THE YELLOWFIN TUNA FISHERY IN THE EASTERN TROPICAL ATLANTIC

(Preliminary Study)1/

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(Translated from French by J. P. Wise*)

ABSTRACT

This study presents the results of an investigation carried out on the live-bait tuna clippers which landed their catches at Point Noire (Congo-Brazzaville) in 1964. Two-thirds of the trips were analyzed. The analysis allows us to describe the characteristics of the live-bait fishery in the region: catch per unit of effort, yield, and the gross relationship between the distribution of the concentrations of yellowfin and the oceanographic structure of the surface. Eighty percent of the catches were made in waters of 24° to 25° C. (the frontal zone). This relationship makes it possible to use knowledge of the oceanography of the surface, and its seasonal variations, in scouting for fish.

I. INTRODUCTION

The yellowfin (Thunnus albacares) fishery actually began in the Point Noire (Congo-Brazzaville) area in September 1963 with the construction of cold-storage facilities. After 10 years of attempts (cruises of the vessels Laurence, Columbia, Marinero, and Bertin), there had been no commercial exploitation established because the distances between the fishing areas and the ports prejudiced the economic yield.

Since the arrival of the tuna fleet in September 1963 we have begun an investigation to determine the principal characteristics of the fishery (yields) in the region and to obtain the first estimates of the seasonal movements of the fish concentrations.

In establishing contacts with the fishing captains we tried to obtain as much information as possible about their trips: duration, position, catch, time devoted to catching bait, surface temperature, and average size of fish captured. In spite of the relative imprecision of some of the information, this method has the advantage of furnishing a synoptic picture of the situation and a large number of observations (at least in the region exploited). In addition, this type of analysis is the only one permitting the beginning of a study of the influence of exploitation on the stock.

The results of the study are particularly satisfactory in that they shed light on the problem of seasonal movements of the concentrations of yellowfin. Monthly charts2/ of the relative abundance of the fish at the surface have been constructed; they furnish a partial picture of the migrations.

The work presented in this paper is the result of a rapid analysis of the data collected during 1964. This preliminary version was written with as little delay as possible in order to make the results available to the tuna fleet before the beginning of the 1965 fishing season.

II. DESCRIPTION OF THE WORK

Our first idea was to give to the fishing skippers a log sheet to fill day by day at the same time they filled their own logs.

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1/"La pêche de l'albacore (Neothunnus albacares Bonnaterre) dans la zone orientale de l'Atlantique intertropical - Étude preliminaire," Document No. 263 - S.R., 1965. Travaux du Centre Océanographique de l'Office de la Recherche Scientifique et Technique Outre-Mer à Pointe Noire, Diréction Générale: 24, rue Bayard, Paris (8e)- Centre O.R.S.T.O.M. de Pointe Noire: B.P. 1086, République du Congo.

2/Available as an appendix attached to the reprint (Sep. No. 739) of this article.

Notes: (1) Metric tons and °C. used in this article.
(2) Certain changes have been made by the Editor to increase readability in English. Also included are slight modifications as suggested by the authors.

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Tonnage Landed

Yellowfin ____________
Big-eye (> 30 kg) _____
Skipjack ____________

TOTAL

CAPTURES

Name of the boat ______________
Sailing date ______________
Landing date ______________

Captain's Name ______________
Length of trip ______________ days

BAIT

Number of days . . . .
Location. . . . .
Weight . . . .
Species . . . .
Average size. . . . .

1	2	3	4

TUNAS*

Half-Month Period	Date	Position (Statistical Square)	Number of Hours in This Square	Surface Water Temp.	Tonnage Captured	Description	
						Species	Average Size

*Fill this out every day, even if you see no tuna during the day.

Fig. 1 - Form of daily log sheet distributed for use by fishing skippers. (Original printed in French.)

Unfortunately, in practice we were only able to obtain the information regularly by going aboard ourselves to copy the fishing logs, or, if these had not been kept, by interviewing the captains. The precision of information varied considerably from boat to boat. It depended on the good will of the captains and the care with which their logs were kept. While some logs gave day by day all the information needed, others did not even exist; our investigation then was based only on oral information. The sheets filled out under the latter conditions only give overall information, such as: "so many tons in so many days in such and such a region," or even more roughly, "trip identical to that made by such and such a boat."

We attempted to record all the trips which landed their catches at Point Noire. But we only covered 70 of the 113 trips in 1964, that is 4,194 metric tons out of the 6,875 metric tons landed (two-thirds). The logs from two long-liner trips were not used, and one live-bait trip recorded in a very rough manner was not used in the calculations of averages.

We were, however, in a position to request the tonnages unloaded and weighed from the books of the lightering company in charge of operating and maintaining the port. The landings were sorted into yellowfin and skipjack before October 1964; after that date, into yellowfin, bigeye (only those individuals of a weight exceeding 30 kilograms are separated from the yellowfin), and skipjack. Therefore, all bigeye were included with the yellowfin until October, and even then some bigeye weighing less than 30 kilograms were still included with the yellowfin. In general, when the logs were well kept, the captains' estimates of the quantities caught day by day corresponded pretty well with the quantity weighed after landing. Underestimations, which varied according to the captain, were less than 5 percent; but when the logs were incompletely filled out the underestimations could be larger. In general, the captains only remembered reasonably well the days when fishing was the best. Analysis of incomplete logs caused us certain difficulties, and we were obliged to make estimations. In those cases for which we had the fishing locality, the monthly catches by statistical square were extrapolated in applying the relationship between landings and estimated catches.

The catches in the region under study were greater than the amount of fish landed for these reasons: (a) practically none of the Japanese boats unloaded at Point Noire, (b) some transfer to refrigerator ships took place at sea, and (c) in February-March and in November, when the fleet was fishing in the north, the tuna caught in the study region were unloaded at Abidjan or Dakar. On the other hand, few catches made in other regions were unloaded at Point Noire.

This type of study cannot be complete unless the same work is carried out in all the ports where west African tuna are discharged: Tema, Abidjan, Dakar, and Las Palmas.

Our study only deals with the live-bait fishery. We have data on only one trip by a seiner and two trips by long-liners.

III. PRINCIPAL CHARACTERISTICS OF THE LIVE-BAIT FISHERY IN THE EASTERN TROPICAL ATLANTIC

1. QUANTITIES LANDED - DISTRIBUTION OF THE CATCHES BY SPECIES AND BY NATIONALITIES: In 1963, from September to December, 1,178 tons were landed, the result of 14 trips for which we have only fragmentary information.

In 1964 we have information on 6,875 tons, which is a little more than actually landed because we occasionally obtained information on trips which did not land at Point Noire (table 1).

Table 1 - Tuna Landings at Point Noire, 1964

Species	French			Japanese			Spanish			Total		
	Tons	%	Trips	Tons	%	Trips	Tons	%	Trips	Tons	%	Trips
Yellowfin	5,818.2	98.1	97	339.4	-	5	563.0	-	11	6,720.6	97.8	113
Bigeye	16.7	0.3	97	-	-	-	-	-	11	16.7	0.2	113
Skipjack	94.5	1.6	97	8.4	-	5	34.8	-	11	137.7	2.0	113
Total	5,924.4	86.2	97	347.8	5.1	5	597.8	8.7	11	6,875.0	100.0	113

In the Spanish catches the trip made by the seiner Lerez is included (85.1 tons of yellowfin and 8.3 tons of skipjack in 6 days). Two trips by Japanese long-liners are not included in the table, because that type of fishing is carried out on different stocks (albacore and yellowfin). Since the information we have on these types of fishing is very fragmentary, we have not treated them separately.

Table 1 shows the primary importance of the yellowfin in the catches (98 percent of the total), however that percentage is slightly overestimated because, as we have previously pointed out, some bigeye are included. The skipjack and the large bigeye make up the other 2 percent; those species are little sought after, particularly by the French fishermen, because they are of much less commercial value than the yellowfin.

We may note the importance of the French fishery (86.2 percent of the total). Although our data for the Spanish vessels are correct, the same cannot be said for the Japanese catches. Though the latter are considerably the more important, they transfer their catches directly at sea or land at other ports (Tema and Las Palmas). The Spanish vessels fish by preference from Abidjan, where they have a cold-storage facility. For this reason they do not usually come into the region that we have studied. The landings by the fishermen of those two nationalities (Spanish and Japanese) are too small to consider the differences in the species composition by nationality.

Our studies permit us to sum up the data on the catch of 4,194 tons (or 70 of the 113 trips) landed at Point Noire (table 2).

Table 2 - Landings at Point Noire of 70 of the 113 Tuna Trips Reported in 1964								
Species	French		Japanese		Spanish		Total	
	Live-Bait				Seiner	Live-Bait		
	Tons	%	Tons	%	. . . (Tons) . . .		Tons	Trips
Yellowfin	3,747.8	98.5	261.7	-	85.1	25.4	4,120.0	70
Bigeye	18.0	0.5	-	-	-	-	18.0	70
Skipjack	36.3	1.0	10.4	-	8.3	1.0	56.0	70
Total	3,802.1	90.6	272.1	6.5	93.4	26.4 119.8 (2.9%)	4,194.0	70

The data from the French vessels proved satisfactory. The distribution of the catches by species is very similar to to that of the overall landings. By nationality the Spanish fishermen are slightly under-represented.

We must admit that our coverage of the landings varied with time. The relation $\frac{\text{Tonnage covered}}{\text{Tonnage landed}}$, very small in January and February, thereafter increased regularly to June, R = $\frac{1}{8}$; July-August, R = $\frac{1}{2.6}$; September-October, R = $\frac{1}{1.5}$; November-December R = 1.

2. <u>CATCH PER UNIT EFFORT BY LIVE-BAIT BOATS</u>: The 70 log sheets for 1964 were grouped by month, assigning each trip to the month in which the mid-point of the trip occurred. Their distribution is condensed in table 3.

Table 3 - Summary of Basic Information Collected from 70 of the 113 Tuna Trips Landed at Point Noire

1964 Month	No. of Trips	Average Length of Trip	Average Catch of Tuna Per Trip	BAIT FISHING: Total Catch 1/	BAIT FISHING: Total Time Spent Fishing and Steaming 2/	BAIT FISHING: Percentage of Total Time at Sea	TUNA FISHING: Total Catch 3/	TUNA FISHING: Time Spent by All Trips: Steaming +Scouting +Fishing 4/	TUNA FISHING: Time Spent by All Trips: Percentage of Total Time at Sea	TUNA FISHING: Time Spent by All Trips: Time Spent only in Tuna Fishing 5/		Total Time at Sea (Bait and Tuna Fishing) by All Trips	Tuna Catch Per Day by All Trips: For Total Time at Sea	Tuna Catch Per Day by All Trips: Actually Spent Tuna Fishing
		Days	Tons	Tons	Days	%	Tons	Days	%	Days	%	Days	Tons/Day	Tons/Day
January	1	30.0	45.0		0	-	45	30	100.0	25	83	30	1.5	1.8
February	2	27.5	23.5		10	17.5	47	47	82.5	20	35	57	0.8	2.4
June	2	23.5	58.0		1	2.1	116	46	97.9	30	64	47	2.5	3.9
July	3	20.3	83.0		16	22.5	250	55	87.5	22	31	71	3.5	11.7
August	7	18.8	77.4		25	18.9	542	107	81.1	53	40	132	4.1	10.4
September	23	21.3	68.0	105 × $\frac{70}{33}$	69	15.4	1,567	380	84.6	269	60	449	3.5	5.8
October	19	19.8	52.3		114	30.3	994	262	69.7	175	46.5	376	2.6	5.7
November	11	21.6	47.0		56	23.5	517	182	76.5	117	64	238	2.2	4.4
December	2	22.0	58.0		7	15.9	116	37	84.1	22	50	44	2.6	5.3
Total	70	20.6	60.0	230.0	298	20.0	4,194	1146	80.0	733	50	1,444	2.9	5.7

1/Not possible to calculate catch by month since only 33 of the 70 trips reported the amount caught. Total bait catch by 33 trips was 105 tons.
2/Time devoted (steaming and fishing) to catching bait.
3/Yellowfin made up 98.5 percent of the catch; balance was bigeye and skipjack.
4/Time spent for steaming, scouting, and fishing for tuna.
5/Time spent actually fishing tuna. But values are overestimated because in some instances information obtained did not separate time spent scouting from time fishing.

The analyses of the monthly data in table 3 leads to some interesting conclusions. The quantities for the months of January, February, June, July, and December are so small that they support only speculation. The data for August, September, October, and November are considerably more significant; the fishing and our coverage were considerably more intensive.

(a) <u>Bait</u>: DIFFICULTIES: Of the 1,444 days at sea for the 70 trips, 298 days (20 percent) were used in bait fishing. The percentage is generally small, but in October, 30.3 percent of the time at sea was devoted to bait fishing. There are two reasons for this: (1) the difficulty of getting suitable bait in the fishing areas themselves; and (2) with the movement of the yellowfin towards the south and the impossibility of getting bait off the Angolan coast, the distance between the fishing areas for bait sardines (Gabon) and tuna (Angola) lengthened and the time spent steaming correspondingly increased. (Only 2 vessels were able to get bait off the Angolan coast.)

This caused the tuna fishing fleet to move northward. In November and December only a few vessels stayed in the region where they could more easily get bait (in November 23.5 percent of the total time at sea was spent bait fishing, and, in December, only 15.9 percent). The difficulties in getting bait seem to limit the development of the fishery and to inhibit the establishment of continuous exploitation throughout the year. Scarcity of tuna in October cannot be blamed, as we have previously mentioned, for the departure of the fleet during that month.

FISHING AREAS: We have noted 86 bait-fishing areas, which are distributed in the following manner:

Area Description	No. of Times Bait Fishing was Carried On	Season
Ghana - Accra	1	
Annobon	2 (for anchovies)	
Gabon - 0°30' N. - 0°30' S. - Libreville	15	Throughout the year
0°30' S. - 1°30' S. - Cape Lopez	4	
1°30' S. - 2°30' S. - St. Catherine	47	
2°30' S. - 3°30' S. - Nyanga-Mayumba	11	
Congo - 3°30' S. - 4°30' S. - Bas Kouilou	2	August - September - October
4°30' S. - 5°30' S. - Point Noire	2	
Angola - 7°00' S. - 8°00' S. - Ambrizette-Ambriz	2	October - November
Total	86	

Practically all the bait came from off the coast of Gabon (Libreville and expecially St. Catherine), throughout the year. Considering this restricted distribution of bait, the question might be raised if it would not be preferable to use one or two vessels specially equipped for bait fishing, and much less expensive to operate than tuna vessels. The bait would be kept in live-wells at some point on the coast (Port Gentil, for example) where the tuna vessels could load up without losing time. Taking 3.2 tons of bait as the average needed per trip (105 tons recorded for 33 trips), the total fishing for tuna in 1964 required 360 tons of bait for 113 trips. The same extrapolation applied to the time necessary for seeking the bait (298 days x $\frac{113}{70}$ gives an estimate of 480 days (20 percent of the total time at sea). These figures demonstrate that it would be beneficial to improve the operation of the bait fishery. However, it is evident that the proposed organization could not be realized unless a tuna fleet operated throughout the year in the region.

SPECIES FISHED: The great majority consists of "sardine," or "massoundji" (*Sardinella aurita*) of small size. This is the least common species of *Sardinella* and schools of young individuals are hard to find. The Japanese fishermen want bait of very small size (less than 12 cm.), whereas the French fishermen use individuals up to 20 cm. Supplements of scad (*Trachurus* sp. and *Decapterus* sp.) and mackerel (*Scomber japonicus*) are also used. The vessels fishing around Annobon have sometimes been able to make up their bait from the schools of anchovy (*Enchoviella guineensis*) frequently found around the island.

(b) Yellowfin Fishery: The tuna fleet is made up of freezer vessels, with only a few seiners (3 out of 31). We only have information from one seiner trip and have grouped it with the trips of the live-bait vessels for the analysis of the correlation between yellowfin concentration and surface temperature. The differences among the bait boats are not important enough to require grouping those vessels in several classes as to their fishing power.

CAPTURE PER TRIP AND CAPTURE PER DAY AT SEA: On the average a trip lasted 20.4 days, during which 60 tons of tuna were captured. If we follow month by month the average length of each trip (table 3), we notice that it does not vary very much; long trips of more than one month are as rare as those of less than 15 days. In general, the vessels came back even if they were not filled up. This explains the parallel between the catch per day and of the average catch per trip (table 3). Those two indices give month by month the overall yield of the fishery. They increase regularly through August and stay high until September. In October and November the yield falls markedly--52.3 and 47.0 tons per trip (2.6 and 2.2 tons per day at sea). We see here the influence of the disappearance of the bait and of the increase in steaming time between the tuna and bait-fishing grounds. As we will see, it can not be concluded that the cause was a decrease in availability of tuna.

CATCH OF TUNA PER ACTUAL FISHING DAY: The monthly figures in the last column of table 3, as well as the time devoted to fishing, must be qualified somewhat, because some logs were only filled in partially and in generalities. But we note:

(1) The well known influence of the concentration of the vessels gives a double advantage: scouting for concentrations of tuna and for zones where the yield is better is faster (combing effect); and it is possible to keep in contact with the schools, even though certain vessels have to leave the fishing grounds to unload or to catch more bait.

This fishing in a group is really not very well executed, however, because the fishermen are paid on the basis of their boat's catch, and this makes for a keen spirit of competition among the vessels; some of them show a certain reluctance to going out alone scouting. From June to September, with the progressive increase in the number of vessels, the catch per day actually spent fishing for tuna increased regularly. It fell off again in November and December when only a few vessels remained in the region.

(2) The probable disadvantageous localization of scouting in the cold season. The particularly low catches at the beginning of the year may be explained by the fact that scouting and fishing are carried out in warm water where the tuna are unlikely to be found in large concentrations (as we will see a little later).

It would seem that in November this phenomenon may equally explain the low yield (4.4 tons per day of actual tuna fishing). Apparently the fleet did not follow the movement of the large concentrations of tuna towards the South. On reaching the "black" water of the Congo, where the tuna do not come to the surface, the fishermen stopped; only two vessels crossed the "black" water and found to the south of it some regions of strong concentrations.

IV. INFLUENCE OF OCEANOGRAPHIC CONDITIONS ON THE SHIFTING OF THE FISHING GROUNDS

For the last ten years, scientists of the Point Noire Center have been especially interested in the movement of the concentrations of yellowfin and have attempted to relate it to oceanographic conditions. Several cruises by the vessel Ombango, carried out by M. Rossignol, have made it possible to form the hypothesis that large concentrations of yellowfin should occur at the limit of the warm water (27° to 23° C.). Those cruises have shown that the schools of yellowfin follow the seasonal movement of the boundary between cool and warm water.

The oceanography of the surface of the region is well known. Work done by G. R. Berrit makes it possible to locate the extreme limits of the warm water in space and time with enough precision for the needs of the fishermen. Thanks to this information, it has been possible for several years to tell the fishermen the region where the concentrations of yellowfin probably will occur, and to predict their seasonal movements.

Our work on tuna fishing has furnished more precise information on the hydrologic preferences of the yellowfin. The largest concentrations are found in waters of 24°-25° C., which characterize the boundary between the warm and cold water.

(a) FRONTAL ZONE (REVIEW OF BASIC INFORMATION): Schematically, the oceanography of the surface of the Gulf of Guinea can be summed up in this manner: a layer of water called "Guinea Water," which is warm (usually 26° to 30° C.) and of low salinity (less than 34 ‰) lies over the "Benguela Water," which is cooler (temperature less than 24° C.) and of higher salinity (more than 35 ‰). In our area, the passage from one water mass to the other is rapid; one finds a gradient of four degrees in a few meters vertically (thermocline) and over a distance of 50 to 100 miles horizontally. We use the name "frontal zone" for the strip of rapid temperature change (an example is shown in fig. 2). The layer of warm Guinea Water, 25 meters thick, is separated from the cooler Benguela Water by a strong thermal gradient.

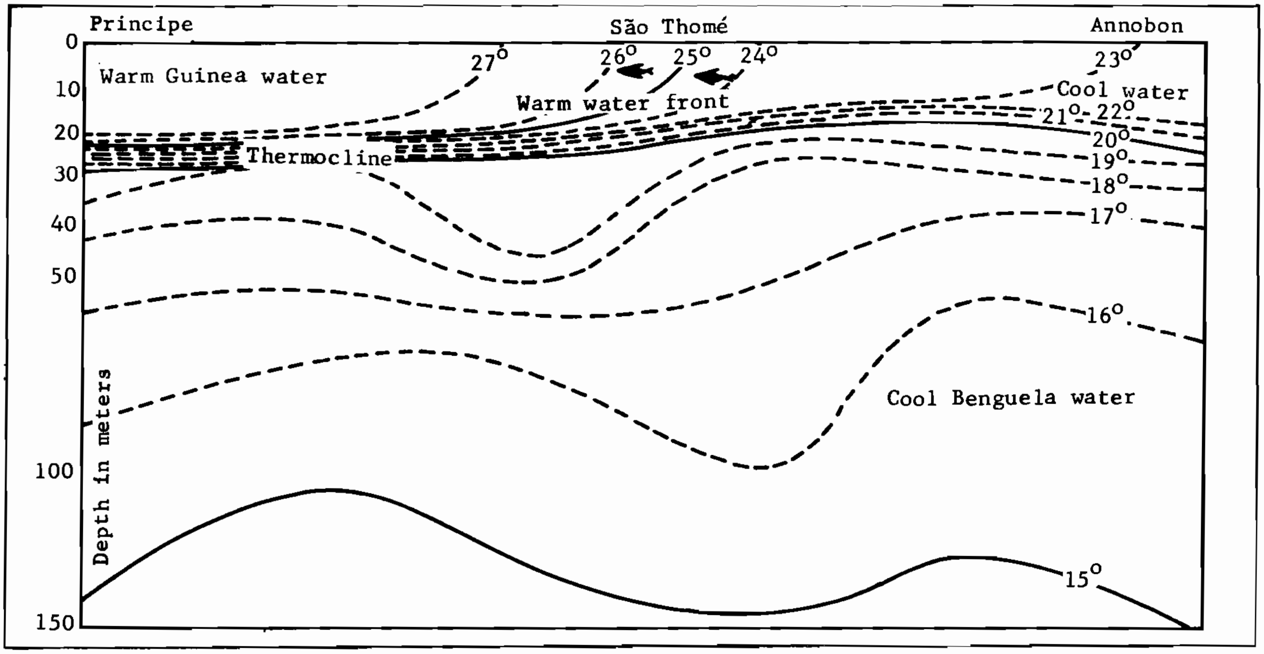

Fig. 2 - Example of the Front: Temperature section from Principe to Annobon in the cold season (May-June 1956), as per G. R. Berrit.

Close to our coast, the frontal zone is distinct. It appears to become less distinct as one goes offshore. In the eastern part of the Gulf of Guinea, the thermocline does not go below a depth of 30 to 35 meters. Towards the west it deepens progressively, reaching 100 to 150 meters near the coasts of the Americas.

In the greater part of the region studied, the temperature changes are accompanied by salinity variations. But in the warm season (November-April), even though the warm water front reaches and passes Loanda in its descent towards the south, one does not pass directly from warm water of low salinity (Guinea Water) to cool saline water (Benguela Water). The salinity gradient is fixed at the latitude of Loanda, although the temperature gradient goes down as far as the latitude of Mossamedes; in that region there is a layer of warm saline water ("Tropical Water").

(b) CORRELATION BETWEEN THE ABUNDANCE OF FISH AND THE TEMPERATURE OF THE SURFACE WATER: Forty-one log sheets show the temperature of the surface water as recorded at the engine intake. Although those temperatures were measured in a crude fashion, the majority of observations show a close correlation between the presence of tuna and the surface temperature. In table 4, we have shown the daily capture of yellowfin as a function of the surface temperature, for all those days when yellowfin were caught. The temperature taken during days when there were no catches are not included in the table.

We may see from table 4:

(1) Little or no fishing in water of temperature below 23° or above 27° C.; only 2 percent of the 206 daily observations exceeded those limits.

(2) The majority (78.6 percent) of the catches and the largest daily yields (or indices of abundance of fish) were obtained in water between 24° and 26° C., characteristic temperatures of the frontal zone.

(a) Average daily catch in water of 24° to 25° C.: 6.3 tons
(b) Average daily catch in water of 25° to 26° C.: 7.7 tons
(c) Average temperature for catches: 24.9° C.

Table 4 - Catch Per Day of Yellowfin as a Function of Surface Temperature

Temperature (°C.)	Relation with Temperature						
	23°-24°	24°-25°	25°-26°	26°-27°	27°-28°	28°-29°	
Tonnage Caught							
0-1	1	9	6	1			
1-2	6	5	3			3	
2-3	2	11	10	2			
3-4	2	5	13	1			
4-5	8	10	8	1			Average
5-6	3	8	6	3	1		
6-7	1	6	5	2			temperature
7-8	2	3	4				
8-9	1	2	5				of all
9-10	1	1		1			
10-11		3	6				catches
11-12			2				
12-13		4	2				24.9°
13-14		2	1				
14-15		1					
15-16		2	4				
16-17		1					
17-18		1	1				
18-19	1	2					
19-20		1*					
20-30		1 1*	2				
30-40			1				
40-50		1*	2				
> 100			1*				
Total	29	77+3*	81+1*	11	1	3	
Percentage	14.1	38.8	39.8	5.3	0.5	1.5	with seiner
Average catch (tons)	5.0	6.3	7.7	4.8	5.5	1.5	without seiner

*Observations from one seiner.

This close correlation between the concentration of yellowfin and the temperature (frontal zone) shown here for surface fish might also exist in the depths. The Japanese long-liners, which we have visited, adjust the depth of their long lines to about 35 meters (the depth of the thermocline) while in our region. Their captures are then made up primarily of yellowfin. These observations, however, are much too few to be studied quantitatively.

(c) CHANGES IN THE FISHING AREA--MIGRATIONS: Our investigations were designed overall to follow (by vessel observations) the changes in the fishing area, and from that to obtain a partial idea of the migrations of yellowfin. The data were grouped by half monthly periods and plotted on a chart of the region, which is divided into statistical squares of 30 minutes on a side. For each fortnight and each square, we summed up: (1) all the daily catches on each log sheet, and (2) the fishing effort (the total days of scouting and fishing in each square by all of the vessels). An average temperature was established for each square. Although the evaluation of the catches is accurate enough (only small underestimations by the skippers affect it), the evaluation of the fishing effort presents many more difficulties and, for that reason, a lack of precision. The log sheets filled in on a daily basis allow scouting and effective fishing to be identified, whereas, the log sheets filled in on an overall or general basis (so many tons in so many days) underestimate the scouting time. Therefore, our data on effort are underestimated, and it is necessary to consider them as more nearly indices of observation density than as precise measures of fishing effort.

Because the temperatures are not precise and the average observations per square are for 15 days, it is impractical to construct a network of isotherms; however, the average position of the front can be fixed. To indicate this, we have plotted the isotherms of 24° and 25° C. We used the results of oceanographic cruises made by the Center during the same periods in previous years for those two-week periods during which we do not have observations.

The 17 charts 3/ show the following facts:

1. As we have pointed out in the analysis of tuna versus temperature, the largest concentrations of yellowfin were found in the frontal zone.

The two charts for the month of June clearly show the distribution of the fish at the beginning of the cold season. The front was situated between Port Gentil and São Thomé. During the first part of June, one boat went south of Point Noire to Benguela, and saw not a single tuna. The temperatures observed during that trip were always 24° C. or below. By the second half of June, the boats, moving considerably to the north, found tuna on the front.

3/Available as an appendix attached to the reprint of this article.

From June to August (cold season), the front was stabilized perpendicular to the coast between Port Gentil and Libreville. The fishing was carried out in that area, principally off Libreville.

At the end of August, the front was beginning to descend to the south and the vessels followed.

In September-October, the process was accelerating. A tongue of warm water was descending along the coast; it reached the Congo at the end of September.

From November to April (warm season), we only have a few observations on the fishery from the Congo to Mossamedes, where the front was then located. In November and December only two vessels went there; they found yellowfin in large concentrations.

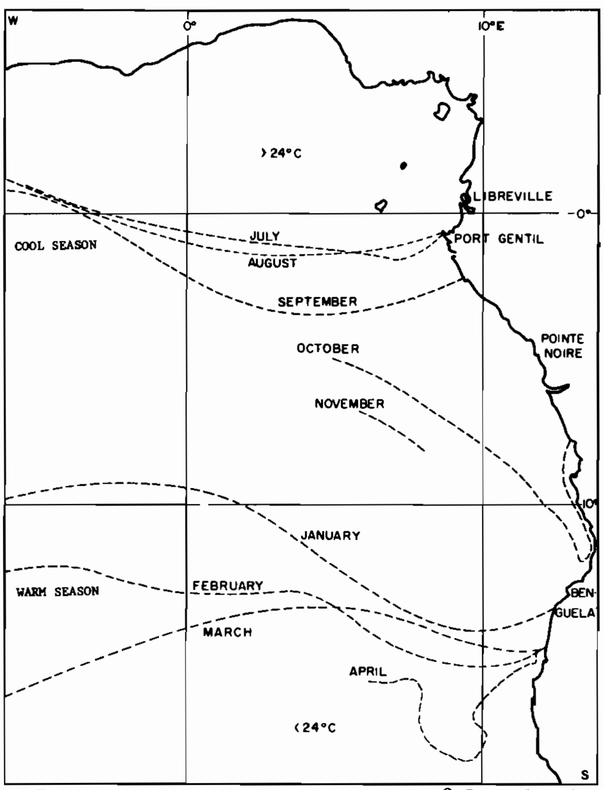

Fig. 3 - Seasonal movement of the front (24° C. isotherm).

The three charts from January 16 to February 29 demonstrate that the fishery was carried on in very warm water (28° C.), and that the overall yield was poor. From January to April the warm water reached its southernmost position (Mossamedes) and spread out farther and farther from the coast to attain a position perpendicular to it. On the other hand, we know that tuna fishing was carried out at Baia Farta (Benguela) from the end of September to March-April.[4]

We have seen that to the south of Loanda a warm, salty water mass (Tropical Water) extends to the cold-water front. It would be interesting to see if the change in salinity of the waters then inhabited by the yellowfin influence their distribution.

In May there were no observations on yellowfin; the front was rapidly returning to its cool season position (Cape Lopez-Annobon).

2. In the warm season, that is to say when the front moved to the South, the island of Annobon was surrounded by warm water (26°-28° C.). Nonetheless, the schools of yellowfin were always seen there and slways caught (charts for January and February-November and December). This phenomenon of a permanent concentration around islands is well known to Pacific fishermen; the Americans call those fish "home guards."

3. Influence of the Congo Waters: We have grouped data relative to the period from 15 September to 31 December on the same chart. This is the period during which the southward moving front crosses the outflow of the Congo. The form and the extent of that outflow have been studied by the Center at Point Noire; its northern limit, in the period of maximum discharge (observations in November-December 1963), narrowly marks the southern limit of the catch of tuna during the same period in 1964. Almost all of the tuna vessels stop there, associating the disappearance of the yellowfin with the appearance of "black" water. Only two live-bait vessels crossed that water; they found the tuna once again when they entered clear water. It seems very probable that the tuna passed underneath the thin layer of "black," low

4/In a personal communication, F. Correia da Costa has furnished us some information on the live-bait fisheries at Baia Farta. This is carried out by small (10 meters) open boats which make one-day trips on the Continental Shelf. The catches are made up of yellowfin, bigeye, and little tuna. Each boat catches from 250 to 300 tons each season.

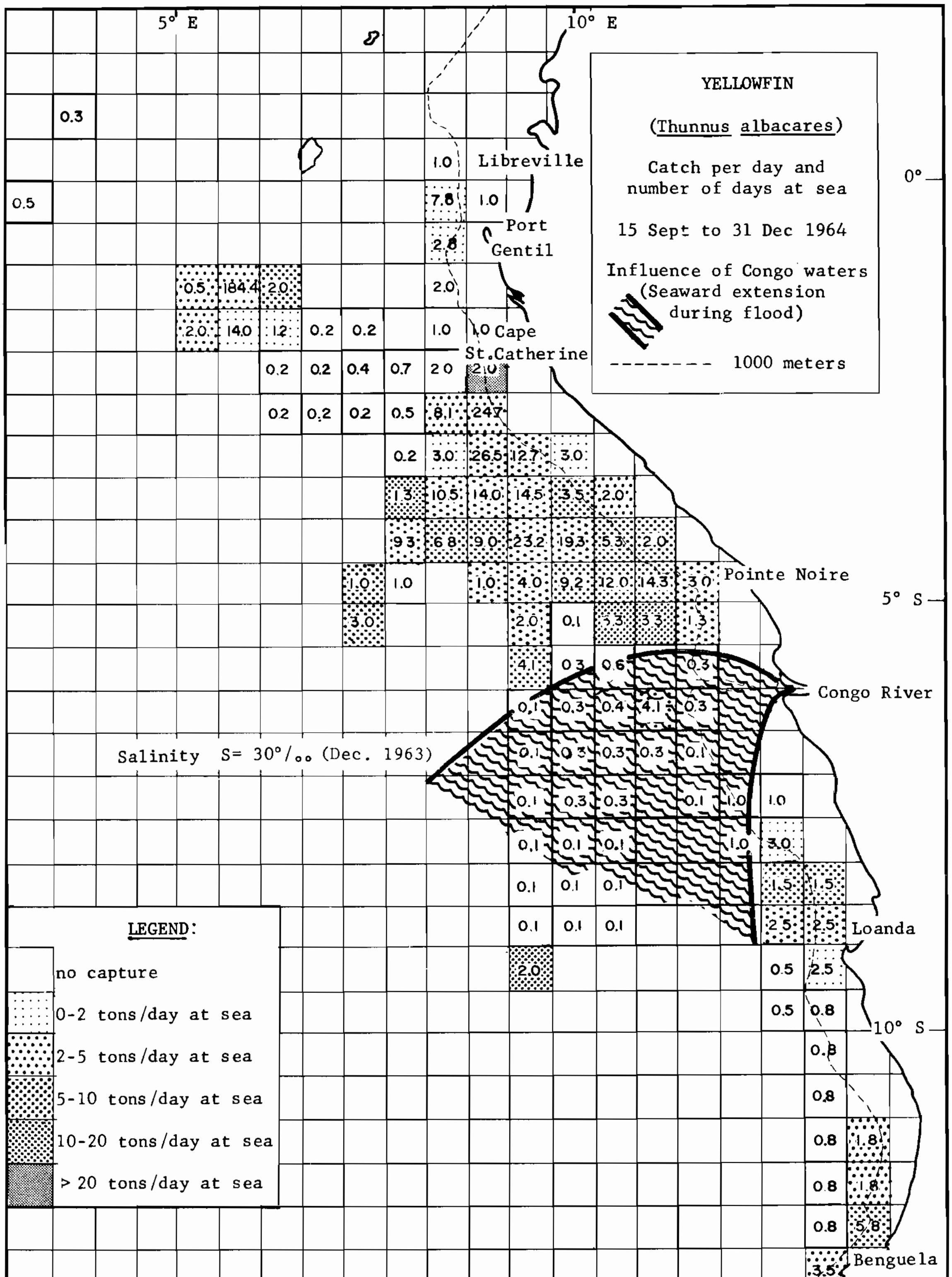

Fig. 4 - Influence of Congo waters is shown in data for September 15-December 31 grouped in this chart.

salinity water. During the second half of November, a French vessel spotted some Japanese long-liners fishing in those waters. Because the layer of "black" water is very thin, it is sometimes possible by chumming to make the tuna come up to the surface and to fish them there by pole-and-line (the fishery around $6^{\circ}30'$ S. by $10^{\circ}30'$ E. during the second half of November).

4. Optimum Areas for Tuna Concentrations. Judging from the overall picture on the charts, it appears that the yellowfin school more densely in some select areas: (1) around islands (Annobon in particular); and (2) off the Continental headlands at Libreville, Point St. Catherine, Nyanga, Mayumba, Point Noire, Loanda, Port Ambouin, and Benguela. However, the concentrations are not limited to a narrow band parallel to the coast. The French vessels have operated at a distance of about 160-200 miles offshore, but in January-February 1965, some Japanese live-bait vessels were seen 400 miles southwest of Point Noire, approximately where the 24° C. isotherm is located at that time. It remains to be seen if the progressive separation of the 24° and 25° C. isotherms as one goes offshore has a certain influence on the abundance of the yellowfin. In fact, beyond about 100 miles offshore, the horizontal gradient weakens so much that one can no longer define the limit of the warm waters of the frontal zone.

V. CONCLUSIONS

This study has permitted us to demonstrate the enormous role played by oceanographic conditions in the geographical distribution and perhaps the bathymetric distribution of the yellowfin in our region. This fish shows a well defined preference for the zones characterized by a strong thermal gradient (the frontal zone and without doubt the thermocline), which separates the Guinea Water and the Tropical Water from the Benguela Water. Four-fifths of the captures made in 1964 by the French live-bait vessels in the eastern tropical Atlantic came from the frontal zone (24° to 25° C.). These ecological relationships of the yellowfin are very similar to those demonstrated by studies in the Pacific. In the eastern Atlantic, studies on the ecology, stocks, and dynamics of the yellowfin are quite rare and the lack of them becomes more and more evident. To which physico-chemical or biological and feeding (plankton) characteristics this close correlation is due, it is impossible to say at this point in our studies, for the temperature is only an index of a type of water having a whole series of related properties. Furthermore, the ecological laws which regulate the migration of the yellowfin must vary with their age and physiological state (sexual state). This preliminary study does not permit any analysis of this sort; analysis of the average lengths of the fish captured (when available from the logs) has not given any information in relation to time or location.

However, the overall conclusions we have reached should help the fishermen in their scouting. We are able to show that during certain periods of 1964, the activity of the vessels was carried out outside the probable zone of strong concentration. It may be hoped that this study, based on the vessels' own logs, will help them to better localize their activity.

Continuous temperature observations should become a general rule. Using a recording thermometer (such as exists on certain boats), location of the frontal zone is easy in conjunction with the charts of the probable monthly position of the 24° C. isotherm. Zones of rapid temperature change should be scouted.

For several vessels, 1964 was the year of first contact with our region. In spite of imperfect knowledge of the yellowfin and difficulties in capturing bait, the results are encouraging. The catches per day at sea have been comparable with those of the California fishermen on the Pacific coast of America between California and Peru (R. C. Hennemuth 1961).

VI. APPENDIX

The 17 charts mentioned in the article are available as an appendix attached to the reprint of this article. Write for Separate No. 739. There is a chart for each 15-day period showing catch of yellowfin per day and number of days at sea. Covered are the months of January, February, June, July, August, September, October, November, and December 1964.

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DONGUY, J.R., J. HARDIVILLE et J.C. LEGUEN
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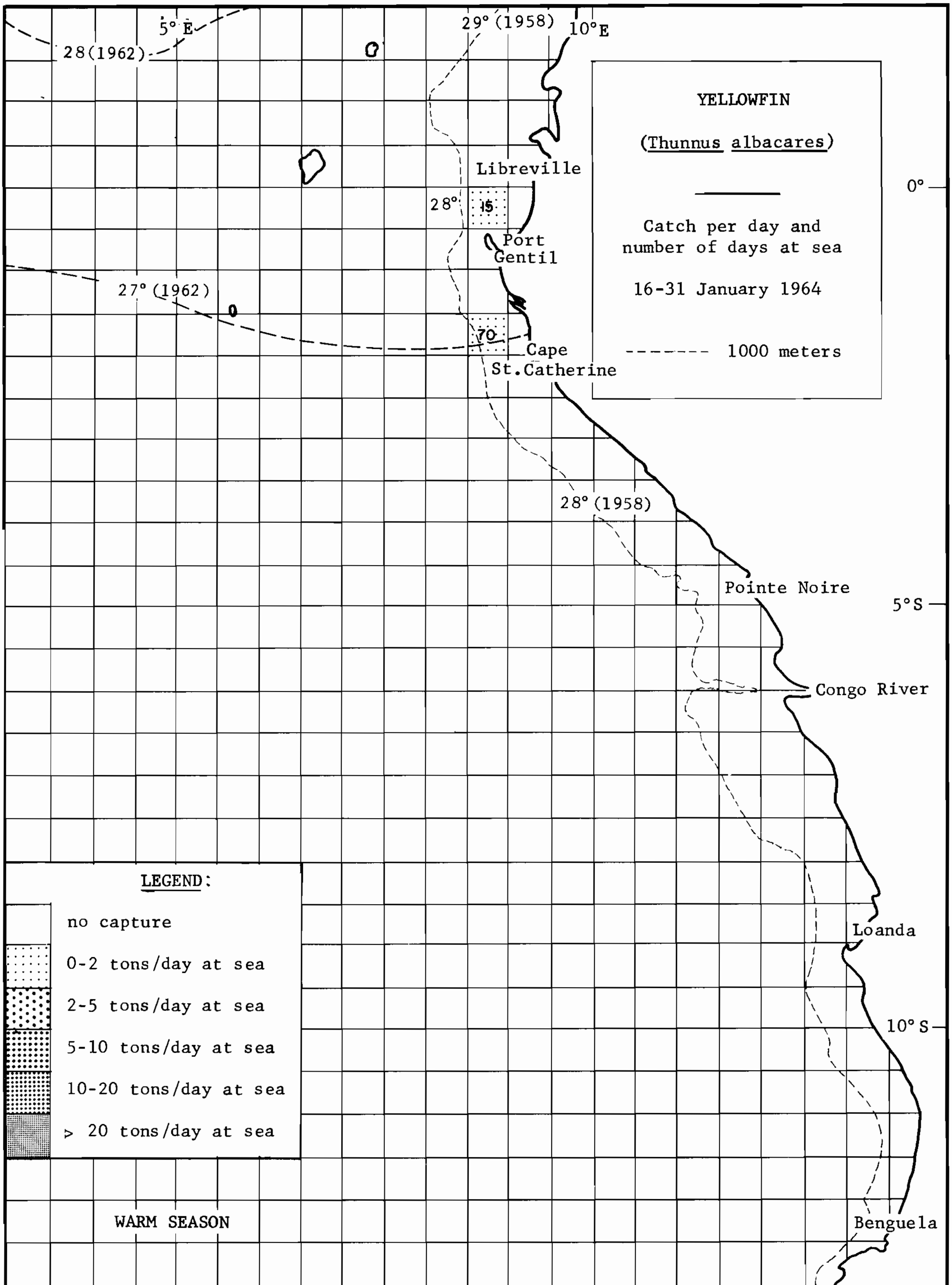
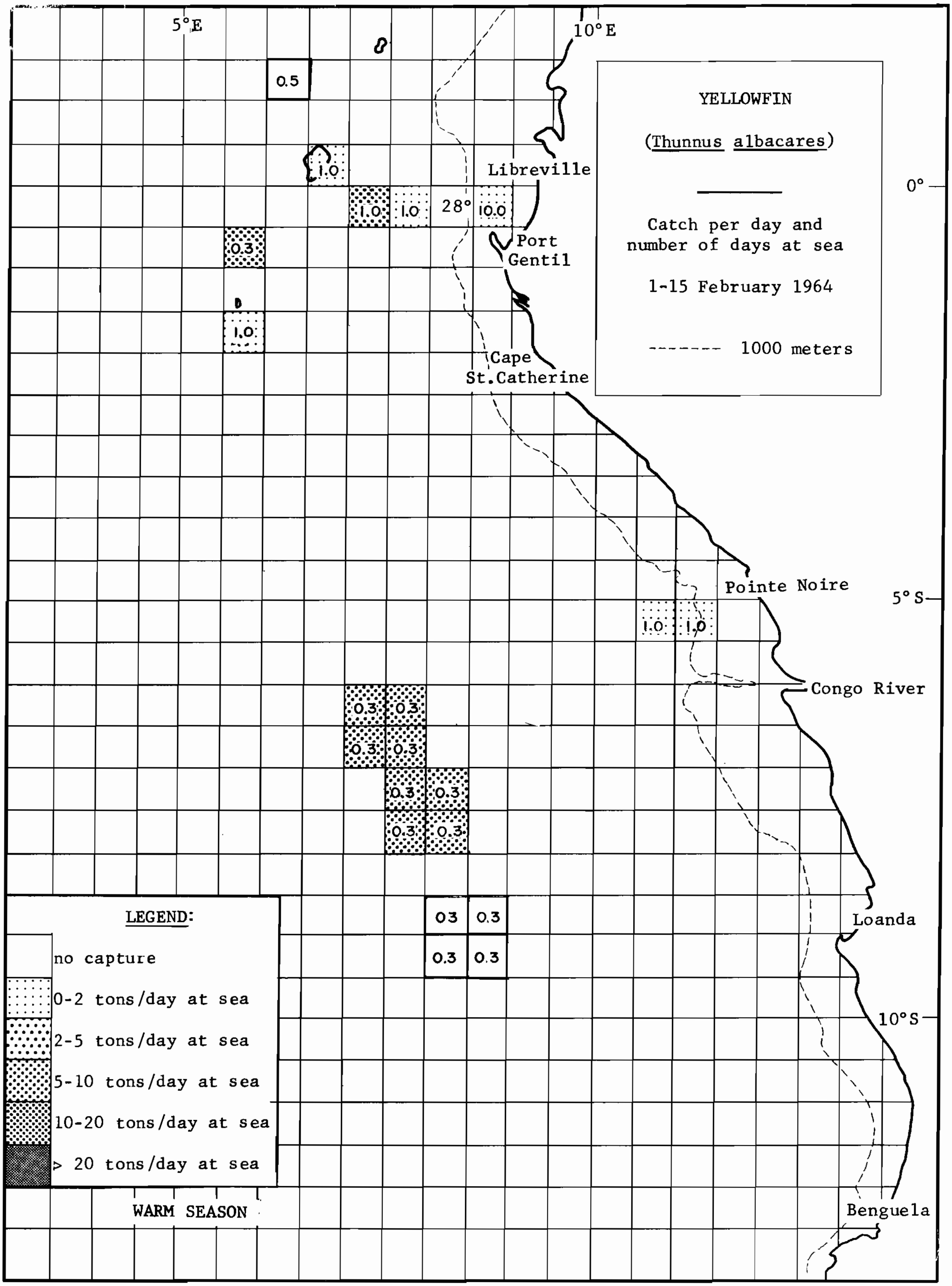
HENNEMUTH, R.C.
1961. Year Class Abundance, Mortality, and Yield per Recruit of Yellowfin Tuna, in the Eastern Pacific Ocean, 1954, 1959. Inter-American Tropical Tuna Commission, bulletin, vol. VI, no. 1.

Created in 1849, the Department of the Interior--a department of conservation--is concerned with the management, conservation, and development of the Nation's water, fish, wildlife, mineral, forest, and park and recreational resources. It also has major responsibilities for Indian and Territorial affairs.

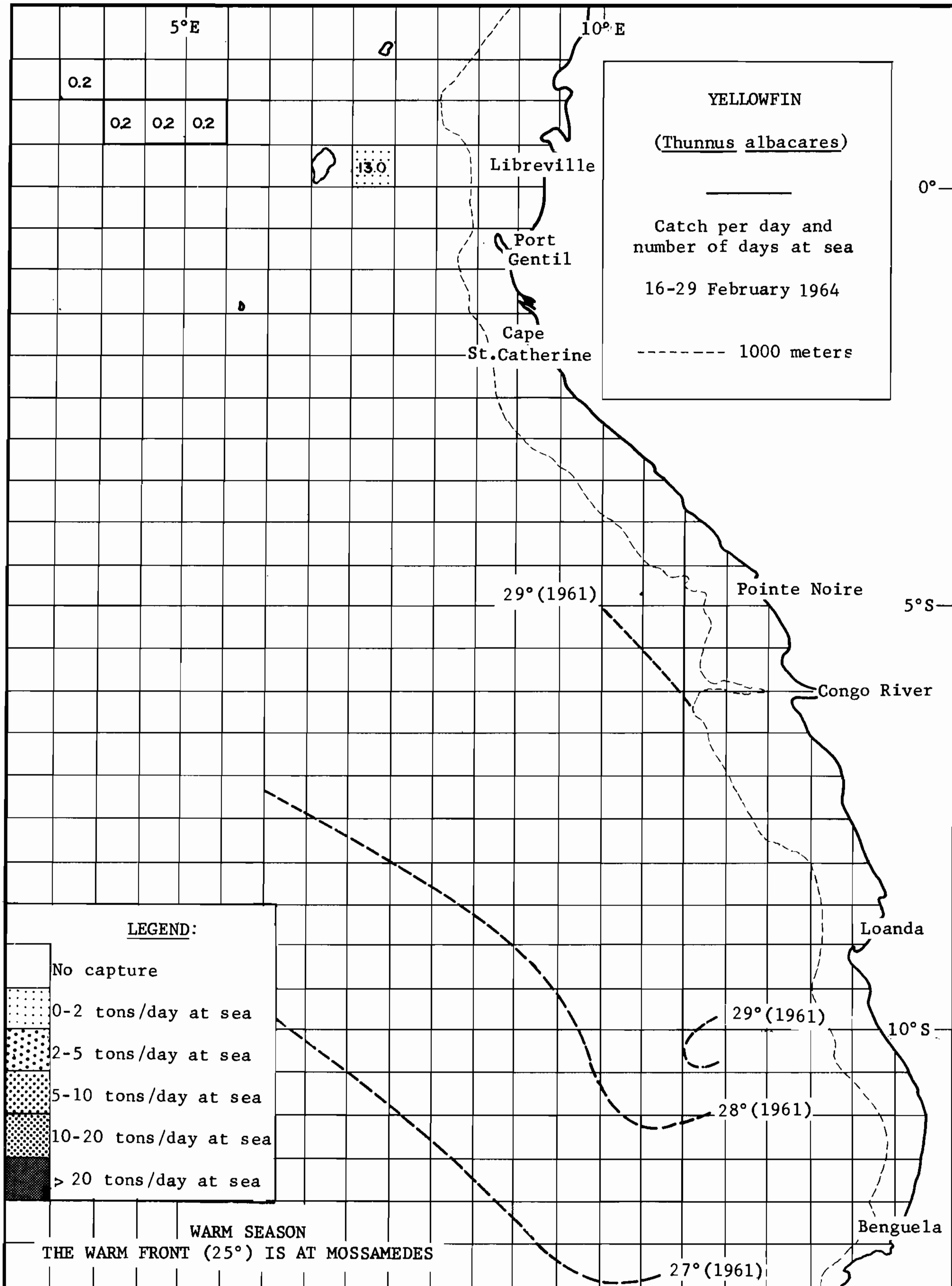
As the Nation's principal conservation agency, the Department works to assure that nonrenewable resources are developed and used wisely, that park and recreational resources are conserved for the future, and that renewable resources make their full contribution to the progress, prosperity, and security of the United States--now and in the future.

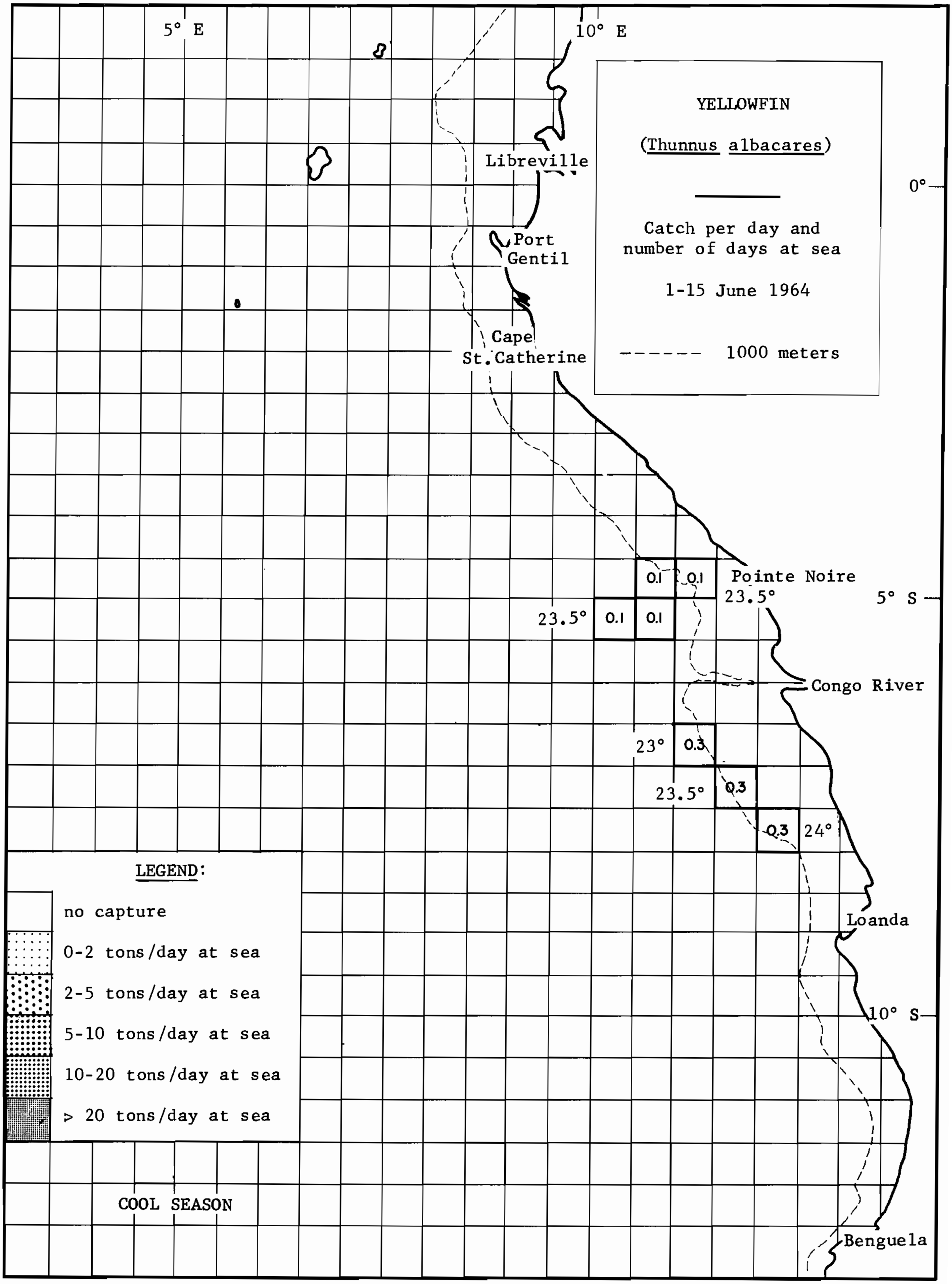


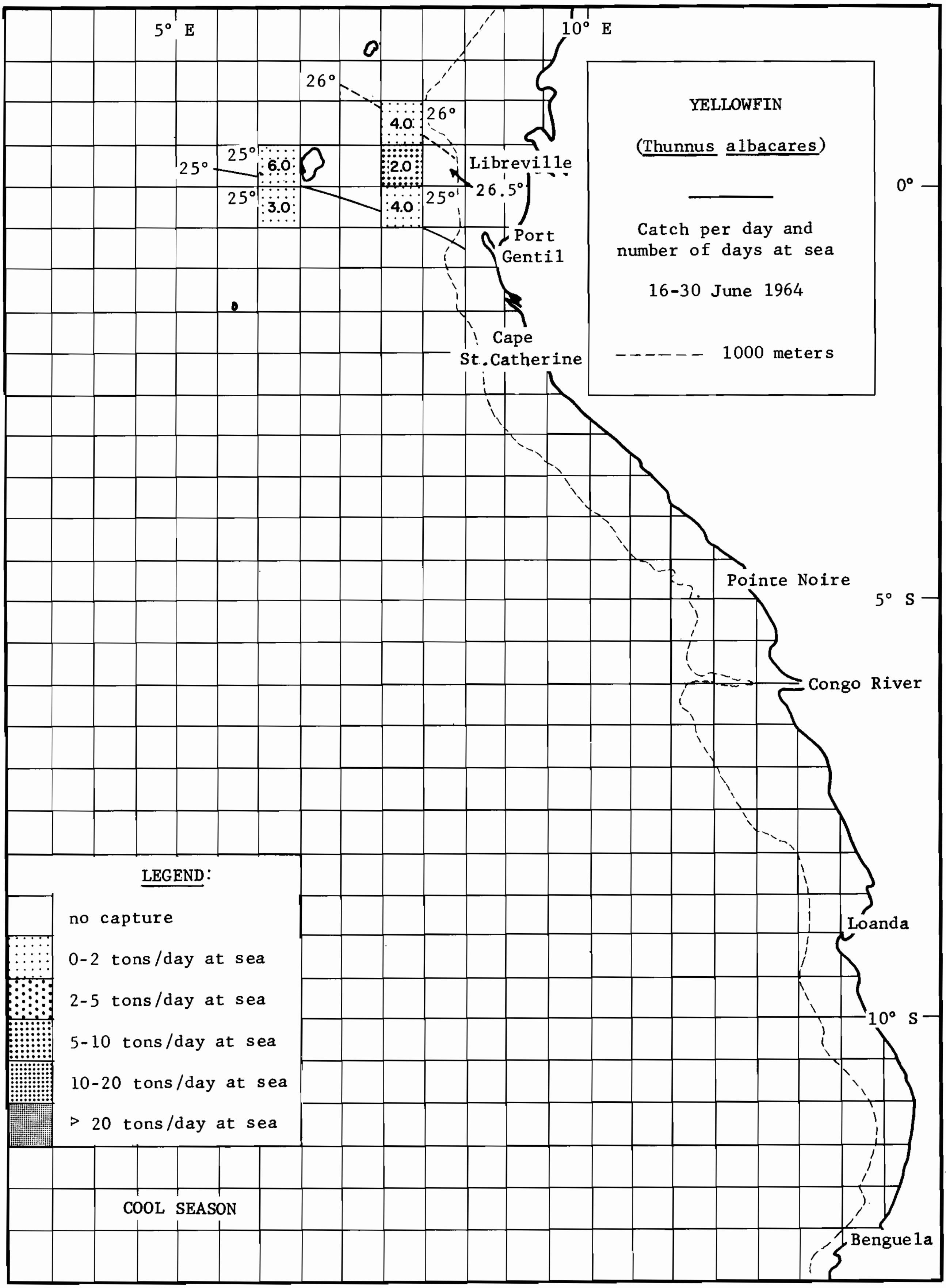
YELLOWFIN
(Thunnus albacares)
Catch per day and number of days at sea
16-31 January 1964
1000 meters
5° E
28(1962)
29° (1958)
10°E
Libreville
28°
15
Port Gentil
27° (1962)
0
70
Cape St.Catherine
0°
28° (1958)
Pointe Noire
5°S
Congo River
Loanda
10° S
Benguela
LEGEND:
no capture
0-2 tons/day at sea
2-5 tons/day at sea
5-10 tons/day at sea
10-20 tons/day at sea
> 20 tons/day at sea
WARM SEASON



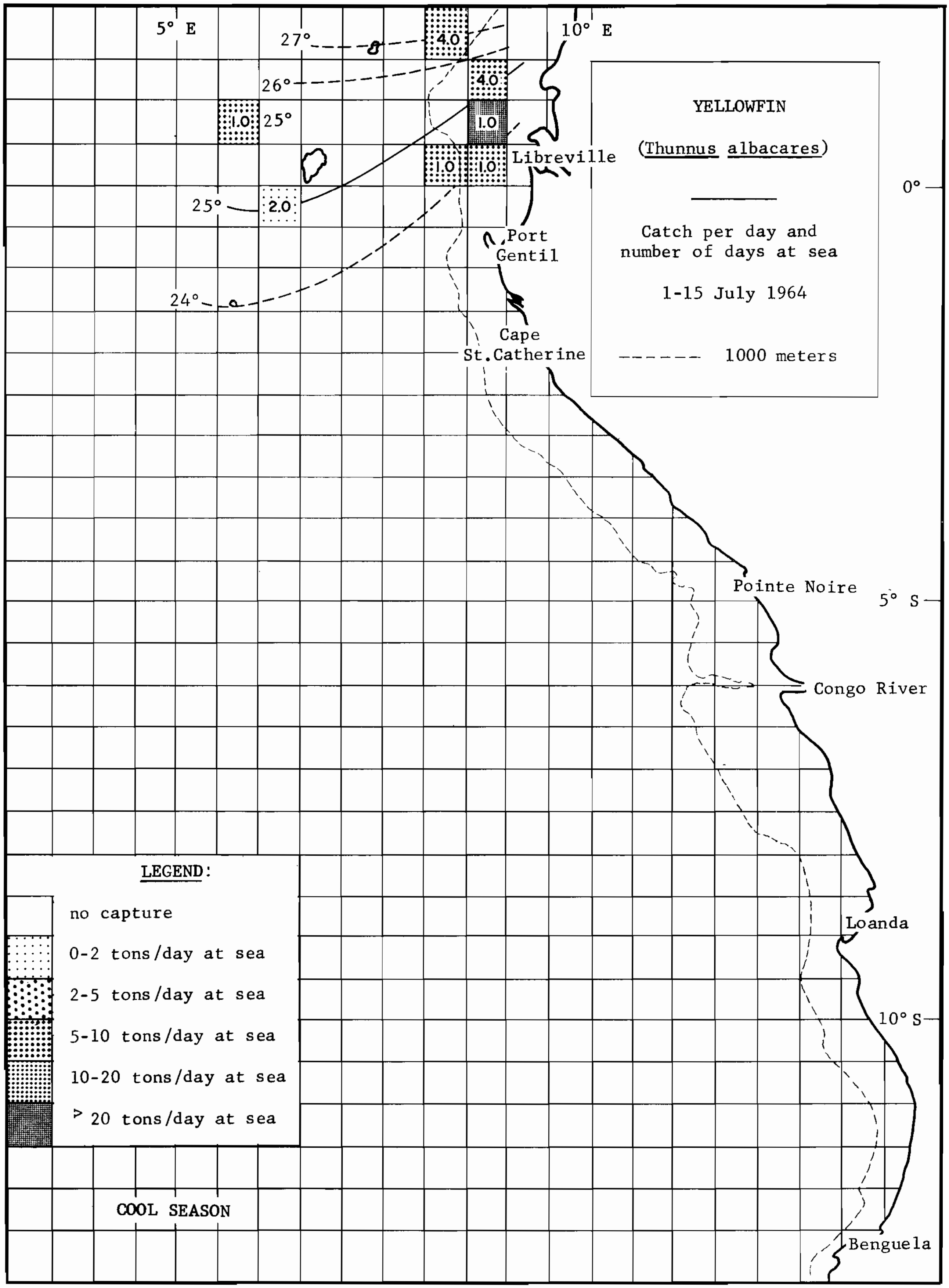
YELLOWFIN
(Thunnus albacares)
Catch per day and
number of days at sea
1-15 February 1964
1000 meters
5°E
10°E
0°
5°S
10°S
Libreville
Port
Gentil
Cape
St.Catherine
Pointe Noire
Congo River
Loanda
Benguela
0.5
1.0
1.0
1.0
28°
10.0
0.3
1.0
1.0
1.0
0.3
0.3
0.3
0.3
0.3
0.3
0.3
0.3
0.3
0.3
0.3
0.3
LEGEND:
no capture
0-2 tons/day at sea
2-5 tons/day at sea
5-10 tons/day at sea
10-20 tons/day at sea
> 20 tons/day at sea
WARM SEASON


5°E
10° E
0.2
0.2
0.2
0.2
13.0
Libreville
Port Gentil
Cape St.Catherine
YELLOWFIN
(Thunnus albacares)
Catch per day and number of days at sea
16-29 February 1964
-------- 1000 meters
0°
29°(1961)
Pointe Noire
5°S
Congo River
Loanda
29°(1961)
10°S
28°(1961)
27°(1961)
Benguela
LEGEND:
No capture
0-2 tons/day at sea
2-5 tons/day at sea
5-10 tons/day at sea
10-20 tons/day at sea
> 20 tons/day at sea
WARM SEASON
THE WARM FRONT (25°) IS AT MOSSAMEDES

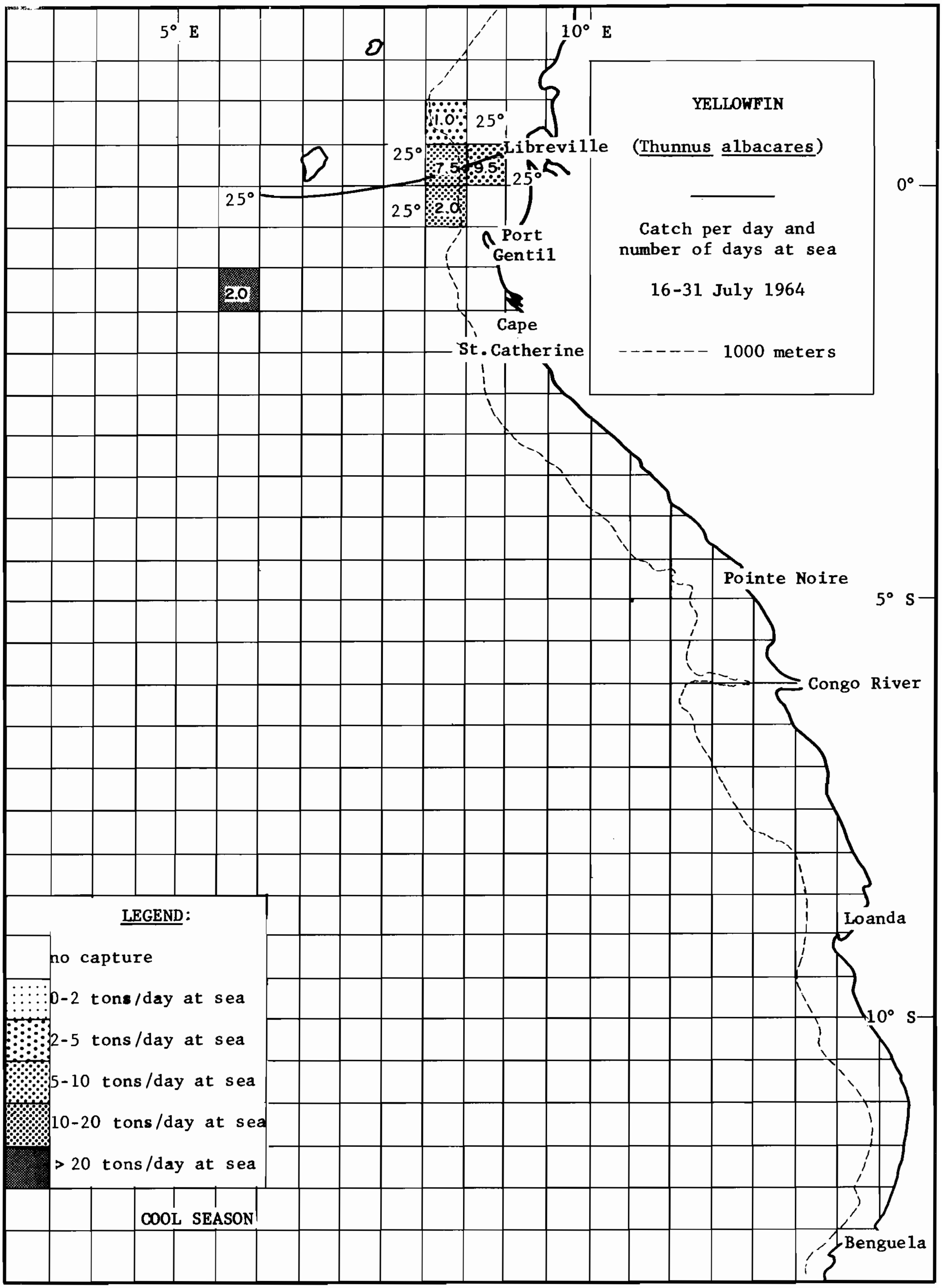

5° E
10° E
YELLOWFIN
(Thunnus albacares)
Catch per day and
number of days at sea
1-15 June 1964
1000 meters
Libreville
0°
Port
Gentil
Cape
St.Catherine
0.1
0.1
Pointe Noire
23.5°
5° S
23.5°
0.1
0.1
Congo River
23°
0.3
23.5°
0.3
0.3
24°
Loanda
10° S
Benguela
LEGEND:
no capture
0-2 tons/day at sea
2-5 tons/day at sea
5-10 tons/day at sea
10-20 tons/day at sea
> 20 tons/day at sea
COOL SEASON



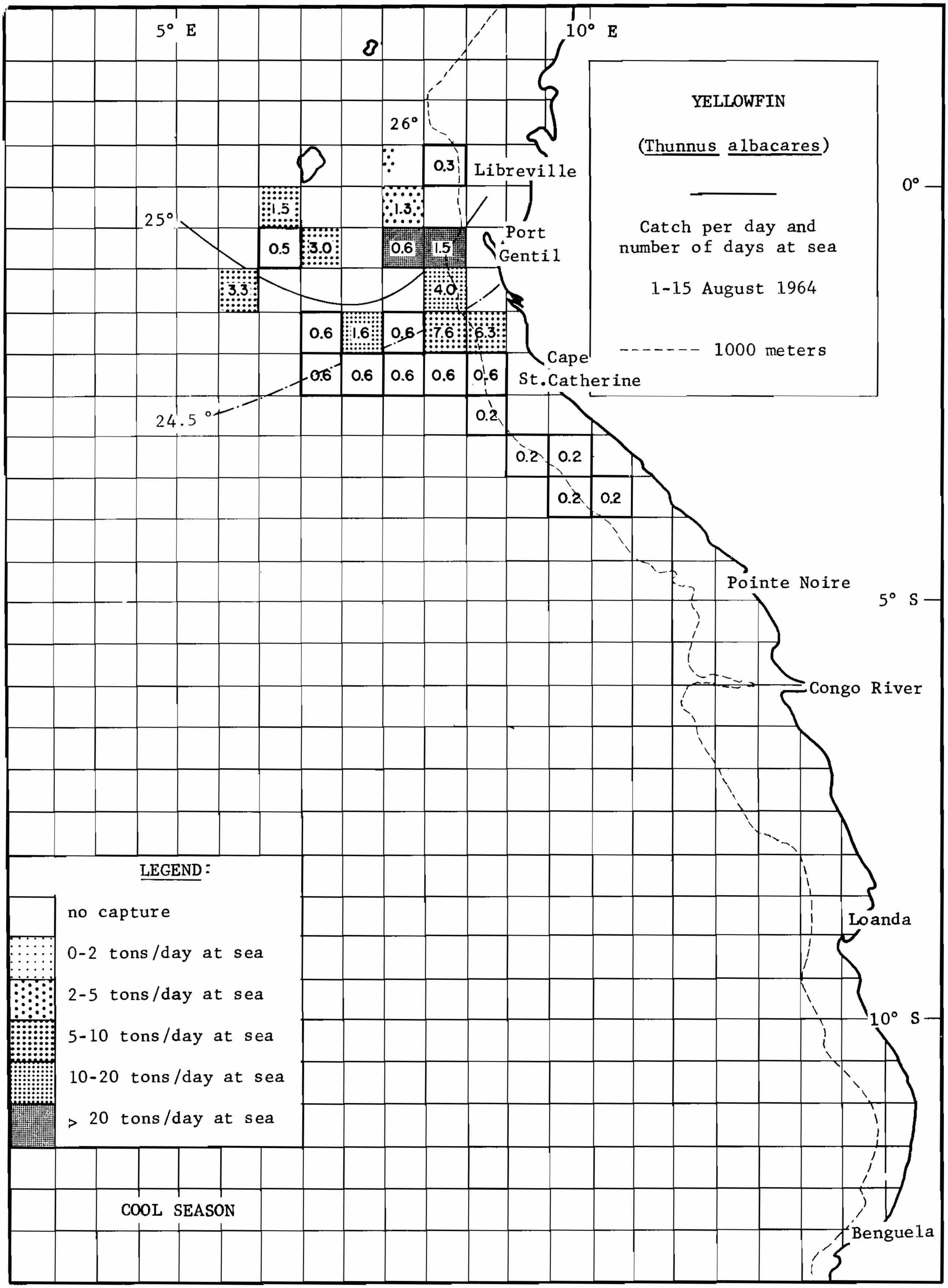
5° E
10° E
YELLOWFIN
(Thunnus albacares)
Catch per day and
number of days at sea
16-30 June 1964
1000 meters
0°
5° S
10° S
Libreville
Port
Gentil
Cape
St.Catherine
Pointe Noire
Congo River
Loanda
Benguela
26°
26°
25°
25°
25°
25°
26.5°
4.0
6.0
2.0
3.0
4.0
LEGEND:
no capture
0-2 tons/day at sea
2-5 tons/day at sea
5-10 tons/day at sea
10-20 tons/day at sea
> 20 tons/day at sea
COOL SEASON

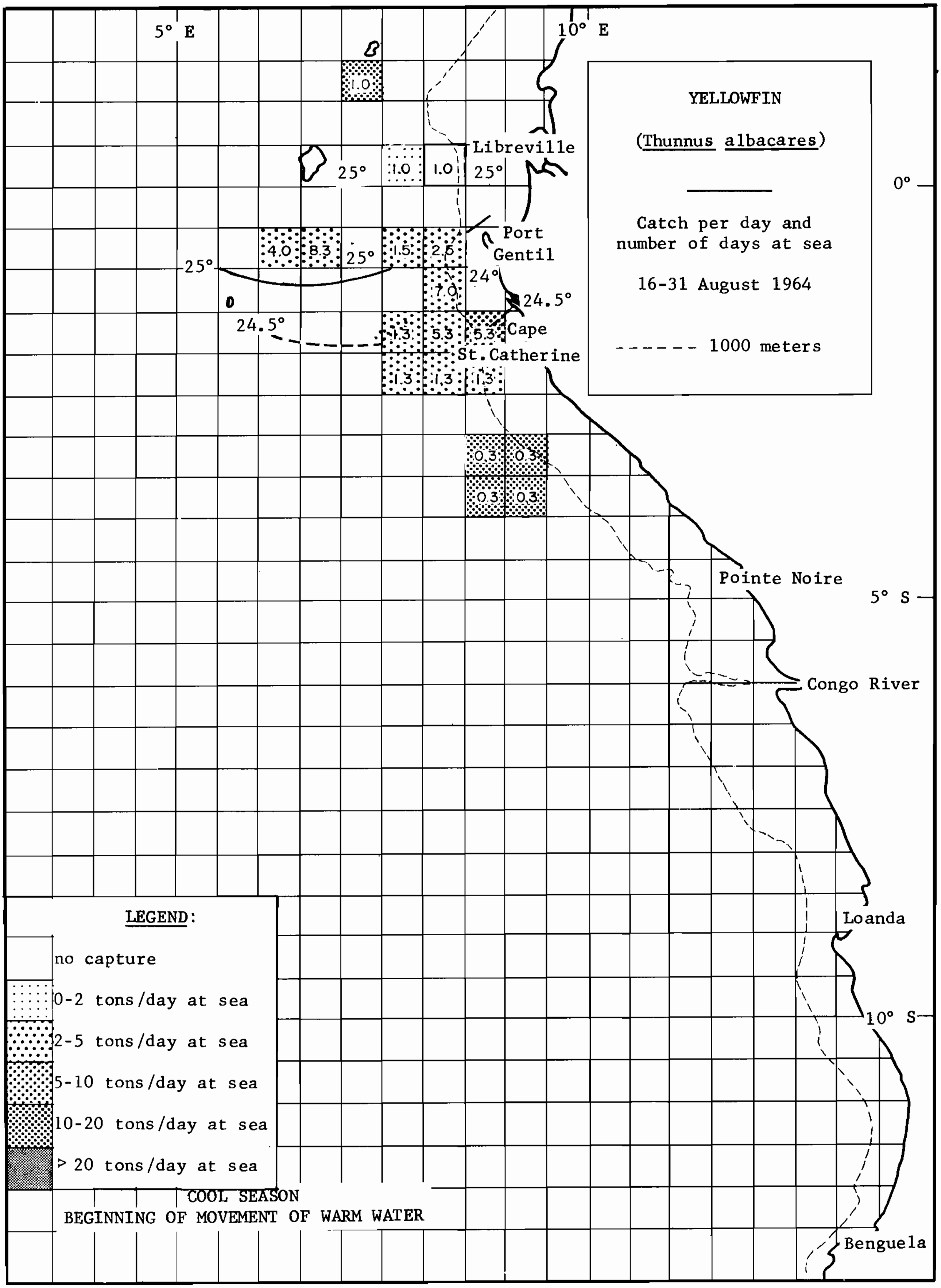


5° E
10° E
27°
26°
25°
25°
24°
4.0
4.0
1.0
1.0
1.0
1.0
2.0
Libreville
Port Gentil
Cape St.Catherine
Pointe Noire
Congo River
Loanda
Benguela
0°
5° S
10° S
YELLOWFIN
(Thunnus albacares)
Catch per day and number of days at sea
1-15 July 1964
1000 meters
LEGEND:
no capture
0-2 tons/day at sea
2-5 tons/day at sea
5-10 tons/day at sea
10-20 tons/day at sea
> 20 tons/day at sea
COOL SEASON

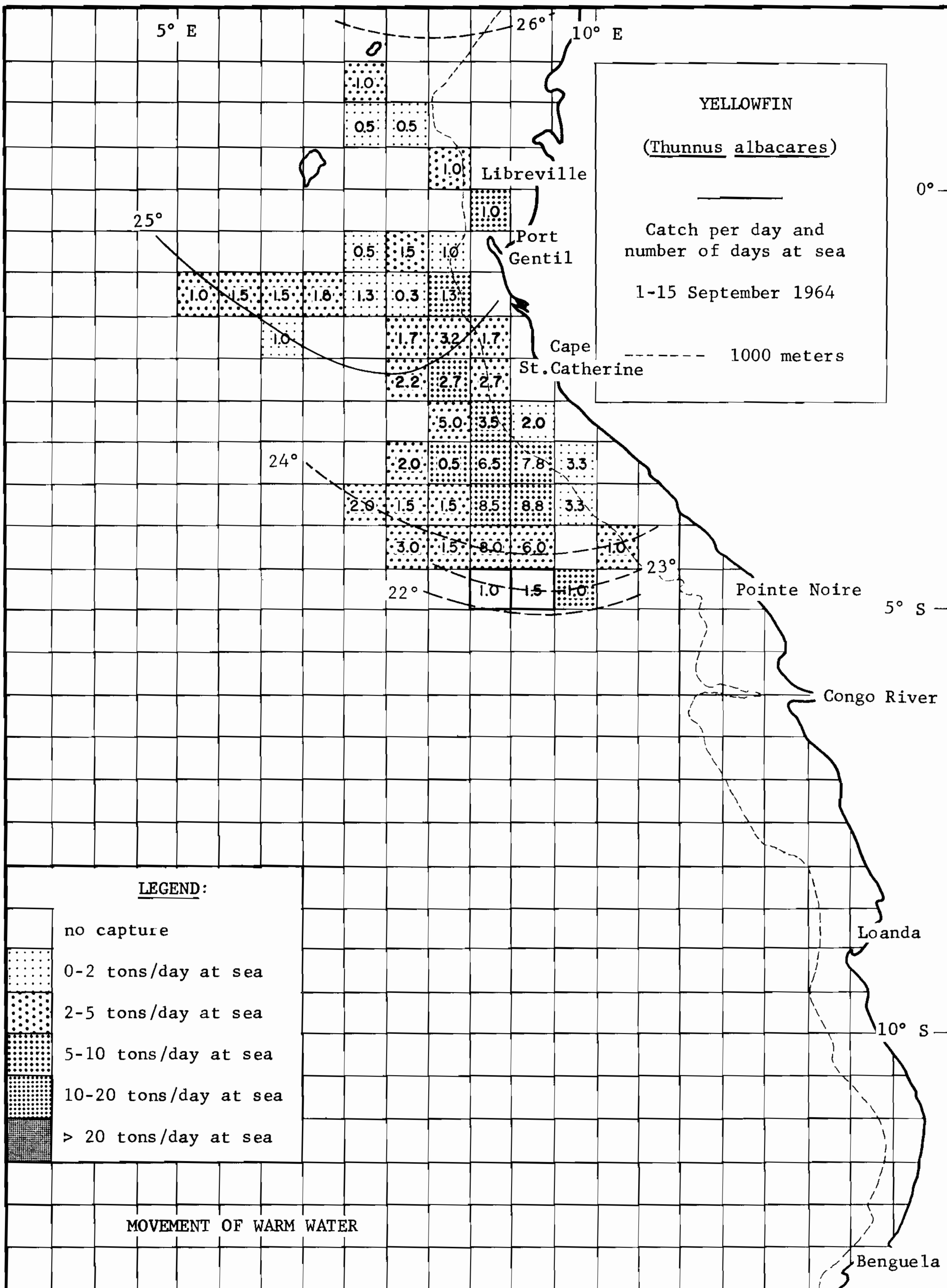


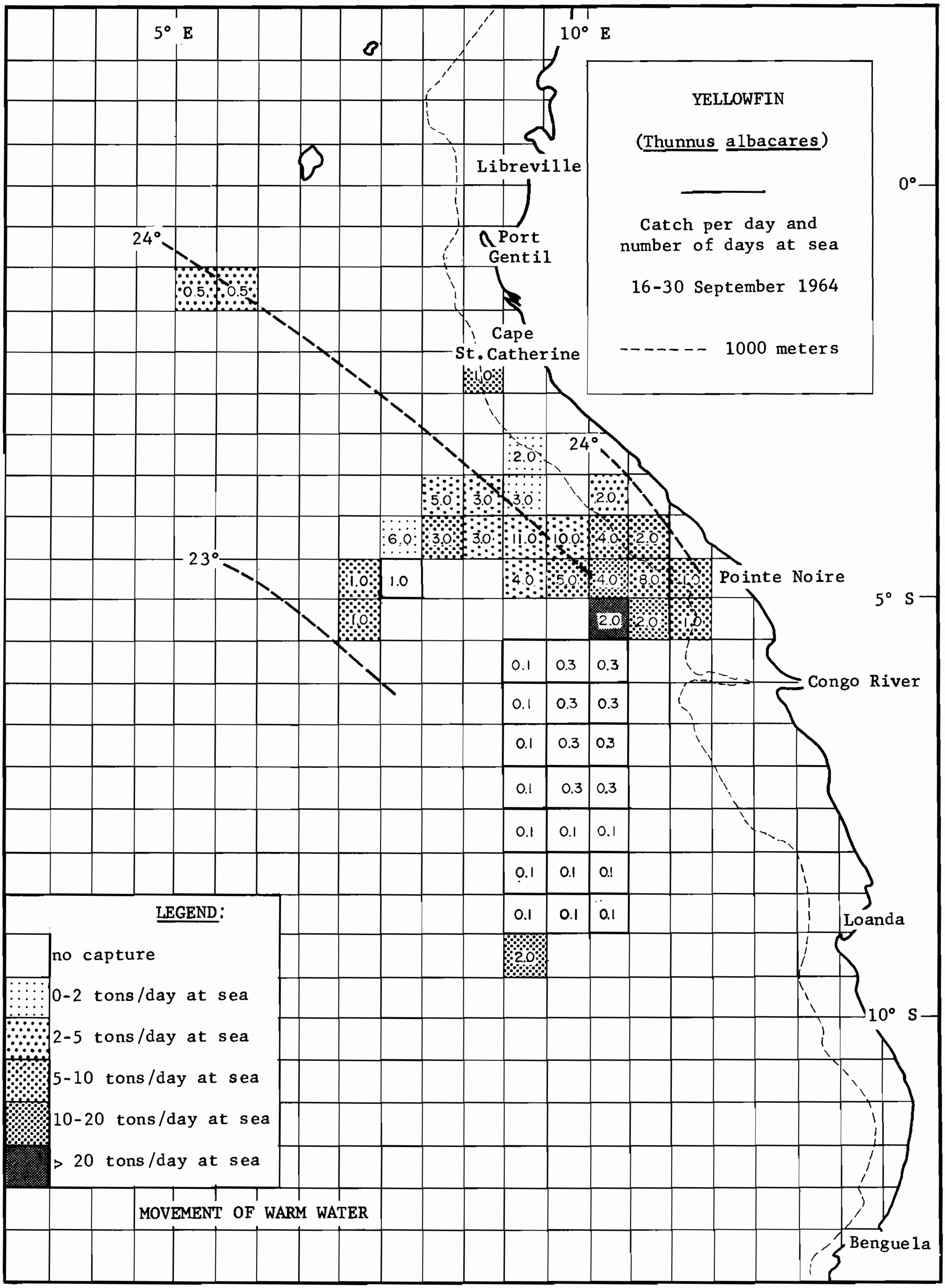
5° E
10° E
YELLOWFIN
(Thunnus albacares)
Catch per day and
number of days at sea
16-31 July 1964
1000 meters
1.0
25°
Libreville
25°
7.5
9.5
25°
25°
25°
2.0
Port
Gentil
2.0
Cape
St.Catherine
0°
Pointe Noire
5° S
Congo River
Loanda
10° S
Benguela
LEGEND:
no capture
0-2 tons/day at sea
2-5 tons/day at sea
5-10 tons/day at sea
10-20 tons/day at sea
> 20 tons/day at sea
COOL SEASON


YELLOWFIN
(Thunnus albacares)
Catch per day and number of days at sea
1-15 August 1964
1000 meters
5° E
10° E
0°
5° S
10° S
26°
25°
24.5°
Libreville
Port Gentil
Cape St.Catherine
Pointe Noire
Congo River
Loanda
Benguela
0.3
1.5
1.3
0.5
3.0
0.6
1.5
3.3
4.0
0.6
1.6
0.6
7.6
6.3
0.6
0.6
0.6
0.6
0.6
0.2
0.2
0.2
0.2
0.2
LEGEND:
no capture
0-2 tons/day at sea
2-5 tons/day at sea
5-10 tons/day at sea
10-20 tons/day at sea
> 20 tons/day at sea
COOL SEASON

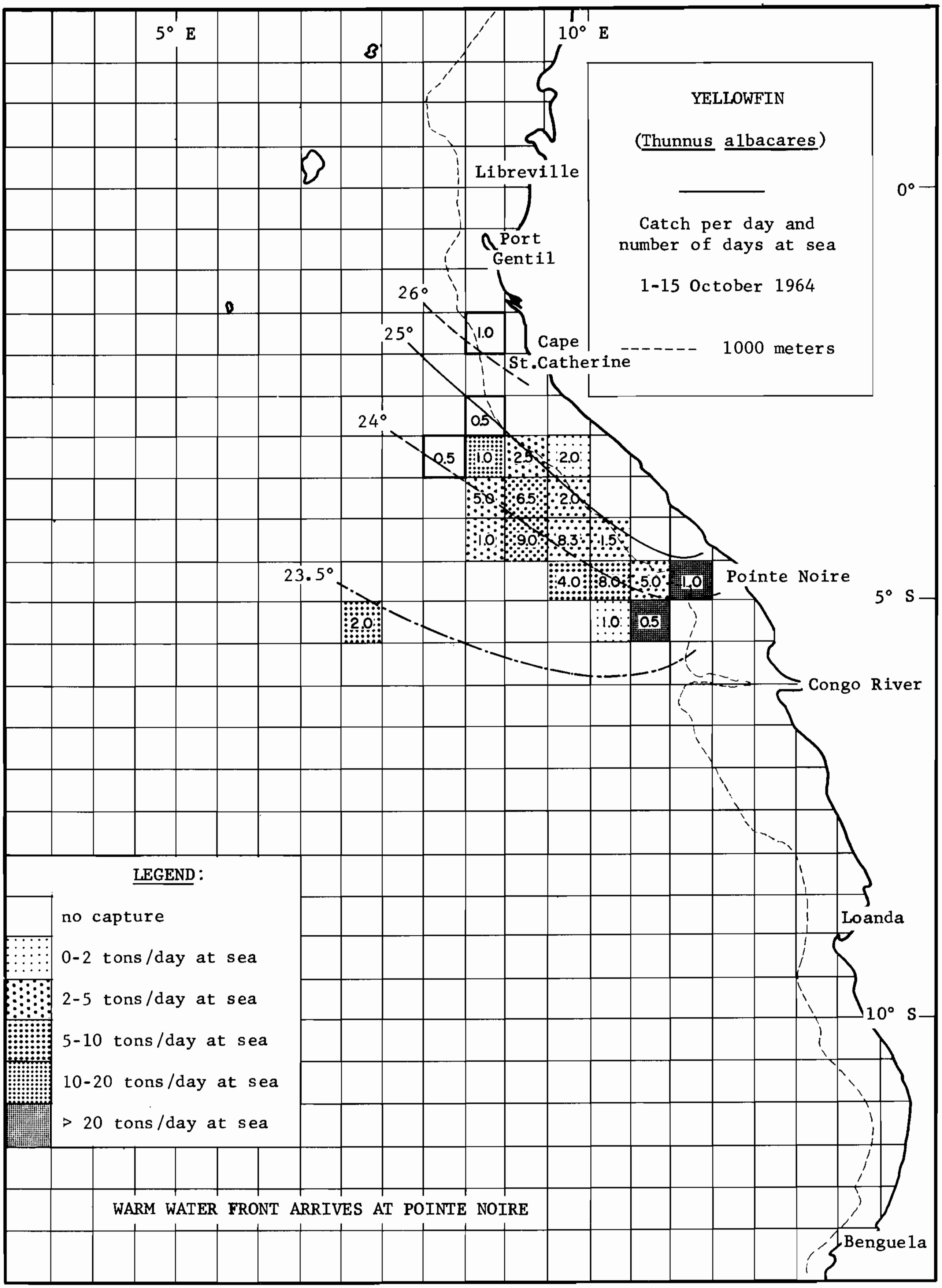


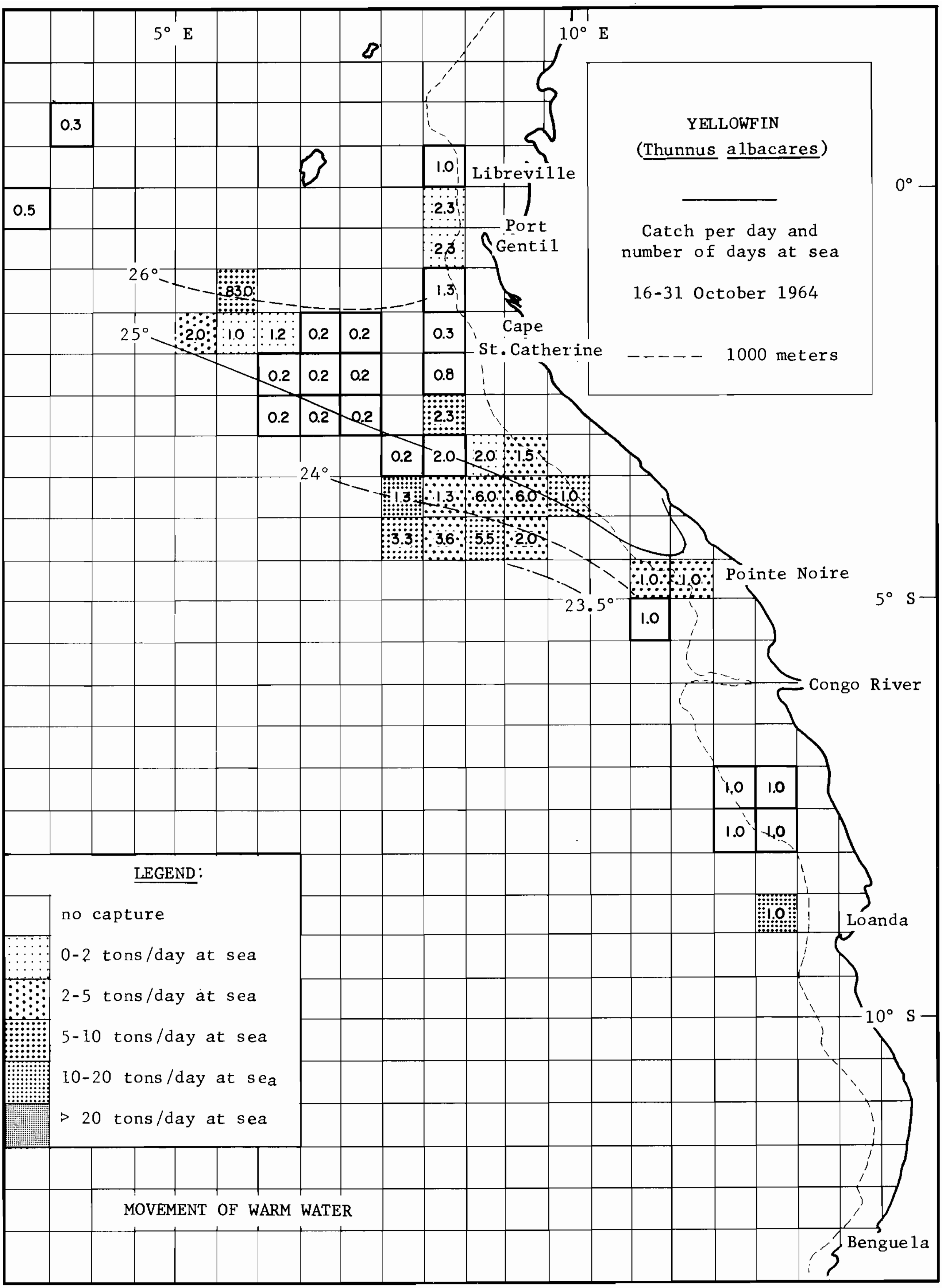
COOL SEASON
BEGINNING OF MOVEMENT OF WARM WATER


YELLOWFIN
(Thunnus albacares)
Catch per day and number of days at sea
1-15 September 1964
1000 meters
5° E
10° E
0°
5° S
10° S
26°
25°
24°
23°
22°
Libreville
Port Gentil
Cape St.Catherine
Pointe Noire
Congo River
Loanda
Benguela
LEGEND:
no capture
0-2 tons/day at sea
2-5 tons/day at sea
5-10 tons/day at sea
10-20 tons/day at sea
> 20 tons/day at sea
MOVEMENT OF WARM WATER

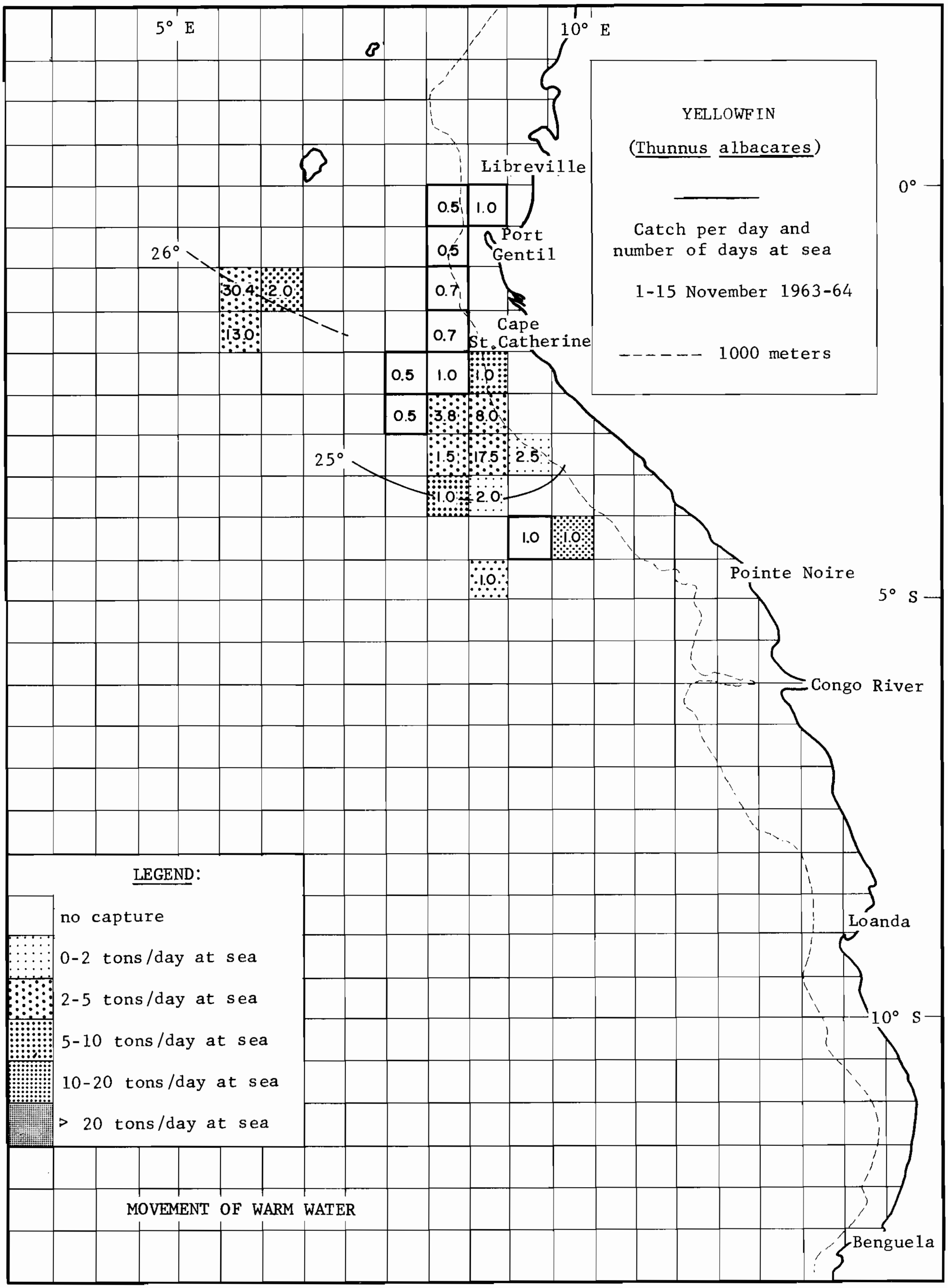


YELLOWFIN
(Thunnus albacares)
Catch per day and number of days at sea
16-30 September 1964
1000 meters
5° E
10° E
0°
5° S
10° S
Libreville
Port Gentil
Cape St.Catherine
Pointe Noire
Congo River
Loanda
Benguela
24°
23°
0.5
0.5
1.0
2.0
5.0
3.0
3.0
2.0
6.0
3.0
3.0
11.0
10.0
4.0
2.0
1.0
1.0
4.0
5.0
4.0
8.0
1.0
1.0
2.0
2.0
1.0
0.1
0.3
0.3
0.1
0.3
0.3
0.1
0.3
0.3
0.1
0.3
0.3
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
2.0
LEGEND:
no capture
0-2 tons/day at sea
2-5 tons/day at sea
5-10 tons/day at sea
10-20 tons/day at sea
> 20 tons/day at sea
MOVEMENT OF WARM WATER

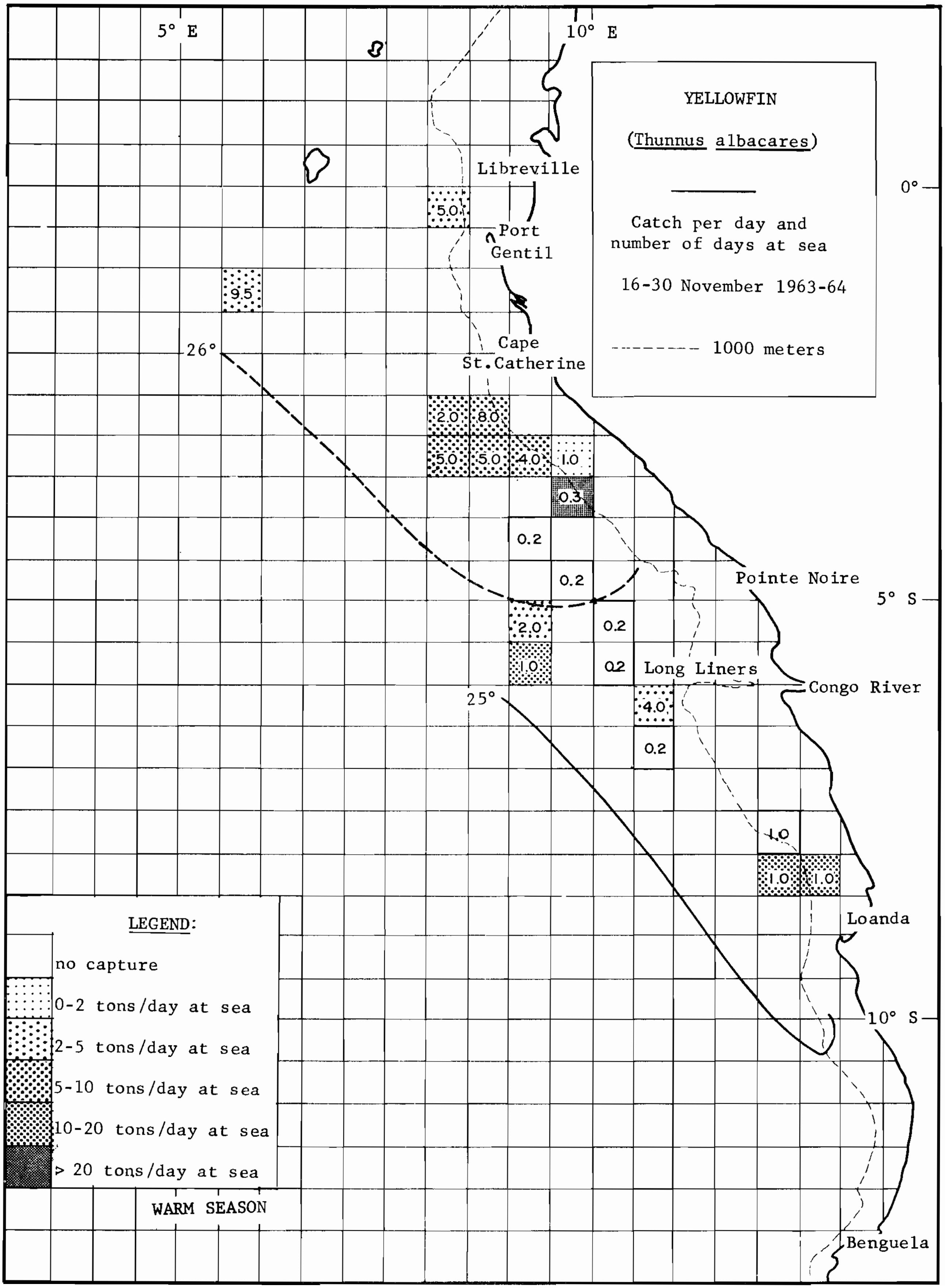

5° E
10° E
YELLOWFIN
(Thunnus albacares)
Catch per day and
number of days at sea
1-15 October 1964
1000 meters
Libreville
Port
Gentil
Cape
St.Catherine
Pointe Noire
Congo River
Loanda
Benguela
0°
5° S
10° S
26°
25°
24°
23.5°
1.0
0.5
0.5
1.0
2.5
2.0
5.0
6.5
2.0
1.0
9.0
8.3
1.5
4.0
8.0
5.0
1.0
2.0
1.0
0.5
LEGEND:
no capture
0-2 tons/day at sea
2-5 tons/day at sea
5-10 tons/day at sea
10-20 tons/day at sea
> 20 tons/day at sea
WARM WATER FRONT ARRIVES AT POINTE NOIRE

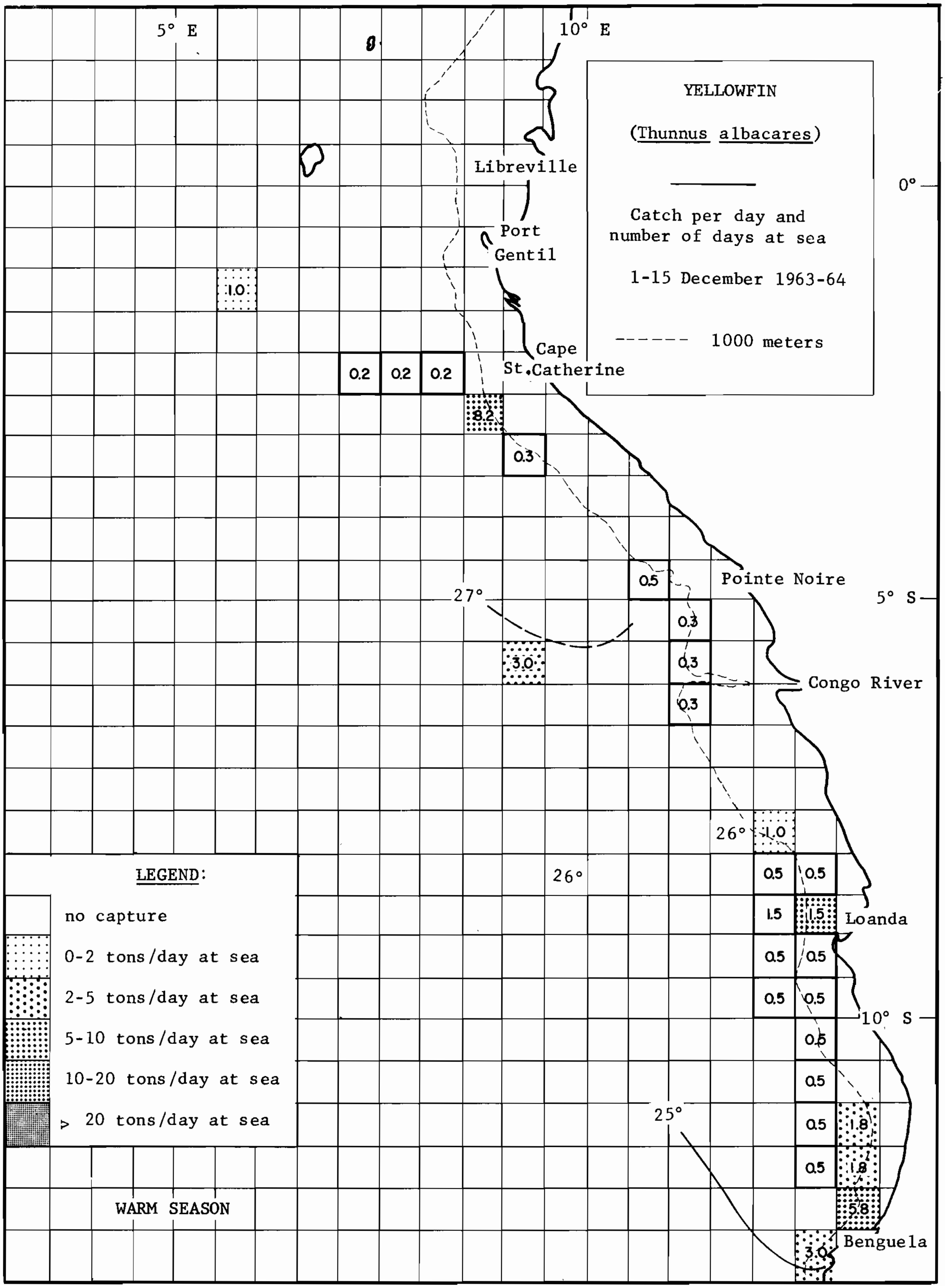


5° E
10° E
0°
5° S
10° S
YELLOWFIN
(Thunnus albacares)
Catch per day and number of days at sea
16-31 October 1964
1000 meters
Libreville
Port Gentil
Cape St. Catherine
Pointe Noire
Congo River
Loanda
Benguela
26°
25°
24°
23.5°
0.3
0.5
1.0
2.3
2.3
1.3
830
2.0
1.0
1.2
0.2
0.2
0.3
0.2
0.2
0.2
0.8
0.2
0.2
0.2
2.3
0.2
2.0
2.0
1.5
1.3
1.3
6.0
6.0
1.0
3.3
3.6
5.5
2.0
1.0
1.0
1.0
1.0
1.0
1.0
1.0
1.0
LEGEND:
no capture
0-2 tons/day at sea
2-5 tons/day at sea
5-10 tons/day at sea
10-20 tons/day at sea
> 20 tons/day at sea
MOVEMENT OF WARM WATER

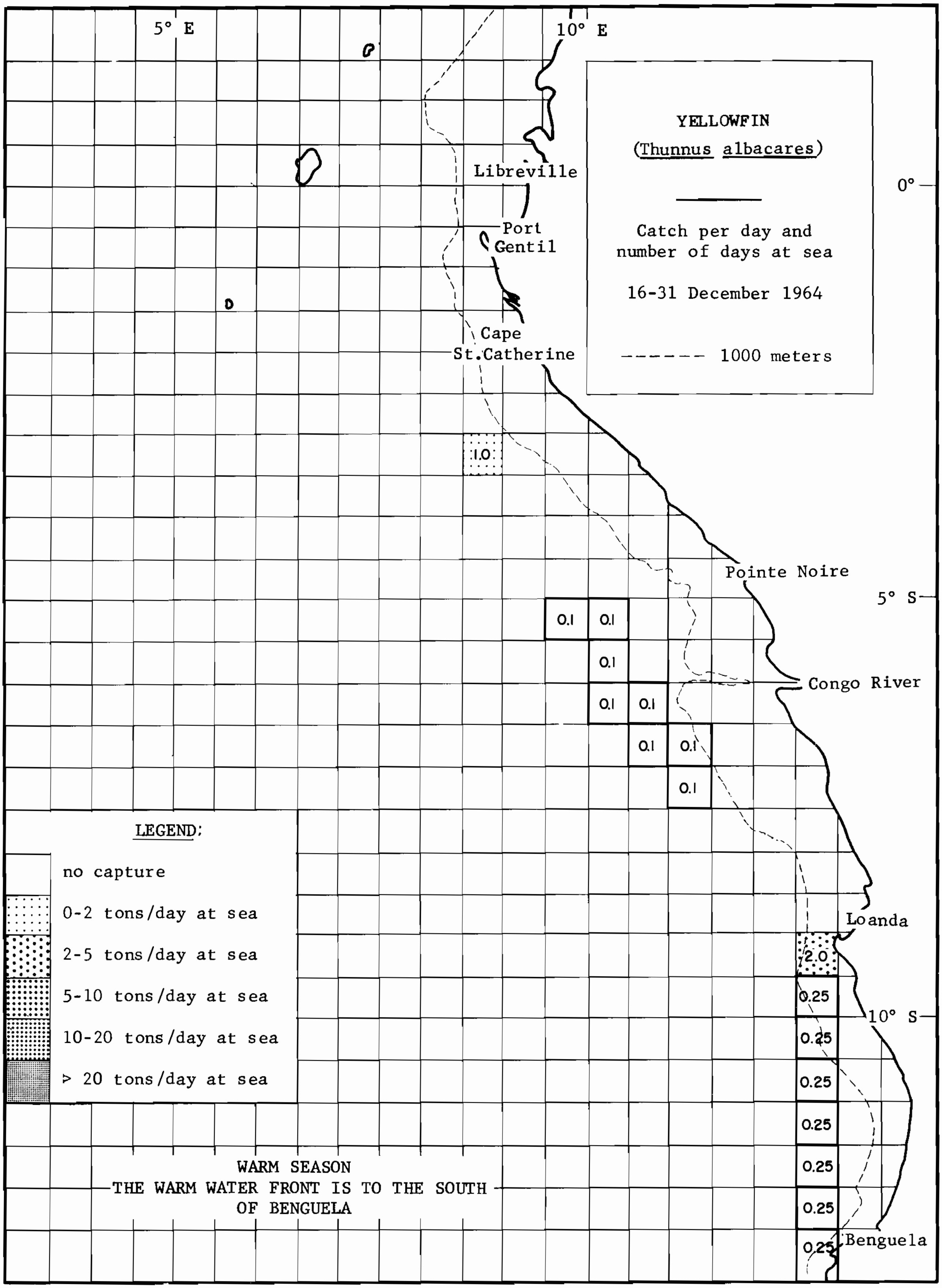


YELLOWFIN
(Thunnus albacares)
Catch per day and number of days at sea
1-15 November 1963-64
1000 meters
5° E
10° E
0°
5° S
10° S
Libreville
Port Gentil
Cape St.Catherine
Pointe Noire
Congo River
Loanda
Benguela
26°
25°
0.5
1.0
0.5
0.7
0.7
30.4
2.0
13.0
0.5
1.0
1.0
0.5
3.8
8.0
1.5
17.5
2.5
1.0
2.0
1.0
1.0
1.0
LEGEND:
no capture
0-2 tons/day at sea
2-5 tons/day at sea
5-10 tons/day at sea
10-20 tons/day at sea
> 20 tons/day at sea
MOVEMENT OF WARM WATER


5° E
10° E
YELLOWFIN
(Thunnus albacares)
Catch per day and number of days at sea
16-30 November 1963-64
1000 meters
0°
5° S
10° S
Libreville
Port Gentil
Cape St.Catherine
Pointe Noire
Long Liners
Congo River
Loanda
Benguela
26°
25°
5.0
9.5
2.0
8.0
5.0
5.0
4.0
1.0
0.3
0.2
0.2
2.0
0.2
1.0
0.2
4.0
0.2
1.0
1.0
1.0
LEGEND:
no capture
0-2 tons/day at sea
2-5 tons/day at sea
5-10 tons/day at sea
10-20 tons/day at sea
> 20 tons/day at sea
WARM SEASON



5° E
10° E
YELLOWFIN
(Thunnus albacares)
Catch per day and number of days at sea
1-15 December 1963-64
1000 meters
0°
5° S
10° S
Libreville
Port Gentil
Cape St.Catherine
Pointe Noire
Congo River
Loanda
Benguela
27°
26°
26°
25°
1.0
0.2
0.2
0.2
8.2
0.3
0.5
0.3
0.3
0.3
3.0
1.0
0.5
0.5
1.5
1.5
0.5
0.5
0.5
0.5
0.5
0.5
0.5
1.8
0.5
1.8
5.8
3.0
LEGEND:
no capture
0-2 tons/day at sea
2-5 tons/day at sea
5-10 tons/day at sea
10-20 tons/day at sea
> 20 tons/day at sea
WARM SEASON



5° E
10° E
0°
5° S
10° S
Libreville
Port Gentil
Cape St.Catherine
Pointe Noire
Congo River
Loanda
Benguela
YELLOWFIN
(Thunnus albacares)
Catch per day and number of days at sea
16-31 December 1964
1000 meters
1.0
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
2.0
0.25
0.25
0.25
0.25
0.25
0.25
0.25
LEGEND:
no capture
0-2 tons/day at sea
2-5 tons/day at sea
5-10 tons/day at sea
10-20 tons/day at sea
> 20 tons/day at sea
WARM SEASON
THE WARM WATER FRONT IS TO THE SOUTH OF BENGUELA