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AREAS, PERIODS AND CONDITIONS OF BIGEYE TUNA, THUNNUS OBESUS (LOWE), SPAWNING IN THE TROPICAL PART OF THE ATLANTIC OCEAN

G. P. Rudomiotkina

Atlantniro

SUMMARY

The spawning areas of bigeye tuna are located in the east central part of the ocean north of 5°N and in the Gulf of Guinea with the adjacent waters on the northwest and on the south. The spawning takes place in the areas of high biological productivity - the borders of quasistationary eddies, peripheries of local upwellings ("Guinean Dome," "Angolan Dome"), divergence regions of the Inter Trade Wind (Equatorial) countercurrent, the northern branch of the Southern Trade Wind current. In each geographic area spawning is confined to the warmest season of the year (temperature of 24.3-28.8°C; salinity of 33.8-36.0%).

RESUME

Les zones de ponte du thon obèse se situent dans la partie centre-est de l'océan, au nord des 5ºN, et dans le golfe de Guinée dans les eaux adjacentes du nord-ouest et du sud. La ponte a lieu dans les eaux à productivité biologique intense - en bordure de courants presque stationnaires, sur la périphérie des affleurements (Dôme de Guinée et Dôme d'Angola), zones de divergence du contre-courant (équatorial) des alizés, dans la partie nord du courant de l'alizé sud. Dans chacune de ces zones géographiques la ponte est limitée à la saison la plus chaude (température: 24,3-28,8ºC; salinité: 33,8-36,0 %.

RESUMEN

Las zonas de desove del patudo se encuentran en la parte centro-oriental del océano, al Norte de 5ºN y en el Golfo de Guinea, con aguas adyacentes al Noroeste y al Sur. El desove tiene lugar en las zonas de gran productividad biológica - límites de remolinos localizados, periferia de afloramientos locales ("Guinean dome", "Angolan dome"), regiones de divergencia de la contracorriente Ecuatorial y rama Norte de la corriente de los alisios del Sur. En cada una de las zonas geográficas, el desove sólo tiene lugar durante la temporada mas cálida del año (24.3 - 28.8ºC, salinidad 33.8 - 36.0%).

The bigeye tuna, Thunnus obesus (Lowe), is one of the major commercial tuna species. Usually, the pre-spawning and spawning aggregations are fished, therefore, the knowledge of the spawning periods, areas and conditions is of the great practical importance.

The data on reproductive areas and periods are reported by Kume, Morita (1976), Alekseev and Alekseeva (1978). Richards (1969), Richards and Simmons (1971), Nishikawa, Kikawa, Honma and Yeyangi (1978) also reported on the captured larvae.

In the present paper the results of our studies based on the long-term materials of the ichthyoplankton collections (1963-1981) from the Tropical Atlantic Ocean are considered (fig.1, Table 1). The studies were aimed at the definition of the areas, dates, th thermal and haline conditions of spawning of the bigeye tuna based on the distribution of small larvae.

In the Central Atlantic, north of 5°N, the intensive spawning was observed in summer, with the peak in July-August (Kume, Morita, 1976) and June-July (Alekseev, Alekseeva, 1978). This was confirmed by the gonad condition. The latter authors distinguished a reproductive area (approximately 5-10°N, 30-40°W), where the tunas are likely to concentrate in the spawning season from the adjacent regions. During the Equalant I and II surveys the larvae were found only in August-September, and were absent from the ichthyoplankton collections in February-April (Richards, 1969). In the Sierra Leone area the larvae were found in March and April (Richards, Simmons, 1971). In our collections from this area, which were taken throughout the year (fig. 1), the small larvae were caught only in the warmest period of the year (July-September) (fig. 2-III). The area of high larvae catch, (approximately 10 sp.) (fig. 2-III) was confined to the southern periphery of the powerful upwelling south-east of the Cabo Verde Islands between 10-16°N and 20-24°W of the Guinean Dome. The subsurface water temperature in the sites, where the larvae were caught exceeded 24°C, which is characteristic of the warm season. Richards (1969) reported 24.6-27.5°; Richards, Simmons (1971) - over 25°C; our data - 26.3-28.3°C; Richards (1969), Richards, Simmons (1971) reported the salinity over 34.0‰; our data - 35.2-36.0‰. In spring, in the waters north of the Cabo Verde Islands latitude at the gradual decrease of the temperature (to 23°C) the larvae were not found (fig. 1-III), although the sampling activities were rather intensive (fig. 3).

In the Gulf of Guinea the fish with the ripe gonads were found only in the southern summer period (Kume, Morita, 1976; Alekseev, Alekseeva, 1978). The latter authors defined two spawning periods in the near-equatorial waters of the reproductive areas, and reported that the peak of the spawning in the second area occurs at the warm season height (January-February), that is the sexual cycle of the tunas from this area is in the counterphase relative to an above-mentioned group in the northern hemisphere. The reproductive area is located in the open part of the Gulf of Guinea. It is likely that the reproductive areas for the bigeye tuna groups occurring in the northern and southern hemispheres partly overlap in the north-western part of the Gulf of Guinea. During the Equalant I surveys conducted in the warm season (February-April) in the Gulf of Guinea the larvae were found everywhere approximately to 10°S (Richards, 1969). During the Jeronimo 3,5 surveys (February-April) the larvae occurred both in the Gulf of Guinea and along the Sierra Leone coast (Richards, Simmons, 1971). A different picture of the larva distribution was observed in the cold season, from August to October (Equalant II and Jeronimo surveys) (Richards, 1969; Richards, Simmons, 1971). During the first survey no larvae were recorded except at two stations along the northern coast of the Gulf of Guinea; during the second survey they were collected in the waters adjacent to the Gulf coast (fig. 4) and were absent from the collections taken at outer stations of the transects, which, in the authors opinion, can be explained by "a low sampling intensity". In the Fernando Po Island area the surveys were conducted in summer (December-March) and in winter (June, August), but the larvae were also found at the warm season height in March (Richards, 1969). South of the equator, with the onset of the warm season (October-December) the larvae were recorded during the surveys of "Shoyo Maru" (Nishikawa et al., 1978). According to our data, the larvae were common and widely spread all over the vast area of the Southern Trade Wind Current area only in

January-March (fig. 2-I), although the intensive ichthyoplankton sampling was carried out throughout the year (except in April-June) (fig. 1). During this period the largest collections of the larvae (to 5 sp/haul) were taken along the border of the divergence zone at the northern edge of the Southern Trade Wind Current. Only one case was recorded of collecting the larvae in the cold season (July-September) (fig. 2-III). The temperature in the sites where the larvae were collected both in the warm or cold seasons (July-October, sparse) was typical of the warm season (over 24°C) and was 27-28°C (Richards, 1969), 28.4-29.8°C (Richards, 1969), 24.0-29.5°C (Richards, Simmons, 1971), 25.8-28.4°C (our data). Salinity varied between 34.0 and 36.4‰ (Richards, 1969), 33.0-33.6‰ (Richards, 1969), 34.4-36.0 (our data). It is beyond doubt that the larvae prefer the water with the temperature over 25-26°C and are absent from the areas with the temperature below 24°C. The salinity varying between 34 and 36‰ does not seem to exert such a considerable limiting effect as the temperature does. It is evident, however, that the larvae avoid the freshened waters with the salinity below 33-34‰ (fig. 4).

Below a review of the periods of the larvae occurrence in the Gulf of Guinea is given once again.

During the warm season (November-April) the larvae were always found all over the Gulf area. In the cold season (July-October) the range of the larva distribution was limited to the north-western part of the Gulf (north of 0-3°N), where they were rather sparse. Against this background, a comparatively rare occurrence of the larvae in the northern part of the Gulf of Guinea in the cold season (July-October) should not be attributed to the fact of low sampling intensity. This is rather a consequence of episodic spawnings taking place there due to favourable thermohaline conditions of the tunas from the group, which uses to reproduce in the Central Atlantic (north of 5°N) during the northern summer.

In the area off the Congo-Angola coast the mature females were found during the first quarter of the year (Kume, Morita, 1976), and the adult specimens with ripening gonads in the calendar autumn and winter (warm season) (Alekseev, Alekseeva, 1978). Richards (1969) reported on the occurrence of the larvae only in February-April (a prolonged warm season) at the temperatures of 27.0-28.8°C and salinity over 34‰, and on their absence in August-October (cold season). In our collections the small larvae were found in April-June and October-December (the end and beginning of the warm season) (fig. 2-II,IV). The region of occurrence of the larvae, where rather high catches were taken (approximately 5 sp./haul) in the north-eastern periphery of the Angolan Dome is located south of the Congo River mouth in April-June (fog. 2-II), and displaces to the north of it in October-December (fig. 2-IV). This can be attributed to the seasonal dynamics of the Congo River discharge (World water balance and water resources of the Earth, 1974). The high water and low water seasons fall on November-January and June-August respectively. Evidently, the environmental conditions in the rich in food although comparatively muddy water are favourable for the larvae collected in April-June (a transitional period from the high water to low water season). On the contrary, in October-December (the beginning of the maximum discharge) the larvae inhabited only the areas north of the Congo River mouth avoiding the rich in food, but freshened and muddy waters.

Thus, in the Tropical Atlantic the reproductive areas of the bigeye tuna are located in the East Central part of the ocean north of 5°N and the Gulf of Guinea with the adjacent waters on the north-west and on the south. In terms of oceanology, the first reproductive area is located in the system of the northern tropical cyclonic eddy (fig.5). The second one has a more complicated structure, and in addition to the southern tropical cyclonic eddy, it envelops a zone of equatorial upwellings from the West African coast to, as it seems, the South American coast (fig. 5). The oligothrophic waters of the northern branch of the equatorial countercurrent are a natural boundary dividing the reproductive areas.

Within the reproductive areas the spawning takes place in the regions of high biological productivity, namely, in the tropical cyclonic eddies. To be more exact, the spawning areas are confined to the sites of adjoining warm and cold waters (eddy boundaries) or to the periphery of local upwellings in the Guinean Dome, in the divergence regions of the Inter-Trade Wind countercurrent, in the Angolan Dome and in the northern branch of the Southern Trade Wind current.

The spawning in both reproductive areas takes place in summer of the corresponding hemisphere. Sexual cycles of spawning groups in these areas are in counterphase .

The spawning period in each geographic area is timed to its warmest season (table 2): August in the waters off Senegal; April-August off Sierra Leone; April-September in the central part of the ocean, north of 5°N; December-April in the Gulf of Guinea, south of 1-2°S; November-February off Congo-Angola.

The spawning takes place in a rather narrow range of the subsurface waters, which corresponds to thermal conditions of the warm season: 24.3°- 27.5°C north of the equator, and 25.8-28.8°C south of the equator. The peak of the spawning is observed at the temperature over 26.0°C. In the spawning season the salinity widely varies between 33.8 and 36.0‰. The lowest limit of the thermohaline conditions appropriate for the spawning is 24.0°C and 34.0‰.

Our studies have confirmed an earlier suggestion that the single bigeye tuna school consists of two groups ocurring in the northern and southern hemispheres which have their sexual cycles being in counterphase, and that a partial overlapping of the reproduction areas of tunas of these two groups, may take place in the north-western part of the Gulf of Guinea.

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Table 1

List of larvae catches

Positions	Data	Time of the day	Surface temperature	salinity
03 37 S 30 04 W	26.02.63	22.10		
08 35 N 39 00 W	18.09.64	19.00		35.97
11 34 N 20 25 W	14.11.68	05.25	28.2	35.21
03 23 S 32 07 W	21.11.68	17.45	27.2	35.37
06 00 S 33 40 W	22.11.68	15.30	26.7	
03 05 S 09 00 W	19.02.70	07.25	26.6	
05 49 S 09 09 W	21.02.70	07.30	26.5	35.75
07 03 S 09 03 E	11.04.70	16.18	28.3	31.22
10 12 S 12 22 E	15.04.70			
10 39 S 04 32 W	21.01.72	20.25	24.8	35.85
02 34 S 05 00 W	18.02.72	21.45	26.9	35.60
05 57 S 02 47 W	29.02.72	20.12	26.8	35.18
08 13 S 07 36 W	08.03.72	20.10	26.7	36.02
06 36 S 10 02 W	11.03.72	22.50	27.3	
03 00 S 10 00 W	17.03.72	02.30		
10 00 N 17 36 W	29.06.72			
12 08 N 19 15 W	01.07.72			
04 42 N 06 18 W	05.08.72			
07 20 N 22 35 W	16.08.72	08.00		
07 50 N 23 08 W	16.08.72	16.00		
08 01 N 24 10 W	17.08.72			
08 13 N 24 39 W	18.08.72			
06 13 S 06 15 W	04.02.73	00.19		
09 58 S 02.32 W	26.02.73	00.50	25.0	
10 17 S 07 44 W	13.03.73	00.41	26.9	
07 54 S 07 30 W	14.03.73	23.50	24.7	
05 13 S 07 24 W	15.03.73	22.45	28.0	
03 02 S 07 31 W	17.03.73	20.30		
06 20 S 09 58 W	27.03.73	00.57		
09 30 S 10 00 W	30.03.73	00.50	27.3	
09 58 S 12 30 W	31.03.73	01.48	27.0	
09 30 S 05 00 W	08.02.75	23.20	24.7	36.44
07 50 S 07 30 W	15.02.75	22.50	25.7	36.50
08 10 S 12 30 W	04.03.75	21.30	26.7	36.13
01 14 S 07 05 E	14.11.76	19.07		

Table 2

Times of bigeye tuna spawning

Area	Northern seasons I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Author
Senegal								X					Richards, 1969
Central Atlantic, north of 5°N				X	X	X	X	X	X				Richards, 1969; Richards, Simmons, 1971; Kume, Morita, 1976; Nishikawa et al., 1978; Alekseev, Alekseeva, 1979; our data
Gulf of Guinea, south of the equator						X	X	X	X				Richards, 1969; Kume, Morita, 1976; Nishikawa et al., 1978; Alekseev, Alekseeva, 1979; our data
Congo-Angola				X	X	X	X	X	X				Richards, 1969; Kume, Morita, 1976; Alekseev, Alekseeva, 1979; our data

	VII	VIII	IX	X	XI	XII	I	II	III	IV	V	VI
	spring				summer				autumn			
Southern seasons												

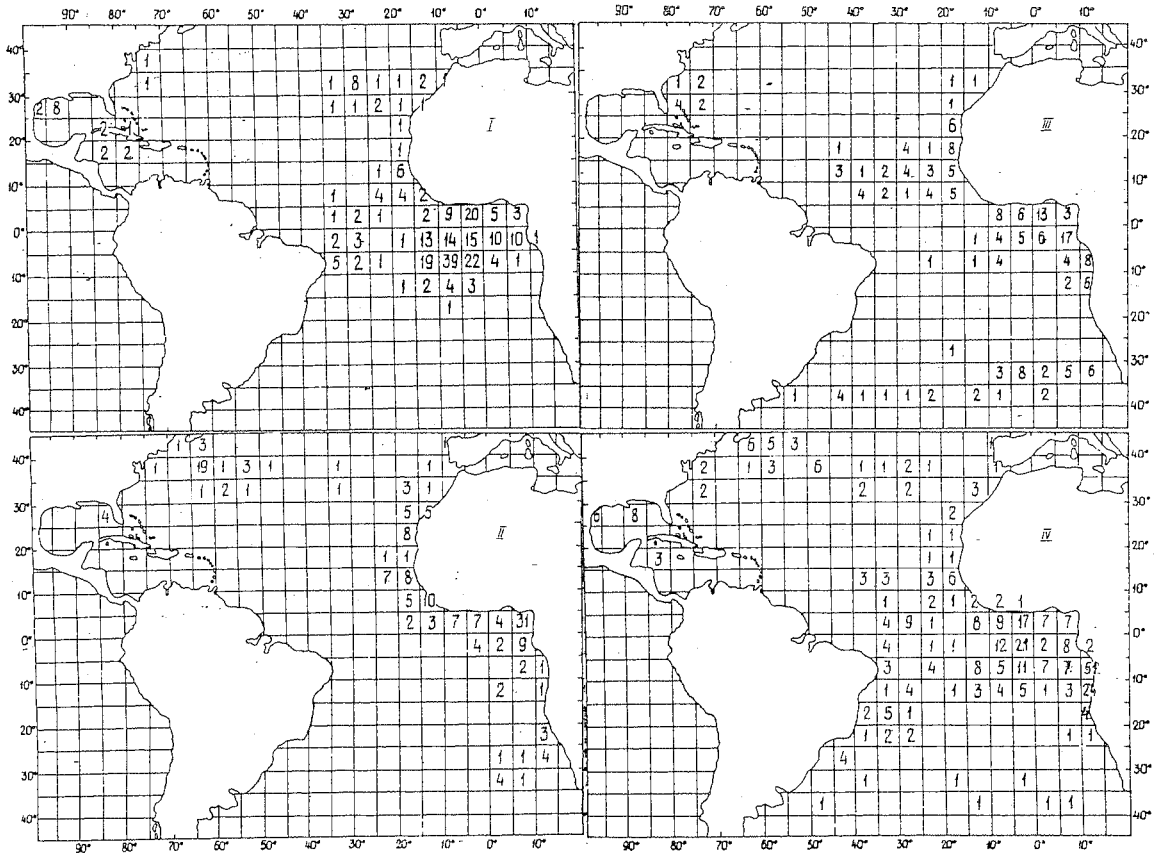

Fig. 1. Distribution of ichthyoplankton collections
I - January-March; II - April-June;
III - July-September; IV - October-December.

Note. Figures denote the number of ichthyoplankton collections by 5°-side square.

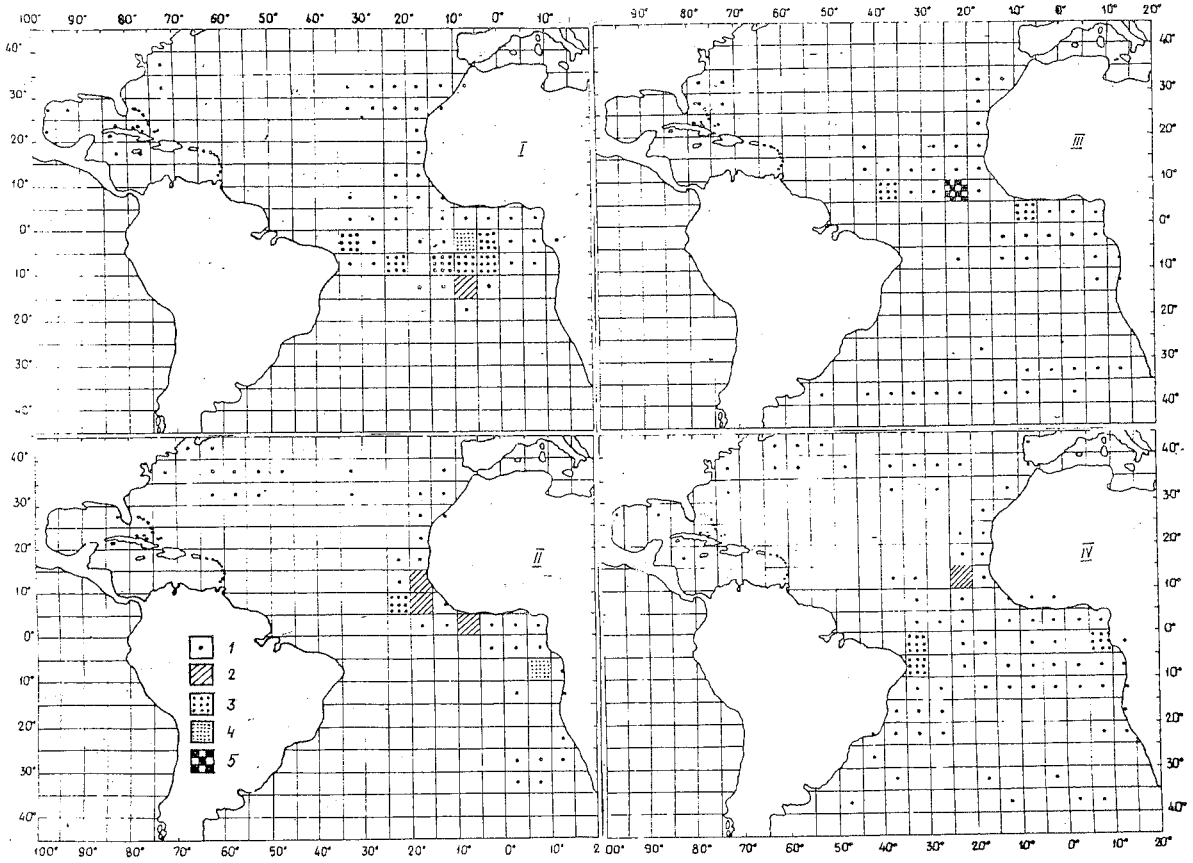

Fig. 2. Distribution of larvae in January-March (I); April-June (II); July-September (III); October-December (IV).

Definitions: 1- larvae absent
2- less than 0.09 larva per haul
3- 0.1 - 1.0 larva per haul
4- 1.1 - 5.0 larvae per haul
5-5.1 - 10.0 larvae per haul

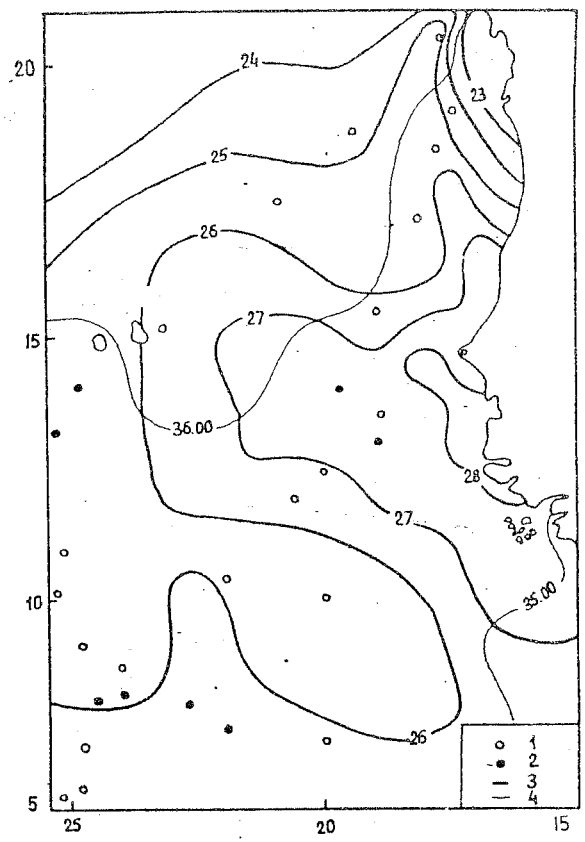

Fig. 3. Distribution of larvae in June-September (Richards, 1969; our data):
1 - ichthyoplankton stations
2 - larvae catches
3 - isotherms
4 - isohalines in August (from the Hydrometeorological directory on the waters of the western coast of Africa, 1964).

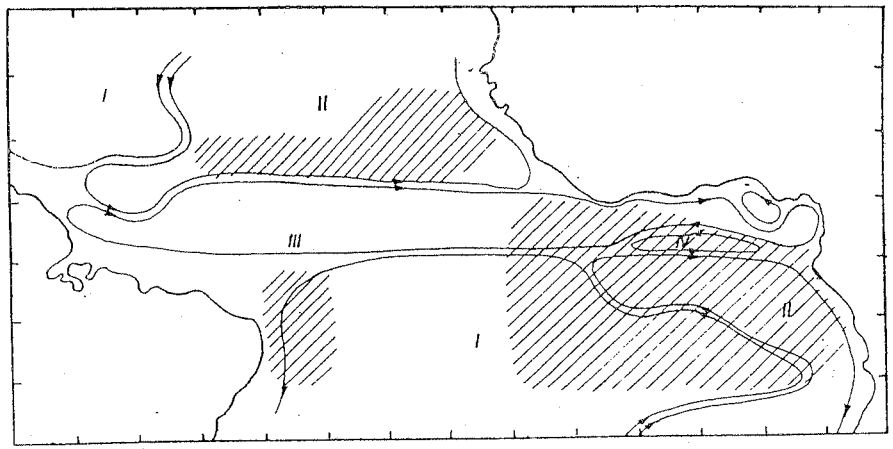

Fig. 4. Distribution of larvae in July-October (Richards, 1969; Richards, Simmons, 1971; our data).
Definitions see in fig. 3.

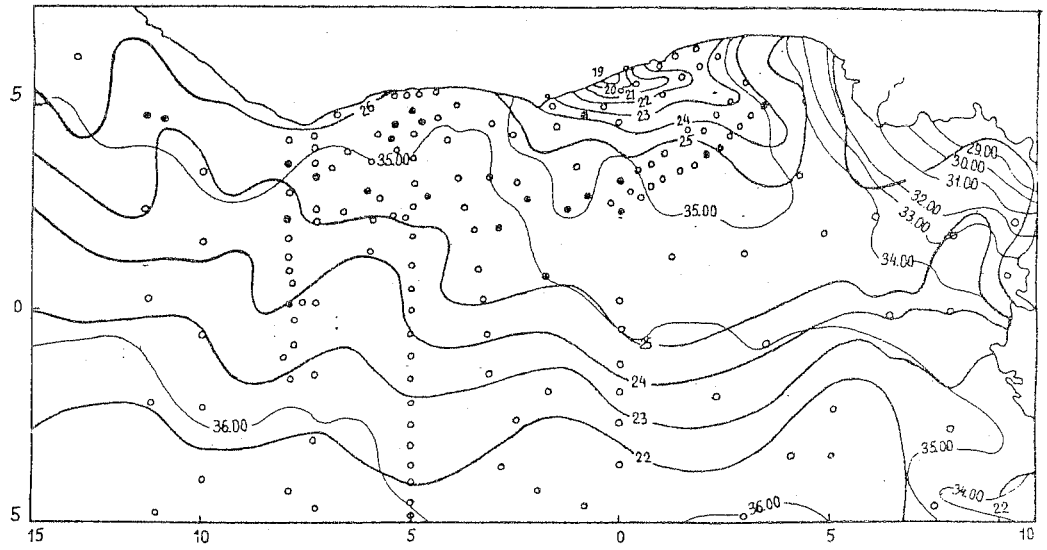

Fig. 5. The scheme of the water circulation in the surface layer (northern and southern quasistationary eddies) and reproductive areas of bigeye tuna:
I - subtropical anticyclonic
II - tropical cyclonic
III - tropical anticyclonic
IV - equatorial cyclonic (Khlystov, 1976)