A C T A A D R I A T I C A
INSTITUT ZA OCEANOGRAFIJU I RIBARSTVO - SPLIT
SFR JUGOSLAVIJA

Vol. XIV. No. 10

THE BEHAVIOUR, DISTRIBUTION AND QUANTITY OF SARDINES IN THE BAY OF KAŠTELA

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IVO KAČIĆ

SPLIT 1972

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1. INTRODUCTION

For several years the echo sounder has been used in different fields of research on the seas and oceans. But they became fully appreciated in fisheries particularly in detecting and catching of pelagic fish. It was started originally by Ball (1947) who installed the first type of echo sounder on his drifter »Violet and Rose« (from 1933 up to 1937). Today, fishing fleets are equipped with various types of echo apparatus for detecting and estimating the size of fish concentration.

The echo sounder has a special use in the catching of pelagic fish. With its help it is possible, especially recently, to examine a large area in a relatively short period of time and reveal almost any significant concentration of fish, and therefore the catch is larger then ever before.

Beside the use of the echo sounder for practical fishing purposes its use is getting more important in fisheries biology for the purpose of researching and solving a series of problems about the ecology of fish. The echo sounder made it possible to penetrate under the sea surface and to watch the fish concentration. With its help can be studied the behaviour, distribution and approximate quantity of fish. In such a way much already known information has been confirmed or new information discovered about many types of commercial fish.

Neither the Adriatic nor the Mediterranean have up to now been made on pelagic fish with the help of echo sounder. Dragesund (1964) studied the behaviour of sardines and anchovies in the Gulf of Naples and their reaction to artificial light. Grubišić (1957) had cruised along some parts of the Adr atic in order to collect first hand experience in the work of echo sounder in our waters. Županović (1963) carried out work with echosounders in the Adriatic to discover the concentration and location of sardines, with the object of finding new inshore fishing grounds.

From the above, one can draw the conclusion that research into pelagic fish, especially sardines in their natural conditions, using the echo sounder has been on a very small scale in the Adriatic, and that only a very limited amount of information was obtained leaving many problems of some of the phenomena to be solved.

2. PURPOSE AND THE PROGRAM OF WORK

Research was carried out in order to learn more about sardine ecology. For this purpose the program for investigation was made and can be formulated as follows:

1. To study the behaviour of small pelagic fish with special reference to sardines in the Bay of Kaštela.

2. To determine the distribution of fish concentration.

3. To try to estimate the approximative quantity of fish and its fluctuations from year to year.

3. THE REGION OF INVESTIGATION

The observations about behavior, distribution and quantity of sardine were carried out in the Bay of Kaštela (Fig. 1). The proximity of the Bay of Kaštela and more especially the findings of other researhers into the ecology and movement of the fish population led us to choose it for our investigations.

3.1. **The Bay of Kaštela and its hydrographic properties**

The Bay of Kaštela is situated between the foot of mount Kozjak which forms its northern coast, the northern part of the island of Čiovo and the northern s de of the Marjan pennisula. Its surface area ist about 61 km^2. It is shallowest in the west and northwest part and it is deepest in the middle of the bay (abt. 50 m). The average depth of the bay is 23 m (Z o r é, 1955). Owing to the strong influence of the mainland the maximum surface temperature of the sea sometimes reaches up to 28.05°C and it can also drop as low as 8°C on the surface. The maximum salinity values on the surface can be up to 38,19‰ and as law as 28,17‰. Neither temperature nor salinity are constant during a year are to be found to east and west parts of the bay then in the centre.

The temperature and salinity of the water in the bay are subject to considerable variations over the years, and this plays a very important part in the life of the organisms living it. Desalination of the water in this region is influenced in the first place by the Jadro river and the brook of Pantan. Excess water from underground springs also flow into the bay, the largest amount coming from springs near the coast of Slatine and Arbanija. Meterological factors obviously play a part in the desalination (B u l j a n and Z o r é 1963).

3.2. The catch of pelagic fish, especially of sardines in the Bay of Kaštela[1])

There are several fish companies who are occupied in catching the pelagic fish. The greater majority of them are in Kaštel Kambelovac and then in Slatine and Kaštel Sućurac. Seven purse seiners have been registered in the bay.

From the total annual catch which fishermen of this region realise 90% are sardines and the remaining 10% are mostly anchovies and only a very few mackerel. The average annual catch of pelagic fish is about 500 tons of which 450 tons are sardines.

Sardines are generally caught in May, and from the middle of September up to the end of October and sometimes up to the middle of November. A certain amount is caught during summer, but less then in spring and autumn due to the »warm sea« as fishermen say.

Anchovy is caught mainly in April.

At the begining of autumn sardines start to migrate from the bay of Kaštel Kambelovac to the spawning area.

Small sardines (about 60 fish to the kilo) are more often caught in the latter half of summer. These fish are more often caught around Slatine and the bay of Kaštel Kambelovac.

The amount of sardines caught fluctuates from year to year and in recent years it has varied as follows:

1962. There is no acurate data.

1963. A very good year one of the best. About 500 tons of fish were caught, mostly sardines.

1964. The poorest year. A very small amount of fish was caught amounting to only 250 tons.

1965. abt. 400 tons were caught mainly sardines.

1966. a very good year, abt. 400 tons were caught.

1957. about 400 tons were caught the majority of them being sardines.

In 1968. in two fishing trips the fishermen of the bay of Kaštela caught 100 tons of sardines.

4. METHODS OF RESEARCH

4.1. Work at sea

The observations about behaviour, distribution and the quantity of fish were carried out along three routes (Fig. 1. routes A.B.C.). At first the observations were carried out three times a day: in the morning, in the afternoon

[1]) The data submitted in this chapter was all obtained by fishermen from Kaštel Kambelovac on the 12 June 1968. As there were no official statistics about the amount of fish caught in the bay of Kaštela, then fishermen themselves were the only source of information one must take into consideration certain subjective factors which could have given rise to inconsistences

and at night, mainly at intervals of fifteen days and later once during a day (in the morning) and with longer intervals between individual observations.[2])

Observations started at the begining of route A first at about one hour after dawn. Then on route B and on route C. The afternoon observations ended half an hour before dusk. The night observations were performed during the dark (on moonless nights) and also on nights with a full moon. The routes of detection were divided into sections. Each section was 1.200 meters long, and on each of them observations lasted for 5 minutes. The route A had 13 and routes B and C had 10 sections.

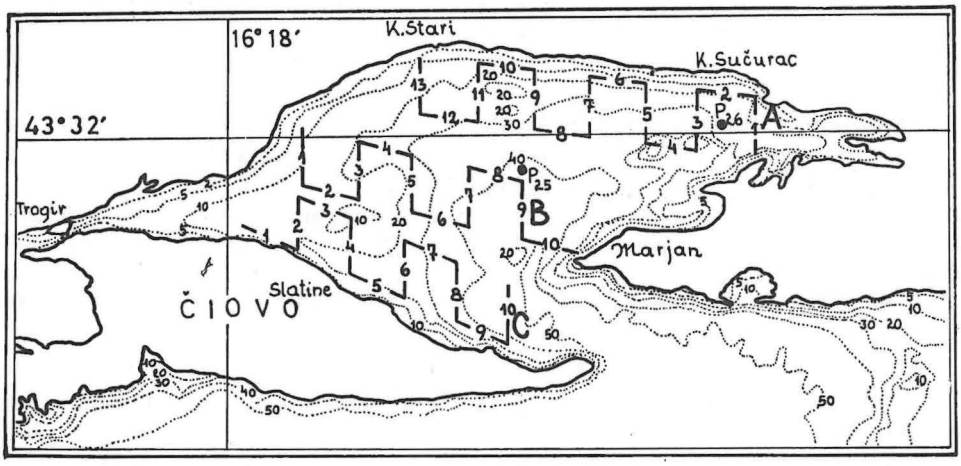

Fig. 1. Shows the bay of Kaštela with routes A, B, C along which the observations by echo-sounder were carried out. The sections of routes are marked with numbers. The hydrographic stations are marked by P 25 and P 26.

The observations were carried out by the R/v »Bios«. The speed of the boat was 240 m/min. The observations were done by means of the echo sounder »Simrad«-type 580—4, operating frequency 30 kHz.

The echo sounder worked with a sensitivity 1 — 2 (according to the sea depth). The observations were performed without »White line« or contrast line, since it was noted during the trial observations that the white lines cannot differentiate between the small differences in depth in the bay of Kaštela.

Once a day the elementary hydrologic data were taken on the two stations P 25 and P 26. On the station 25 situated in the middle of the bay, the data were taken after the dawn during the whole period of research. At the same time meteorological data was also collected. Observations were started in May 1962 and they were varried out up to December 1966. In total 101 observations were performed.

[2]) Annual results had shown that the number of observations on the site could drop, especially durring the winter. Therefore, in the course of time the number of observations had reduced to a certain degree.

4.2. Indentification of traces

The traces of the concentrations of fish which the echo sounder recorded on the recording paper, i. e. the origin of these traces were indentified in many ways:

a) *Direct method*

Very often during research it was noticed how the observed sardine »plays« on the sea surface, when the vessel sailed over the sardine perceived by eye, it was registered on the recording paper of the echo sounder (Fig. 2).

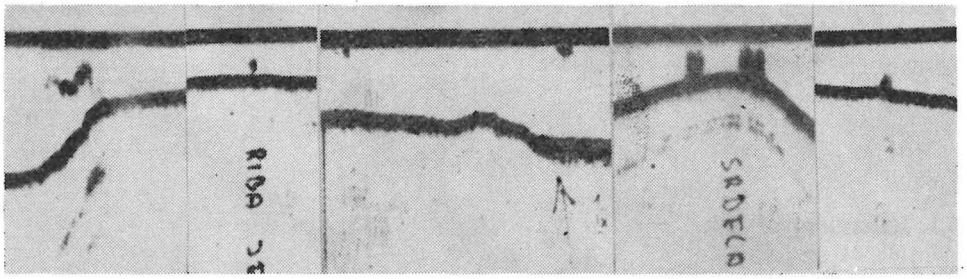

Fig. 2. Echo-grams showing the concentration of sardine. Earlier it was perceived how the sardine »plays« on the sea surface

b) *Indirect method*

The young sardine stays in the bay of Kaštela during the whole year (M u ž i n i ć, 1954, 1957), and in some years are caught in considerable quantities (up to 200 tons per year. Verbal piece of information g ven at the meeting of experts for fishery, Split on 21st December 1965., see also chapter 3.2.).

The catches of sardine, used for experimental work (M u ž i n i ć, 1964——1966), originated mostly from the bay of Kaštela.

4.3. Category of traces

The present results of measuring traces by automatic means or by arranging them in length groups were achieved mainly in the northern seas. Tungate (1958) had in order to follow the concentration of herrings from North Sea, arranged fish according to their length shown in millimetres on the echo--gram. Truskanov and Šerbino (1964) had used similar methods when estimating the quantity of herrings in some parts of the Barents sea.

The traces of fish which were registered on the recording papers of the echo sounder were classified in three categories, according to their dimensions and area, respectively according to the time of duration of the returned signals (table 1).

Table 1. Distribution of fish traces according to dimension (millimetres) and area (sq. millimetres)

Categories	Width of traces		Height of traces		Area of traces	
	Min.	Max.	Min.	Max.	Min.	Max.
I	0,1	1	0,1	1	0,01	1
II	>1	2	>1	3	>1	6
III	>2	5	>3	5	>6	25

The distribution of the traces in three categories was done after series of previous observations which were carried out in the bay of Kaštela. On that occasion it was noticed that the traces of the fish concentration, which on the echo-gram were projected as dark spots, in fact do not exceed the sizes larger from those mentioned in categories.

5. RESULTS

5.1. **Behaviour of fish**

5.1.1. *Supplementary remarks*

The morning observations in the whole were carried out between 0500 and 1100 hours, in the afternoon between 1500 and 2000 hours, and the night ones between 2100 and 2400 hours. At first the night observations were carried out at dead of night or at full moon, by clear sky, and the later researches not immediately after total dusk but between astronomical and official dusk.

Some night observations were carried out in the vicinity of the artificial light, which is used in the catching of small pelagic fish.

The observations were carried out on the routes B and C and those carried out on the route A were not taken into consideration, since the route was treated only by day during full day light.[3])

5.1.2. *The size of the traces*

The traces of the concentration of fish which one encounters in the bay of Kaštela are rather small. Their area on the echo-gram does not extend over 25 mm. Judging by those bordering sizes of the traces it was not established that the fish in the area under investigation formed large concentrations. So in 1963 one of the richest years for fish, 353 traces were recorded in the first category, in the second 175 and in the third category 357 traces of the concentration of fish and none of them exceeded the mentioned size.

[3]) Owing to the objective facts the night observations about behaviour of fish on the route A could not be carried out.

5.1.3. *The behaviour of the fish during the day*

Neither morning nor afternoon observations could be made quite simultaneously as they started first on the route B and ended on the route C and this just before sunset. Meanwhile, regardless of whether the observations were carried out during the morning immediately after sunrise or in the afternoon ending just before sunset the number of traces of fish concentration recorded in the morning was greater than their number which was registered in the afternoon up to sunset (table 2).

Table 2. Number of traces et B and C profile

Part of day	Number of observations	Number of traces of two categories					
		Total			Mean		
		I	II	III	I	II	III
B Morning	12	130	58	27	11	5	2
Afternoon	11	91	23	21	8	2	2
Night	9	24	1	1	3	0,1	0,1
C Morning	12	124	40	17	10	3	2
Afternoon	11	69	21	6	6	2	0,5
Night	6	10	—	—	2	—	—

On the route B more traces were recorded during the morning than during the afternoon hours, and on the route C the number of traces of fish concentration was considerably smaller in the afternoon hours then in the morning. Such number of concentration of fish on the routes can also be related to the space position of the routes and with the time when the observation was carried out, since the route C is located quite near the northern coast of the neighbour island, and the observations themselves on that route were the last to finish.

The number of traces which were recorded during the night is very little (see table 2), and on five observations out of a total of fifteen which were done at night, in a place where there was no artificial source of light no traces of fish concentration were recorded (fig. 3).

In the contrast with day time records those obtained at night are quite small and they come to the first category.

5.1.4. *The behaviour of fish in the course of the day and during the night*

Observations carried out at night moonlight and moonless nights did not show any difference in fish behaviour during these two periods of observations, in both cases a significantly smaller size and number of traces was observed. A considerable smaller number of traces appeared in relation to their daily number (table 3).

Table 3. Number of traces in moonlight and moonless nights

Part of day	Number of observations	Number of three categories: Moonless Total			Mean			Number of observations	Moonlight Total			Mean		
		I	II	III	I	II	III		I	II	III	I	II	III
Morning	14	140	56	27	10	4	2	10	114	40	19	11	4	2
Afternoon	12	87	20	13	7	2	1	10	73	20	20	7	2	2
Night	8	23	—	—	3	—	—	7	11	1	1	2	0,1	0,1

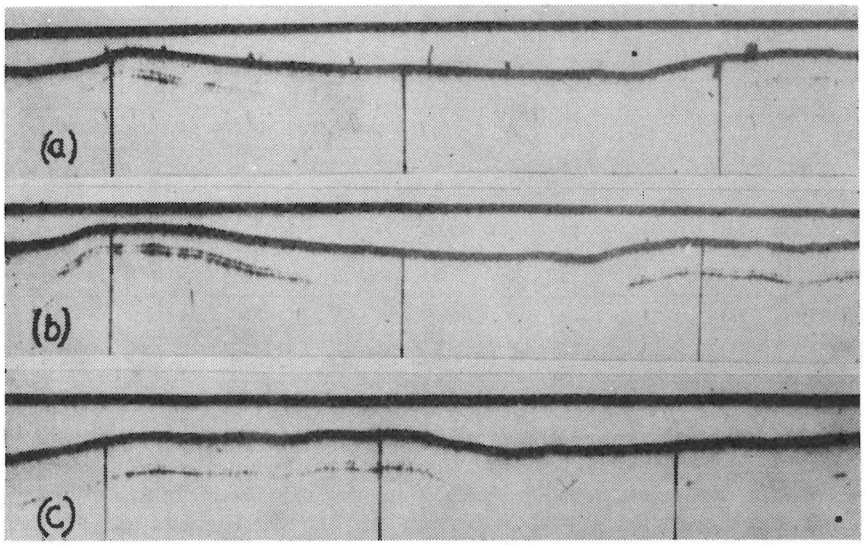

Fig. 3. Fish recorded on the echo-grams on the 14th May 1963. at different times (a, in the morning b, in the afternoon c, at night) on the same sectors of the route B.

5.1.5. *The behaviour of fish in the vicinity of artificial light*

In the vicinity of the artificial light used in fishing the small pelagic fish it was increased only the number of minute »dotty« traces from the first category. Whilst at night, without artificial light, the average number of traces of the first category per observation was two, by night closer to artificial light the average number of marks amounted to 16 per observation. The traces were arranged closer to the light were more conspicuous and darker and those farther from the light were smaller and of poor intensity Dragesund (1964) came across a similar phenomenon when observing the sardine by artificial light in Bay of Naples. He namely noticed that the traces were unevenly arranged around the source of artificial light. Those traces which were under the direct influence of light and closer to the shadow (made by the boat) were more dispersed and more faintly recorded an they were somewhat less in number.

5.1.6. *Vertical distribution of fish during the morning and afternoon*

In May, June and July in the earlier morning hours (between 5 and 8) the fish most often remaind stationary at a depth of about 18 m, while in the later morning (between 10 and 11) they most often were at the very bottom at a depth of some 20 to 24 m. In the afternoon, between 15 and 18 hours the concentrations of fish were at depth of some 20 m. From 18 to 20 hours one can notice the tendency of fish to move towards the surface, so that the mean distance of the traces to the surface between 19 and 20 hours was about 13 m. (fig. 4-A). During August, September and October the fish were generally at

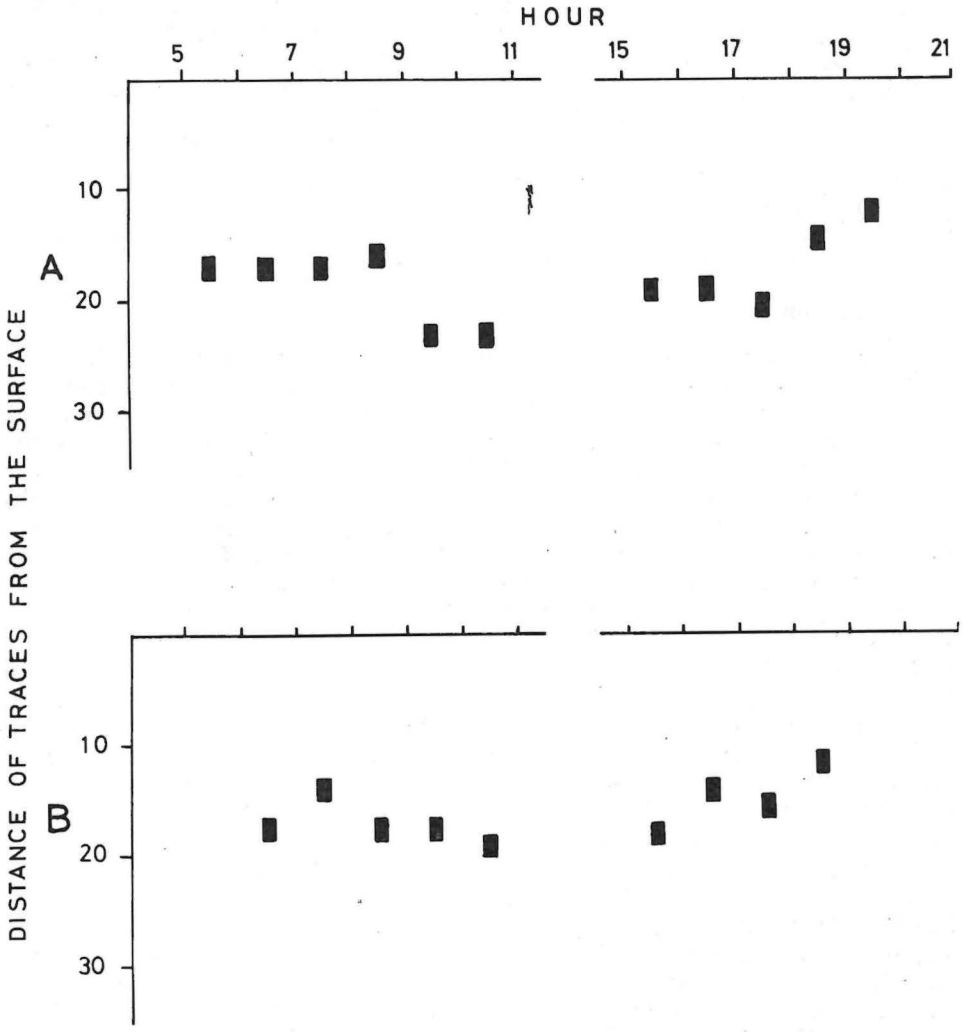

Fig. 4. The vertical distribution of fish A — in May, June and July B — in August, September and October

a somewhat shallower depth in the morning hours (about 18 m) but the tendency of vertical migration towards the surface was also noticed in the later afternoon hours between 18 and 19 hours (fig. 4-B). In such a way besides the smaller number of traces recorded in the afternoon hours their vertical movement was noted.

5.1.7. *The behaviour of fish during bright and cloudy weather*

Observations carried out during bright and cloudy weather had shown that the influence of the cloudy weather to the fish behaviour could not be found. So in the cases of two observations during a month, one of which was under bright weather conditions and the second one during total or partly cloudy weather, differences were found in the arrangement of traces according to categories. However such differences appeared in the cases of both observations during the bright weather (fig. 5). On the chart (fig. 5). are shown the results of observations during summer period 1962—1964, when they were performed twice in a month. It could be not observed that the traces of fish concentration occurred during the cloudy weather with regard to their distance from the sea surface in some specific arrangement. They were at the same depth as during the bright weather (fig. 6).

5.2. **Discussion**

The total number of recorded traces of the concentration of fish in the morning is considerably greater then in the afternoon (tab. 2). It could be supposed that the differences in the number traces recorded in the morning in the afternoon and at night could be determined by the different quantity of light which penetrate the sea water. Reduction of the number of traces in the afternoon or their almost complete absence at night, and especially the absence of traces of the larger concentration of fish bring us to the conclusion that the fish dispersed and scattered and that he beam of ultrasonic waves could not registered it. As the echo sounder is delicate enough and it can detect the presence of smaller concentrations of fish therefore on the basis of the traces recorded in the afternoon and an insignificant number of minute traces recorded during the night it can be supposed that the »degree of packing of fish in shoals« (Cushing and Richardson, 1955) is different in the different part of the day and night.

A smaller number of traces recorded in the later afternoon could be related to observations carried out on the sardines under experimental conditions, where it was noted that at the low intensity of light the fish begins to disperse, but it moves predominantly in one direction (Mužinić, 1964).

The reduction of number of big traces in the twilight and almost complete disappearance of almost all small traces of fish at night was noticed also for herrings, with the explanation that the spots of larger concentrations of fish which can be recorded also at night, and that smaller schools, which are recorded during the day, mostly dissapeared during the night because they have dispersed to such an extent that the echo sounder cannot record them (Jones, 1962). As during the night, at times larger fish concentrations were registered, while the small ones mainly dissappeared which in Jone's

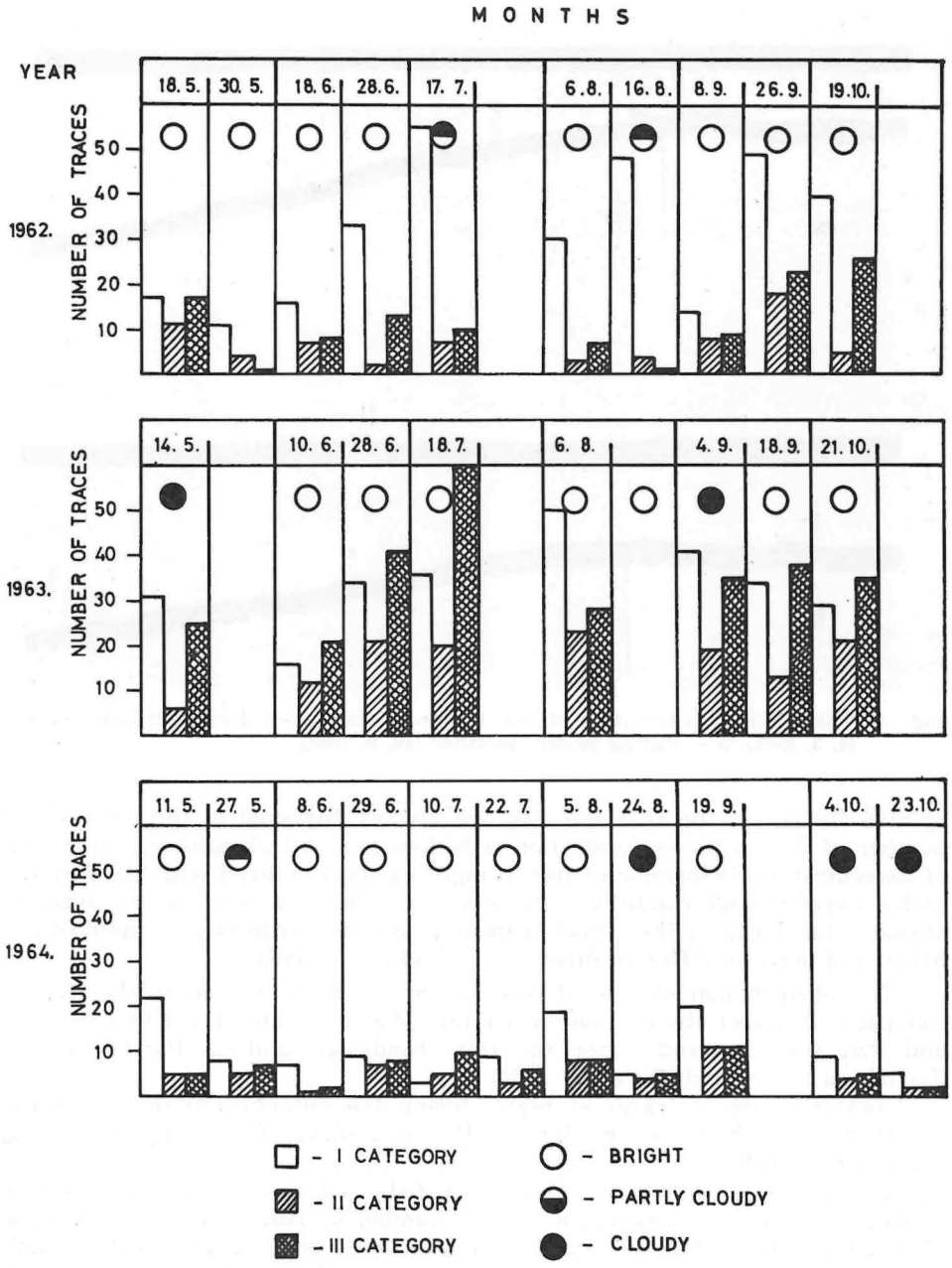

Fig. 5. Relation between cloudiness and number of fish traces concentration

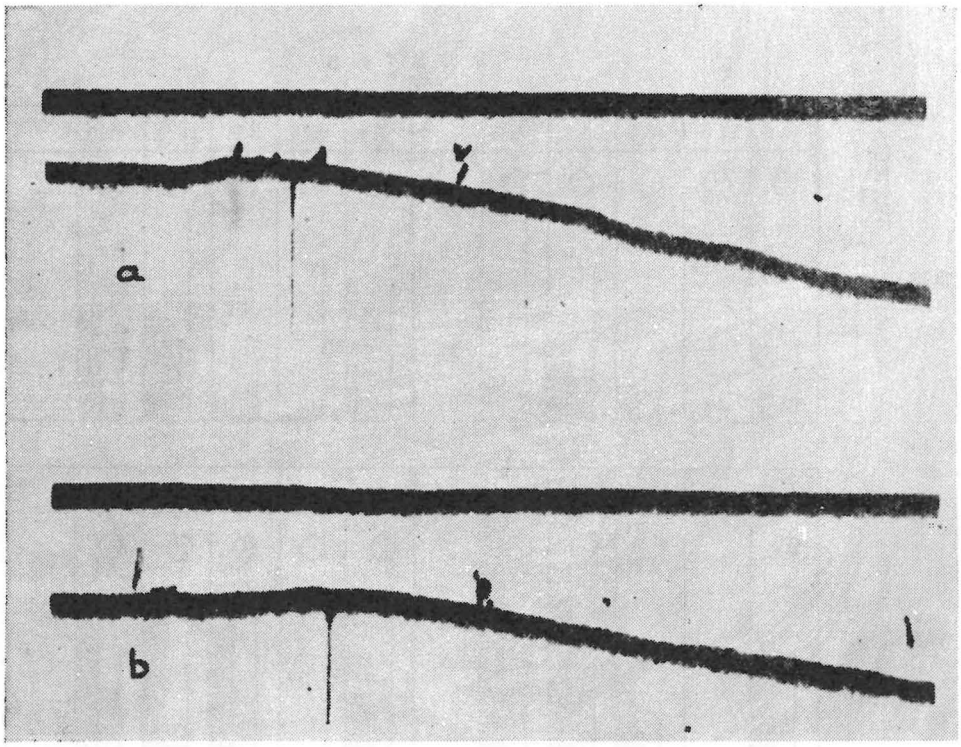

Fig. 6. The vertical distribution of the traces of fish: a — during bright weather (4. 9. 1963), b — during cloudy weather (18. 9. 1963)

opinion (1962), can be that the fish are always dispersed in the dark if the number of fish in the concentration is bellow the critical number and weight of concentration. Dispersion of fish at night has been noticed with the sardines under experimental conditions where it was observed that in the total or almost total darkness the school disperses and the sardines lose their equilibrium and move in different directions (Mužinić, 1964).

The phenomenon of loss of equilibrium has been noticed in the natural conditions in direct observation on herring (Zajcev and Radakov, 1960) and that was observed under aquarium conditions and on Pacific sardine (Loukashkin and Grant, 1969).

Disappearance of traces at night during the observations under natural conditions have been noticed for the Pacific sardines (Jemeljanov and Judovič, 1958).

The noted dispersion of a school of fish, and the increase of distance between individual fishes (i.e. a smaller number of fish in the same volume of water), then the loss of equilibrium was noted under experimental conditions during the period of darkness. This was also found under natural conditions at night with sardines and similar fish. The horizontal and vertical disper-

sion of fish was noteced and bring to the conclusion that this is the most likely reason for the number of reductions and d sappereance of the traces fish in the natural conditions. It must be stressed that the echo sounder is limited in recording the traces, if conditions are not suitable for reflecting the sound.[4])

Since the echo sounder appeared it was possible to follow the changes and the size of vertical migration of clupeids study of which in aquarium conditions is of small significance (Blaxter and Holliday, 1963).

Runnström (1941 b) with the help of the echo sounder was among the first to notice that the schools of atlantic-skandinavien herring rise towards the surface in the twilight and that they descend at daylight.

Blaxter and Parrish (1965) had noticed the migration of herrings towards the surface in twilight between 2000 hours and 2400 hours.

According to Blaxter and Holliday (1963), it seems that vertical migration goes parallel with the dispersion of fish. Vertical migrations of sardines could be established by the change of daylight or by vertical migrations of plankton or by both factors (Vučetić, 1963).

Although it was impossible to follow vertical migration of traces at night, yet it seems that it existed before sunset.

From the observations carried out on sardine (Mužinić, 1964) it is known that at the reduced intensity of light sardines keep in their school.

Although it is not known how high is the coefficient of light extintion in the bay of Kaštela in the relation to the depth, knowing the transparency of the sea water of that region, we can make a conclusion that the coefficient is not high. Therefore, it is likely that the light by day penetrates up to the sea bed just enough to prevent the fish from dispersing because of the lack of light, to the extent that the echo sounder can not record it.

From the observations performed during cloudy weather, it could not be noticed if it was the reason for the registration of a smaller number of fish traces or contrarywise. In the same way it was not noticed that the fish traces were registered only during fair weather. This brings us to the conclus on that the possibility of influence of cloudy weather on the behaviour of fish, which so far in our researches has not been proved.

The observations made on some clupeids in captivity (Loukashkin and Grant, 1959; Blaxter and Holliday, 1963; Mužinić, 1964) and in their natural habitat (Furnestin, 1953; May and Bridger, 1958; Jemeljanov and Judovič, 1958; Radakov and Solovljev, 1959; Jones, 1962; Blaxter and Holliday, 1963; Dragesund, 1964), and compared in the work Mužinić (1965) and Blaxter's and Parrish's observations (1965) show a similarity in the fish behaviour to uor own observations and make us conclude that the traces registered in

[4]) If the beam of ultra sonic waves when passing through the sea do not come accross some obstacle such as the sea bed or the concentration of fish etc., it will not return back an »echo«. In the described case the concentration of fish which by day acts as a barrier for ultrasonic waves and from which they are reflected and recorded on the echo-grams as traces, do not show any traces by night. Therefore, one can supose that the fish are formed by night so that they do not present a barrier from which the sound waves could reflect, and we cannot register them by echo sounder.

the bay of Kaštela are mainly those of the concentrations of the sardine. On the assumption that at times the recorded fish were not sardines, then some other fish (obviously anchovy) behave in a simillar way to the sardine.

5.3. **Some abiotic factor of environment and the number of fish traces**

5.3.1. *Temperature*

The data about temperature was taken on the same day when observation by echo sounder was carried out in the bay of Kaštela. The data of temperature relates only to station 25. Those from station 26 were not taken into consideration, since their values are very alike.

Observations were performed from May 1962 till the end of 1966. Comparison of data about the temperature with the traces of fish cencentration show the following:

The temperature of sea surface reached the highest average level in August and it was 25,00°C on the station 25 (fig. 1 P 25).

The lowest was noted in February and it was about 10,05°C on the station in the middle of the bay. On the depthes from 10 and 20 meters maximum temperatures were in September. They were in walues from about 21,75°C (10 m.) up to 19,50°C (20 m.). The maximum temperature at a depth of 35 m. was in October and it was an average of 19,00°C. The minimum temperature on the above mentioned depth was also in February and it was 12,12°C.

The traces of the concentration of fish of all three categories are most frequent in the period of the highest sea temperatures in the bay of Kaštela (fig. 7). For the illustration two diagrams are given from the same part of the route (fig. 8). A very small number of traces were recorded during these low sea temperatures. About 62 traces of the concentrations of fish were recorded per observation during the highest temperature from July up to August. The analysis of given observation show the following:

(a) The curves which show the number of the traces of the fish concentration and the curves of sea temperature especially the surface and up to a depth of 10 m. show concurrence almost in each month, they show similar increase and decrease during the whole period of investigation.

(b) The average number of traces of the concentration of fish from the second and third category was the highest in July, September and October. Then the temperatures of the sea surface layer were high.

(c) The highest temperature of the sea surface was in August, and the average number of the concetration of fish was not the greates in that month.

5.3.2. *Salinity*

The data of the salinity of the sea in the bay of Kaštela, taken together with the temperature, and the number of traces of the concentration of fish, which were obtained on the same day are shown on the fig. 9. This data shows the following:

The maximum salinity of the sea as noted on the station 25 in August and it was 36,90‰ on the surface. The lowest level of salinity recorded on the

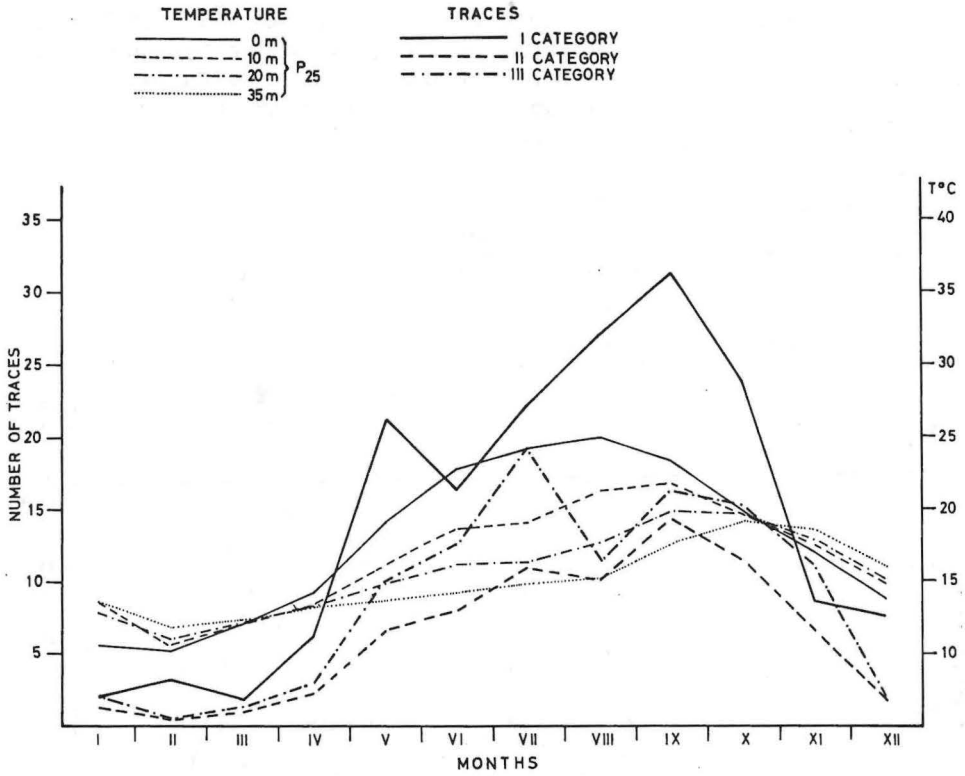

Fig. 7. The mean value of the sea temperature in the bay of Kaštela and the traces of fish concentration

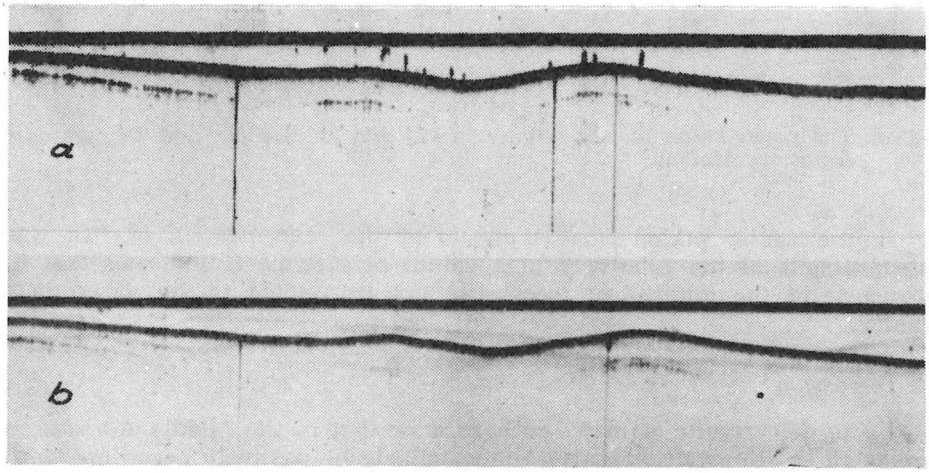

Fig. 8. Fish recorded in summer on 28 June 1963. (echo-gram a) and in winter on 26 February 1963. (echo-gram b)

two stations (P 25 and P 26) in April was on the surface and it varied from 31,90‰ up to 32,45‰. The amplitude of variations of the sea salinity was considerable on the surface at both stations. The curve of average value of salinity of the sea surface coincides to a certain extent traces of the fish concentration from the summer period.

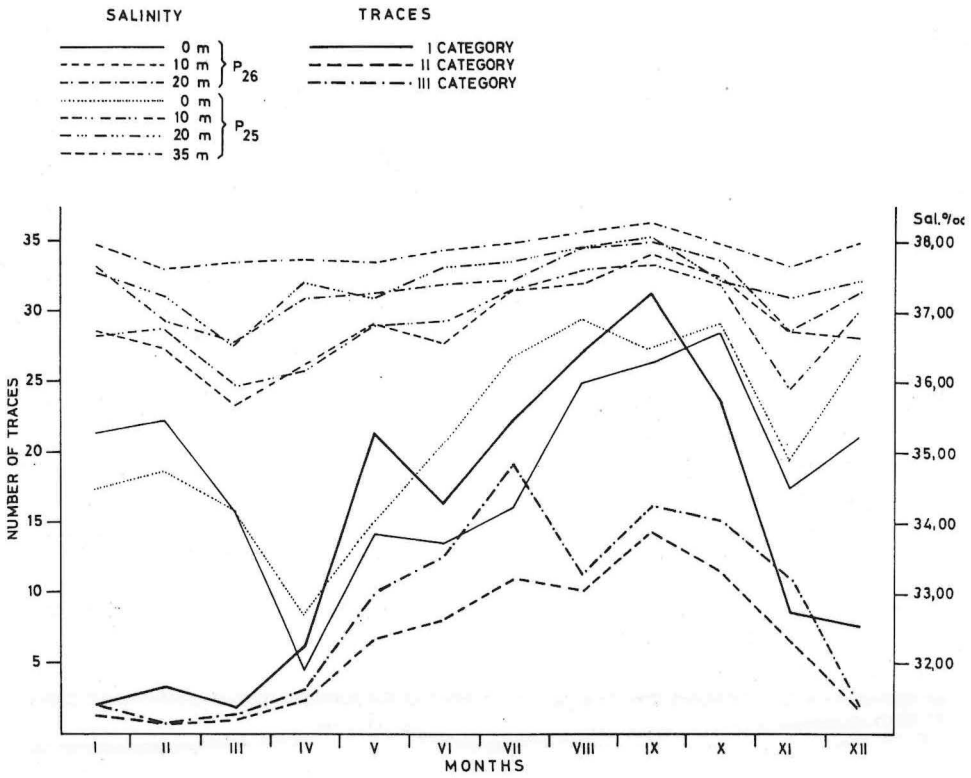

Fig. 9. The mean value of sea salinity in the bay of Kaštela and the traces of fish concentration

In the winter period small numbers of the concentration of fish were noted in spite of the relatively high values of salinity. It indicates that the movement of the number of traces can not be related to the variation of salinity.

5.4. Discussion

Up to date results of many authors show that in the Middle Adriatic the sardine in its life cycle migrates either actively or passively according to the degree of its maturity in the off shore direction of the mainland and towards its coast (Mužinić 1948, 1949, 1954; Vučetić, 1963; Karlovac, 1965).

Vučetić (1965) had investigated the bay of Kaštela and submited the data about variations of total zooplankton biomasses (dry weight) about the fluctuation of density population of copepods Calanus helgolandicus, sardines and anchovies eggs and the other eggs and larvae. According to her information of the quantities found it was possible to notice that according to biomasses of total zooplankton the winter period from November till March was rather poor, while during spring and summer the quantity of zooplankton increased considerably.

Vučetić (1965) carried out research on the sardine eggs in the bay of Kaštela from October to Aprill and she had found only a few of them, while in some years eggs were not found at all. In the winter period 1962 one egg was found on average, in 1963 two and in 1964 and in 1965 only one sardine's egg on average monthly. According to this information and in comparison with the eggs of other fish species in the area of the bay of Kaštela there are very few sardine's in fact almost none.

Spawning of sardines according to Karlovac (1967) was of stronger intensity in the bay of Kaštela and in the channel in the season 1951/52 of Split than in the coastal waters of the open Middle Adriatic, whilst it was of weaker intensity in the season 1952/53. It was also established (J. Karlovac, 1967), on the basis of analysis of the size of the diameter of sardine's eggs and their abundance in the bay of Kaštela that here appears little sharp sardine population (»recruit-spawners«) which spawned in the bay during spring.

Mužinić (1954) found in the bay of Kaštela postlarvae of sardines, which they experienced their metamorphosis. In April 1947 for example, she had found sardine whose modal lenght was 5,5 cm. There she found some species from 20 to 30 mm.

In the course of winter monthes, during maximum sexual activity (the spawning period) the sardine behaves differently from the period when the gonads are at not functioning. Since part of the sardine's population migrate from the bay with the first cold spell the other part which remain in the bay are generally difficult to detect by echo sounder. It is possible to record the fish in greater quantity only from spring when its spawning in the bay (according to Karlovac, 1967) almost ceased. Judging from the insignificant number of fish traces especially during winter, one can suppose that the sardine is dispersed along the bay. The data from the catch by trawler (Mužinić, 1954, 1956) show that the sardine in that period of time can be found near the bottom. From the above observations one can draw the conclusion that in winter the sardine cannot generaly be found in a concentration which could be the barrier for ultra sonic waves.

It must be pointed out that the observed changes in the behaviour of sardine in the bay were done simultaneously with the change of the sea temperature (lower sea temperature lower number of registered traces and vice versa). Whether and in what extent the number of fish traces depends on temperature, up to now it is impossible to find out. It can be only stressed that the smallest number of traces was recorded just at a time when one can expect the most intensive spawning of sardines in the bay, and which is strongest between a water temperature of 11,0 and 12,0°C as has previously been observed by J. Karlovac (1967).

The influence of sea salinity in the bay to the possibility of recording larger or smaller number of fish traces, was not noticed.

5.5. The distribution of fish

5.5.1. *Supplementary remarks*

To explain the results about the distribution of fish in the bay of Kaštela we used the data obtained from the middle of 1962 up to the end of 1966 in the morning hours and in the summer period. The data was collected on all three routes of detection (A. B. and C).

All three categories of traces are taken together as one category, since there was no need to treat each of them separately (all three categories were equally arranged).

5.5.2. *Horizontal distribution of fish traces*

During the observation about the distribution of traces of fish concentration not only once it was it noted that the traces would be equally aranged along the bay. They were often encountered in the west and northwest parts of the bay, and also close to its northern coast, when the investigations were carried out close to the coast. These are the sections 2; 6 and 10 on the route A section 1; 2 and 3 on route B and section 2; 3 and 4 on the route C.

5.5.3. *The distribution of fish traces in relation to depth*

On figure 10 the average number of traces has been shown per observation on every section of the routes. From the distribution of the isobates and the number of traces it shows that the concentration of fish is more frequent in its shallower parts and less frequent in the deeper areas in the middle of the bay.

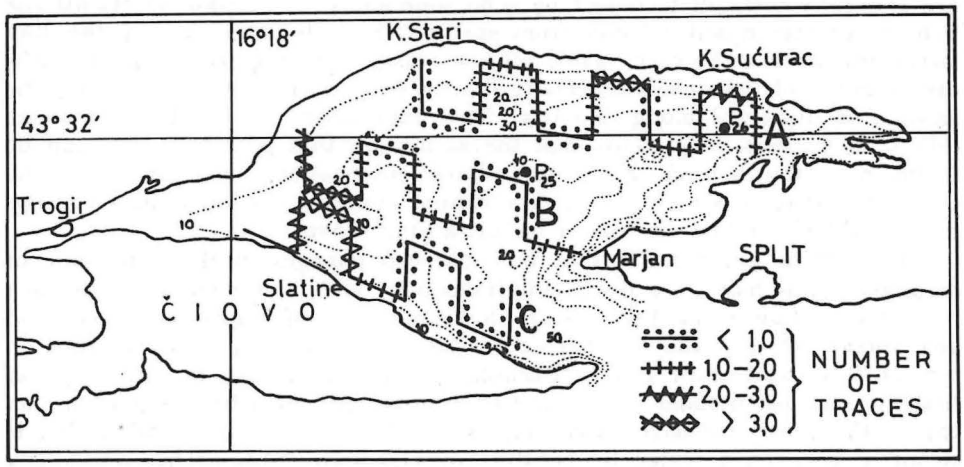

Fig. 10. The distribution of traces of fish concentration per observation

On the tables 4,5 and 6 data is shown the distribution of the traces of the concentration of fish in the special years in relation to the average sea depth for each section. The amount of fish concentration in relation to the depth is shown on fig. 11.

Table 4. The distribution of the traces of fish concentration (the average number) in a specific year on route A. In brackets is shown the number of observations

Section	Average depth m	The number of traces 1962(12)	1963(17)	1964(17)	1965(10)	1966(7)
1	16	0,33	1,41	0,35	1,30	0,86
2	13	1,50	2,06	0,12	1,30	1,57
3	20,5	1,25	0,35	0,47	0,80	0,86
4	19	1,00	1,82	0,35	0,60	0,29
5	23,5	0,67	0,76	0,06	0,70	—
6	14	3,42	2,65	0,35	2,00	0,14
7	20	1,33	1,24	0,47	0,90	0,57
8	24,5	0,42	1,06	0,06	—	—
9	22	0,50	1,59	0,88	0,90	0,57
10	14	2,17	1,94	0,18	1,50	0,86
11	20,5	1,33	2,06	0,59	0,50	1,00
12	24	0,08	0,41	0,24	0,30	0,57
13	21	1,08	0,88	0,12	0,30	0,43

Table 5. The distribution of the traces of fish concentration (the average number) in a specific year on route B. In brackets are shown the number of observations

Section	Average depth m	The number of traces 1962(12)	1963(17)	1964(17)	1965(10)	1966(7)
1	9,5	3,08	1,94	0,94	1,30	2,29
2	11,5	4,00	3,29	0,71	1,90	0,71
3	13	1,92	2,71	0,53	1,40	0,57
4	20	0,42	0,88	0,24	0,40	0,86
5	19	0,50	1,82	0,53	0,60	0,71
6	24	1,25	2,35	1,12	0,40	0,14
7	36	1,17	1,18	0,29	—	0,57
8	36	0,83	0,18	0,18	0,10	—
9	38,5	1,08	0,59	0,24	0,20	0,14
10	20	1,08	1,41	1,35	0,70	0,14

The analysis of this data show that the sea depth in the bay of Kaštela is one of the factors which is connected to the distribution of the fish. Therefore one can see that 82% of all the registered traces are distributed up to a depth of 25 meters. For the illustration on fig. 12 the echo-gram recordings of the west part of route B, were used (fig. 12).

Table 6. The distribution of the traces of fish concentration (the average number) in a specific year on route C. In brackets are shown the number of observations

Section	Average depth m	The number of traces 1962(12)	1963(17)	1964(17)	1965(10)	1966(7)
1	13	1,67	2,24	0,47	1,90	1,86
2	14,5	1,67	2,53	0,24	1,90	2,00
3	14	3,00	5,82	2,29	4,40	4,14
4	14	3,17	1,53	1,29	1,30	1,14
5	18,5	1,25	1,65	0,82	0,90	0,14
6	21,5	1,33	0,94	0,29	0,10	0,14
7	25,5	0,83	0,65	0,29	0,30	0,29
8	32,5	1,25	0,41	0,06	—	0,29
9	35	0,17	1,35	0,12	0,20	0,29
10	39	0,17	0,06	0,12	—	—

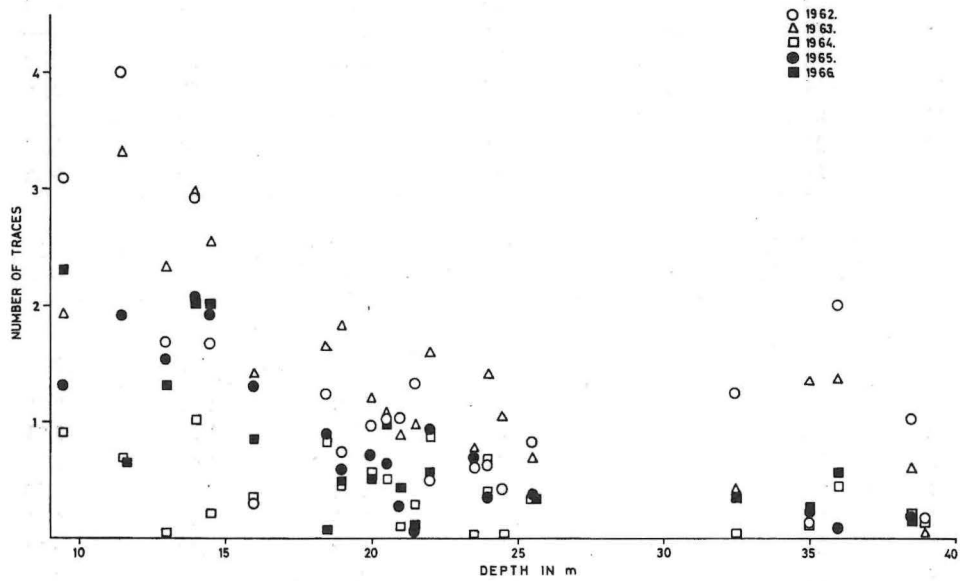

Fig. 11. The number of traces in relation to depth

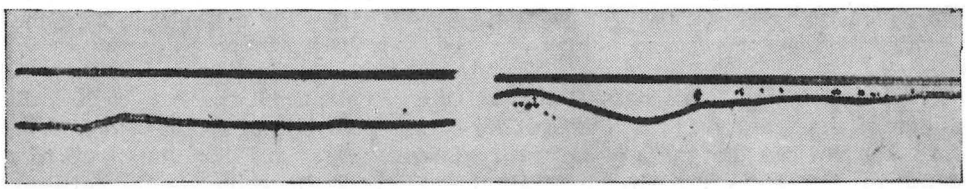

Fig. 12. The distribution of traces in relation to depth

5.6. Discussion

F a g e (1920) wrote that the Mediterranean sardine in a large quantity comes close to the shore before spawning. According to the above mentioned author the Mediterranean sardine spends almost the whole of its first year of life near the shore and it only leaves the shore when the first cold weather arrives.

M u ž i n ić (1954) writes about the regular appearance of young sardine along the Eastern coast of the Adriatic, and how this is connested with the presence of fresh water.

It is because of this that we find the young sardine distributed in the bay of Kaštela, whose waters are desalinated by the influence of the various factors mentioned in the shapter 3.1. of this work.

Fish are unevenly distributed in the bay. They are mainly encountered in the section 2 and 6 of the route A, on the section 2 on the route B, and on the route C on the section 3 and 4. These sections are in the shallow part of the bay. The fish were at small depthes.

During this investigation it was not possible to find out whether the desalinating sources which are in the shallow part of the bay, play any special part in the distribution of fish since the fish were distributed along the shallow part of the bay where there are no such sources.

5.7. Quantity of fish

5.7.1. *Supplementary remarks*

In order to explain the data about the quantity of fish in the bay of Kaštela we used the data obtained only in the morning hours.

When the observations were made twice in the course of a month of the same year, then the average number of the traces was used.

Several authors have described the use of the echo sounder in order to determine the abundance of fish. Recently some attempts were made to introduce an echo-integrator in order to try and estimate the echo-abundance but the relationship between echo-abundance and fish-abundance has not yet been completely solved (M i d t t u n and N a k k e n, 1968).

The method of measuring traces in order to estimate the aproximate quantity of fish cannot be completely reliable. Its disadvantage, of similar methods, is that one cannot determine what quantity of fish is really in question With this method it is only possible to determine the difference between the number of fish concentrations and on the basis of this try to estimate the variations of the quantity of fish.

5.7.2. *Fluctuation of the fish quantity*

The quantity of fish varies in the bay of Kaštela in the warmer part of the year from year, while in the colder part of the year rarely do we encounte: traces of fish concetration (see f g. 8).

In table 7. are shown data about the average number of fish concentration per month for the period from 1962 till the end of 1966.

Table 7. The average number of traces of fish concentration of three categories according to observations in specific months for the period 1962 — 1966. In the brackets is shown the number of observations

Categories	The number of concentrations Months											
	I(3)	II(3)	III(3)	IV(5)	V(6)	VI(8)	VII(6)	VIII(7)	IX(6)	X(6)	XI(5)	XII(5)
I	2,0	3,3	1,7	6,2	21,3	16,3	22,2	27,0	31,3	23,8	8,6	7,6
II	1,3	0,7	1,0	2,4	6,7	8,0	11,0	10,1	14,3	11,5	6,8	1,6
III	2,0	0,7	1,3	3,0	10,0	12,6	19,2	11,4	16,2	15,2	11,2	1,8

The number of the traces of fish concentration of all three categories taken together was generally high in May, June, July and August and especially in September and then in October. The number of traces is considerably lower in November. (the exception is November 1963) December, January and especially in February and March. The number of traces increase from March to April and from April to May and this is clearly visible with traces of all categories.

The period from May to October marks the season for catching sardines.

On the table 8. is shown the number of traces according to categories for two parts of the year during the period from 1962. up to 1966.

Table 8. The average number traces of the fish concentration of three categories, according to observations carried out in the warmer and in the colder parts of the year

Year	The number of observations	May--October I	II	III	The number of observations	November—April I	II	III
1962.	10	33,4	6,8	11,5	2	11,0	—	—
1963.	8	34,0	19,9	35,5	9	9,1	4,4	8,3
1964.	11	10,5	5,1	6,2	6	3,0	1,6	1,7
1965.	6	19,8	13,1	12,1	4	1,8	1,8	1,4
1966.	4	17,9	14,3	10,6	3	1,3	2,3	0,6
1962—66.	39	24,3	11,0	16,0	24	4,5	2,2	2,9

One can see that 1963. differs from the other years and especially from 1964. in the number of fish concentration and the quantity of fish in all three categories. While the number and the size of the traces in 1963. is considerable even November and December, their number in 1964. was very considerably reduced (fig. 13).[5])

The whole period of research from 1962. till the end of 1966. generally shows that the number of the traces of the fish concentration from the first, second and third category are about five times higher in the warmer than in the colder part of the year (table 8, total part).

[5]) In some years a smaller number of observations were carried out and the smallest number was in 1966. It was impossible to find out whether it influenced the difference in the number of traces in individual years.

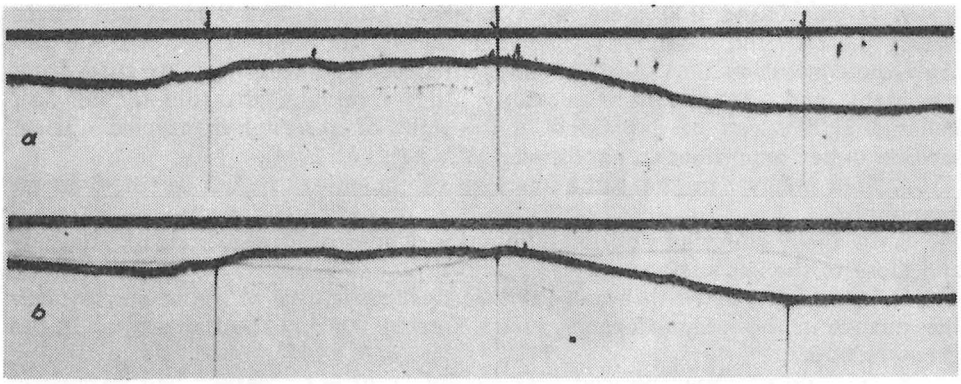

Fig. 13. Quantity of fish. The echo-grams from the year of the highest and lowest number of registered traces of fish concentration. The echo-gram a) was obtained on 18. 7. 1963. and the echo-gram, b) on 22. 7. 1964.

5.8. **Discussion**

The method of putting the fish traces into categories enabled us to follow the behaviour of fish and also it was possible to show the fluctuation of the fish quantity in the bay for each year. The number of fish traces and the quantity of fish rather fluctuate from year to year. 1963. differs considerably from the other years especially from 1964. in the number of fish traces and the quantity of fish. It must be pointed out that the data about the catch produced in the chapter 3.2. coincides with the results obtained by echo sounder, since it has been found out that the catch of sardine in the bay of Kaštela was larger in 1963. then in the other years and especially from the catch realised in 1964.

6. CONCLUSIONS

On the ground of the research carried out in the bay of Kaštela by the echo-sounder about the behaviour, distribution and quantity of sardine for the period from 1962, up to the end of 1966. the following was concluded:

1. It was possible to carry out research into the behaviour and the quantity of fish in the bay of Kaštela due to the recording of the number and the size of fish concetration obtained by echo sounder on the »routes« in the course of the day, the year, and from year to year.

2. From the observation done on some clupeids in natural conditions and from the research of sardine ecology in the Adriatic and also from the observations described in this work, shows that the traces of fish concentration obtained by echo sounder showed primarily the concentration of sardine.

3. Judging from the size of the traces obtained on the echo-gram the fish in the bay of Kaštela do not form large concentrations.

4. It was found that there were a larger number and size of the traces during the day and considerably smaller during the night. From this one can draw the conclusion that the fish behave differently during the day than from the night, and that the light probably plays an imoprtant role in the fish behaviour. This can be explained in the light of observation carried out on sardine under experimental conditions (M u ž i n i ć, 1964).

5. Fish behave in the same manner on moonless nights as they do on mooninght.

6. In the vicinity of artificial light the traces of fish are small »dotted« and close to the sea surface.

7. It has been noted that there is a vertical movement of the traces towards the surface in the later afternoon hours. During the day the fish stayed in the greater depth.

8. It could not been noticed that cloudy or bright weather had any effect on the fish behaviour.

9. A large number of fish traces have been recorded in the warmer part of the year (May — October). The number of traces recorded in the colder part of the year (November-April) is considerably lower.

The difference in the number of traces between warm and cold parts of the year is related to the different behaviour of the fish, especially during the spawning period. Judging from the insignificant number of traces during that period it was presumed that the fish were very likely scattered along the bay. It was also noticed that the differences in the number of traces go together with the changes of the sea temperature in the bay.

10. Fish are more frequently found in the shalow part of the bay in the western part and near to the shore.

11. It was observed that the sea salinity in the bay had any influence on the recording of bigger or smaller number of fish traces in the course of the year.

12. Judging by the number and size of fish traces registered in the warmer part of the year, the amount of fish in some years can be considerable. It was found that 1963. was a better year than the others, especially 1964.

7. SUMMARY

The observations about the behaviour, distribution and quantity of sardine were carried out in the bay of Kaštela in the period from May 1962. up to the end of the year 1966. These observations were carried out by means of echo sounder SIMRAD type 580-4, frequency 30 kHz.

At first the observations were carried out three times a day in the morning, in the afternoon and at night, and later only during the day (in the morning). During the observation elementary hydrographic and meteorological data were taken.

The traces of fish concentration recorded on the echo-gram are put into three categories according to their dimension or their surface area (fig. 1), in order to be able to follow the behaviour and estimation of the quantity of fish.

It was found out that the traces of fish concentration do not extend to an area larger than those mentioned in the categories i. e. 25 sq. mm.
A considerably greater number of traces were recorded during the morning then in the afternoon. The number of traces recorded at night were very small (table 2 and 3). Compared with the traces recorded during the day the traces recorded at night were very few. The small number and minute dimensions of the night traces we tried to explain in the light of observations carried out of sardines under experimental conditions (M u ž i n i ć, 1964).
The traces recorded during the morning were a greater distance from the surface then those recorded during the later afternoon hours. Because of this it was supposed that the fish during the evening hours started to move verticaly towards the surface. Similar behaviour has been seen with some clupeids and it was assumed that the recorded traces showed the concentration of sardine in which anchovies were present in a considerable quantity.

The observations were carried out during the dark on moonless and also on moonlight. In both cases the fish behave in a similar manner.

The observations carried out in the vicinity of artificial light has shown that the traces of the fish were minute and of »dotted« shape, and that they were near to the sea surface.

Observations about fish behaviour were done during bright and cloudy weather, but any difference on the fish behaviour could not be noticed.

The small number of traces recorded during the winter one tried to explain with the help of results obtained by other authors. So it was found that there were recorded a smaller number of traces of fish concentration during the period of the most intensive spawning of the sardine in the bay of Kaštela. It was noticed that fewer traces were recorded as the temperature of the water fell and as the temperature of the water rose, so the greater number of traces were recorded (fig. 7). It was assumed, on the basis of these observations, that the sardine behaves differently at the time of spawning when the sea temperature are low, and very likely a part of sardine population leaves the bay. This supposition is also held by other authors.

It was not possible to find any relationship between sea salinity and the behaviour of fish or the recording of bigger or smaller number of traces and in winter there are very few (fig. 9).

The distribution of fish in the bay is not equal. The greatest number of traces of fish concentration were recorded in the shallowest part of the bay i. e. in its west and northwest parts and on the areas which are near the coast. In the deeper part of the bay the traces of fish are met very rarely (table 4, 5, 6, fig. 10).

On this basis of the recorded traces one tries to estimate the approximate quantity of fish in the each parf of the year and from year to year. In the warmer part of the year the amount of fish increase from March till April, and the greatest quantity are registered in July, September and October. In the colder part of the year the smallest quantity of fish are recorded in February and March (table 7).
The largest number of traces and with them the greatest quantity of fish were registered in the warmer part of 1963. and the smallest in the warmer part of 1964. (tab. 8).

The data about the catch of sardine in the bay of Kaštela collected by fishermen show many similarities with the research carried out by echo sounder.

8. ACKNOWLEDGMENTS

It is a pleasure to make acknowledgment to those who have helped me: Dr R. Mužinić higer research fellow, on her help and advice during the work; the crew of R/v »BIOS«; D. Ratković, M. Alajbeg, Lj. Ivković, M. Kožuh, and F. Vanjaka, technical assistents in Institute for oceanography and fisheries. Theirs help was much appreciated.

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10. PONAŠANJE, RASPODJELA I KOLIČINA SRDELE U KAŠTELANSKOM ZALJEVU

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KRATKI SADRŽAJ

Vršena su istraživanja o ponašanju, raspodjeli i količini srdele u Kaštelanskom zaljevu u razdoblju od svibnja 1962. do kraja 1966. godine. Ova su istraživanja vršena uz pomoć ultrazučnog detektora »SIMRAD« tip 580-4, frekvencije 30 kHz.

Opažanja su vršena dijelom tri puta u toku dana: ujutro, popodne i noću, a poslije samo tokom prve polovine dana. Za vrijeme opažanja uzimani su osnovni hidrološki i metereološki podaci.

Znakovi koncentracija ribe zabilježeni na ehogramima ultrazvučnog detektora razvrstani su u tri kategorije, prema njihovim dimenzijama odnosno površini (tab. 1), radi mogućnosti razmatranja ponašanja i procjene količine ribe.

Ustanovilo se da znakovi koncentracija ribe ne prelaze površine veće od onih spomenutih u kategorijama, tj od 25 mm^2.

Znatno veći broj znakova bio je registriran ujutro nego popodne. Broj znakova zabilježen noću bio je vrlo malen (tab. 2 i 3). Za razliku od dnevnih, noćni znakovi bili su k tome sasvim maleni. Mali broj i sitne dimenzije noćnih znakova pokušalo se objasniti u svjetlu opažanja izvršenih na srdjeli u eksperimentalnim uvjetima (Mužinić, 1964).

Znakovi zabilježeni u toku prije podneva bili su na nešto većoj udaljenosti od površine nego oni iz kasnijih poslijepodnevnih sati. Stoga se pretpostavilo da je riba u toku večerenjih sati počela vršiti vertikalna pomicanja prema površini. Slično ponašanje pokazali su neki klupeidi, pa se pretpostavilo da su registrirani znakovi predstavljali koncentracije srdele u kojima je mogao u određenoj mjeri biti zastupljen i brgljun.

Opažanja su vršena noću za vrijeme mraka i izvan njega. U oba slučaja riba se jednako ponašala.

Opažanja vršena u blizini umjetne svjetlosti pokazala su da su znakovi riba bili sitni i »tačkastog« oblika, te blizu površine.

Vršena su opažanja o ponašanju ribe za vedrog vremena i za vrijeme naoblake, međutim, njihov utjecaj na ponašanje ribe nije se mogao zapaziti.

Mali broj znakova registriran zimi pokušalo se tumačiti uz pomoć rezultata o ponašnju srdele zabilježenih od drugih istraživača. Tako se zapazilo da se za vrijeme najintenzivnijeg mriješćenja srdele, u Kaštelanskom zaljevu zabilježilo veoma malo znakova koncentracija ribe. Zapaženo je pri tome da se usporedo s registriranim manjim brojem znakova ribe snižavala i temperatura

mora u zaljevu i obratno, s povišenjem temperature mora povećavao se i broj registriranih znakova (sl. 8). Pretpostavilo se, na temelju tih zapažanja, da se srdela drugačije ponaša za vrijeme mriješćenja, kada su i temperature mora minimalne, te da po svoj prilici dio naselja srdele napušta zaljev, a to pretpostavljaju i drugi istraživači.

Za istraživanja odnosa između saliniteta mora i ponašanja ribe, odnosno registriranog većeg ili manjeg broja znakova, nije se mogla uočiti nikakva međusobna ovisnost. Zapaženo je, naime, da za jednakog saliniteta mora u ljetnom razdoblju ima, a u zimskom nema, ili se može zabilježiti neznatan broj znakova ribe u zaljevu (sl. 10).

Raspodjela ribe po Kaštelanskom zaljevu nije jednolika. Najviše znakova koncentracija ribe zabilježeno je u najplićem dijelu zaljeva, tj. u njegovom zapadnom i sjeverozapadnom dijelu i na sektorima koji su bliže obali. U dubljim dijelovima zaljeva znakovi riba se susreću rjeđe (tab. 4, 5, 6, sl. 11).

Na temelju broja registriranih znakova pokušala se odrediti približna količina ribe u pojedinim dijelovima godine i iz godine u godinu. U toplijem dijelu godine količina ribe povećava se od ožujka do travnja, a najveće količine registriraju se u srpnju, rujnu i listopadu. U hladnijem dijelu godine najmanje se količine registriraju u veljači i ožujku (tab. 7).

Najveći broj znakova, a s time u vezi i najveća količina ribe, registriran je u toplijem dijelu 1963, a najmanji u toplijem dijelu 1964. godine (tab. 8).

Podaci o lovu srdele u Kaštelanskom zaljevu, prikupljeni od ribara, ukazuju na mnoge podudarnosti s istraživanjima izvršenim pomoću ultrazvučne detekcije.

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