of total catch to successive fork lengths.

			SPAIN	FRANCE
	CM	Area SBY1[1]	SBY2[1]	Area ETRO
1980	50	.56	.22	.28
	60	.81	.52	.56
	70	.86	.60	.60
	80	.87	.69	.62
	$\bar{X}$	61.2	75.3	80.1
	$\bar{W}$	9.5	13.6	17.3
1981	50	.75	.67	.29
	60	.87	.76	.46
	70	.93	.78	.50
	80	.95	.79	.53
	$\bar{X}$	49.3	61.7	89.3
	$\bar{W}$	3.6	10.3	23.3

[1] ICCAT Yellowfin tuna statistical areas

Table 5. Production model of eastern Atlantic yellowfin tuna.

A. Catch, CPUE, and Effort Data

Year	Catch (x10³ MT)	CPUE[1] E. Atl. coastal[2]	E. Atl.[2]	Avg.	Effective effort
1969	81.5	6.17	5.89	6.03	13.52
1970	60.7	2.92	2.92	2.92	20.79
1971	57.7	2.32	2.28	2.30	25.09
1972	28.6	3.37	3.28	3.33	23.60
1973	79.7	2.69	2.56	2.63	30.30
1974	92.2	2.82	2.84	2.83	32.58
1975	108.1	2.00	2.30	2.15	50.28
1976	111.8	2.46	2.36	2.41	46.39
1977	114.5	2.52	2.78	2.65	43.21
1978	118.3	1.90	2.03	1.97	60.05
1979	109.3	1.83	2.05	1.94	56.34
1980	107.1	1.87	1.79	1.83	58.52
1981	123.1	1.33	1.46	1.40	87.93
1982	111.4				

[1] Medium and large purse seiners combined
[2] From Fonteneau and Cayre 1983

B. MSY and Optimal Fishing Effort Estimates (with m=1 model and assumption of ±5% uniform distribution of errors in catch and effort; 1000 iterations)

MSY	%	Opt. Effort	%
104	1.8	64	9.6
105	10.5	65	16.0
106	10.7	66	13.3
107	7.6	67	12.6
108	9.0	68	14.3
109	10.1	69	17.0
110	7.7	70	14.9
111	9.5	71	2.3
112	10.8		100
113	8.7		
114	8.5		
115	5.1		
	100		

Range	104-115 x10³ MT	64-71 x10³ days fished
$\bar{x}$	109.6	67.3
s^2	9.923	4.094
s/x	.029	.030

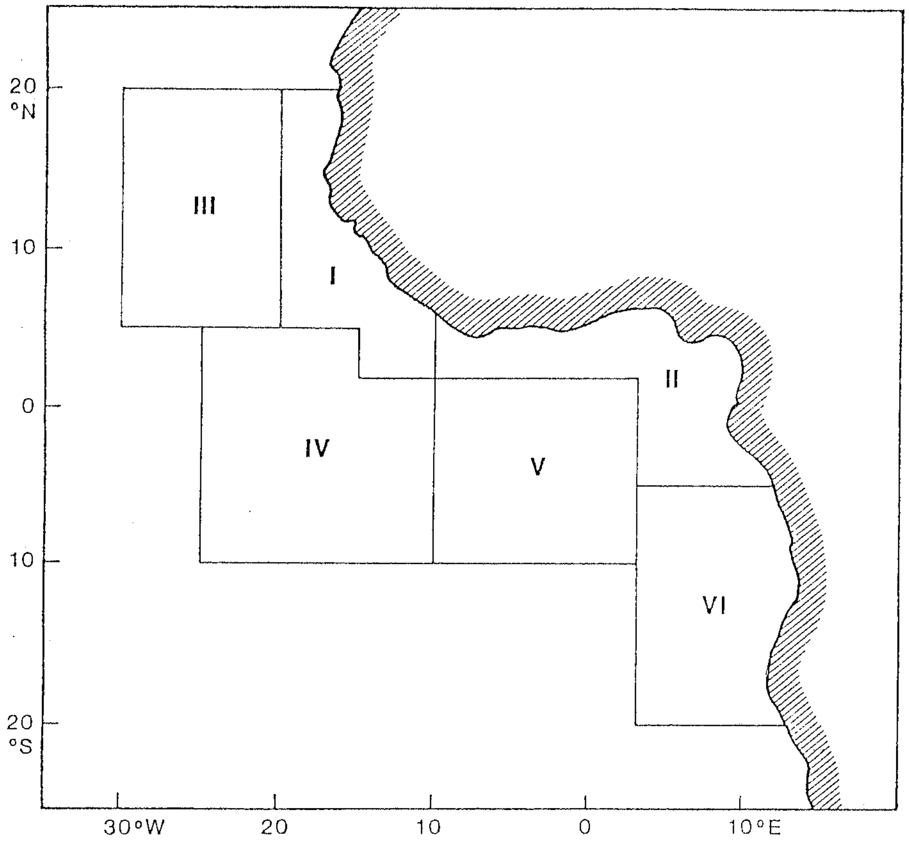

Figure 1. Subareas for study of large purse seine statistics on yellowfin tuna.

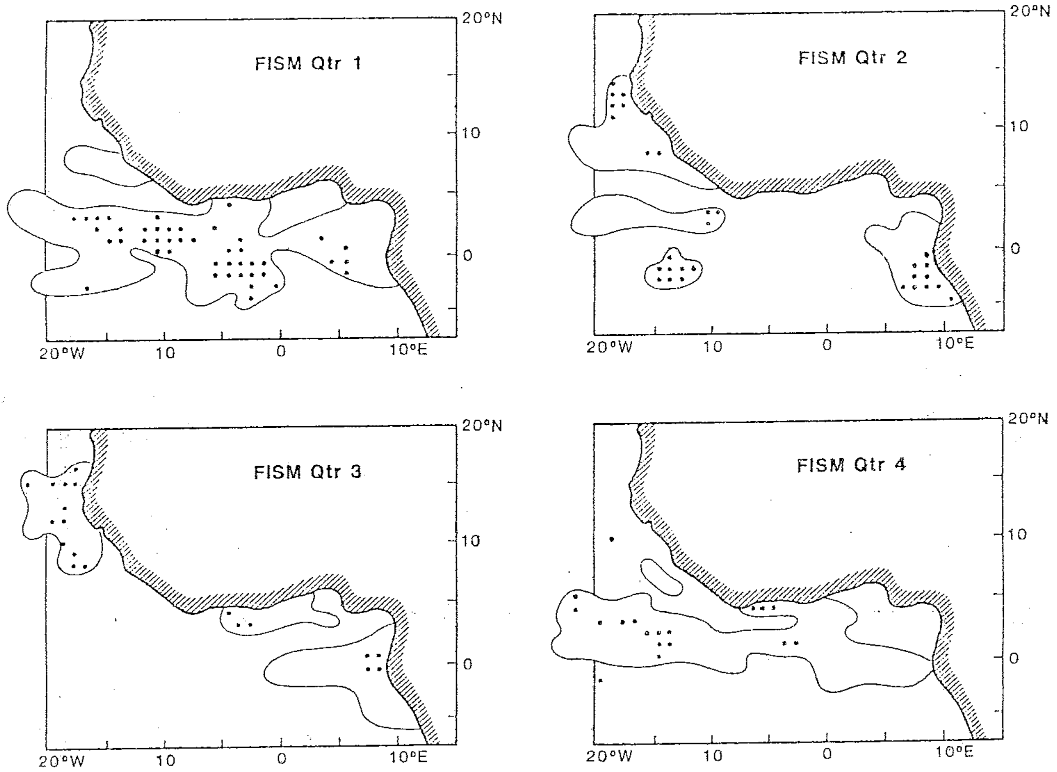

Figure 2. Seasonal distribution of FISM large purse seine catches greater than 50 MT/1° square, 1978-81 (contours) and 1981 catches greater than 100 MT/1° square (dots).