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INTRODUCTION

Gilt sardine, *Sardinella aurita* Valenciennes, spawn in the warmer parts of the Mediterranean. Gilt sardine eggs and larvae were found in the plankton along the coasts of Spain, North Africa, Ionian Sea and Sicily (Ben Tuvia, 1959). Until recently there were no records of this fish plankton stages in the Adriatic. Gamulin (1975) was first who reported the discovery of gilt sardine eggs off the outer sides of islands in the central and southern Adriatic and in the vicinity of Molunat, Budva and Bar. These records refer to the last twenty years, with some interruptions. Small numbers of eggs, from one to three, have ordinarily been recorded, with the exception of one record from the area near Bar where fifteen specimens were found. According to Gamulin, eggs occurred in the plankton in May—July, and in only one ocasion they occurred in August. Temperatures of seawater upper layers at which eggs were found varied between 16 and 17° C in May, and between 20 and 21° C in June and July.

These small numbers of eggs recorded particularly from the southern Adriatic coincide well with the knowledge of the quantity and distribution of this species adults in the Andriatic. Predominantly individual gilt sardine specimens were rarely caught at sites where Gamulin found their eggs. However, during 1974 a considerable quantity of gilt sardine was noted in the commercial catches of small pelagic fish from the channels and coastal waters of the central and even northern Adriatic along the Yugoslav coast, and along the Italian coast up to the Bay of Trieste (Kačić, 1974, 1975). With regard to this unusual numerousness of gilt sardine and small numbers of their eggs recorded from the Adriatic previous to that time, it would be of interest to bring out the data we collected on gilt sardine plankton stages.

METHODS AND MATERIALS

Over a considerable period of years zooplankton material has been collected, particularly for ichthyoplankton, from six stations along the profile transverse to Split (Fig. 1). The investigations have been continuously carried out at Stations Pelegrin (channel area) and Stončica (open sea) since 1962, at Station the Bay of Kaštela (coastal zone) since 1968, and at Station Split sound (channel area) since 1970. Collections are carried out monthly by means of vertical double hauls with a »Helgoland« net (K ü n n e, 1933) from 75 to O m. The exception is the Bay of Kaštela Station where hauls are made from 35 to O m. Stations 11 and 12 (open sea near the Palagruža island) are worked seasonally, in March, June, September and December, by vertical hauls from 75 to O m.

Plankton stages of gilt sardine were found in August and September 1974 and 1975. In addition, one egg found in the Bay of Kaštela in August 1972 is believed to belong to gilt sardine because of its size. A total of 716 eggs, twelve larvae and three post-larvae was caught during 1974 and 1975. The diameter of 186 eggs and oil globes was measured. The length of preserved larvae and post-larvae was taken from the top of snout to the end of notochord (standard length) with the accuracy of 0.04 mm.

Quantities of gilt sardine eggs and larval stages are given per double haul of plankton net. In order to obtain these quantities per 1 m^2 one have to divide each number by 3.2.

RESULTS AND DISCUSSION

Eggs of gilt sardine were found in September 1974 and in August and September 1975. Number of found eggs was considerably larger in 1974 in relation to 1975 (Table 1). Together with this decrease in number in 1975 their spatial distribution also changed. Namely, whereas in 1974 eggs were mainly collected from the Bay of Kaštela, i. e. from the coastal zone (634 eggs — absolute maximum for both years), in 1975 the largest number of eggs was found at Station 12 in the open sea. This may indicate the displacement of the larger concentrations of this fish towards the open sea. As the Table 1. indicates, no egg was found in the channel area. The reason of this discontinuity in the distribution may be that conditions in the channel area were not favourable for the gilt sardine spawning.

Even though it is impossible to determine the distribution of gilt sardine larvae and post-larvae since they were found in small numbers, yet Table 1 shows that they were best represented in the coastal and channel area. The fact that they were found at sites where eggs were not may be accounted for by that they were transported there by currents.

The majority of authours found that, depending on the site, Mediterranean gilt sardine spawned between May—June and September—October (B e n — T u v i a, 1959). The occurrence of eggs in the central Adriatic in August and September is, therefore, in accordance with these data on their spawning period. Our data, however, differ in some respect from those by G a m u l i n (1975) who found gilt sardine eggs only once in August and never in September.

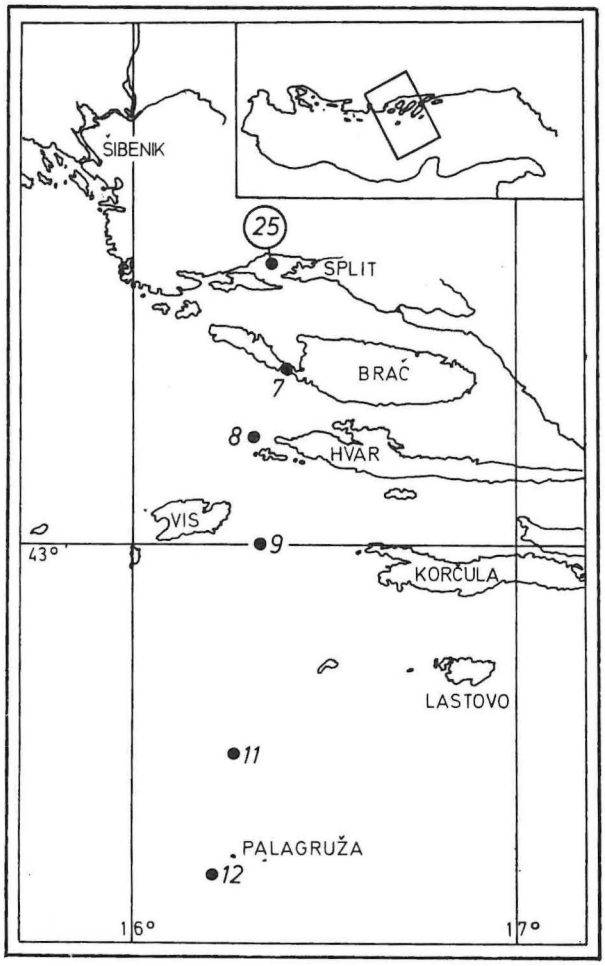

Fig. 1 Area of investigations
Stations: No 25 The Bay of Kaštela
No 7 Split sound
No 8 Pelegrin
No 9 Stončica

Since the gilt sardine eggs are similar to those of sardine *(Sardina pilchardus,* Walb.) and differ from them only in size, it was necessary to test whether the eggs we found do belong to gilt sardine. This test was necessary in another respect also. Namely, sardine may sometimes start their spawning in September. For example, according to personal communication by K a r l o v a c, J., from 1964—1975, sardine eggs were found at Stončica in September 1968 (three eggs with diameter 1.63 mm) and in the Bay of Kaštela in 1971 (fifteen eggs with a diameter range of 1.51—1.72 mm and a mean diameter 1.62 mm) and in 1973 (two eggs with a diameter of 1.46 and 1.51 mm). Eggs

Table 1

Distribution of gilt sardine plankton stages in the area of investigations in 1974 and 1975

Station (Bottom depth)	Year	Date	Eggs	Larvae	Post-larvae	Temperature (°C) X(0—10 m)	Temperature (°C) X(0—30 m)	Salinity (S‰) X(0—10 m)	Salinity (S‰) X(0—30 m)
Bay of Kaštela (42 m)	1974.	15.08	0	0	0	19.63	17.13	37.41	37.80
		24.09	634	2	0	22.75	21.53	36.95	37.33
	1975.	15.08	0	0	0	21.65	18.63	37.76	38.08
		27.09	9	6	0	22.33	21.64	36.98	37.65
Split sound (84 m)	1974.	14.08	0	1	0	—	—	—	—
		22.09	0	0	0	—	—	—	—
	1975.	14.08	0	0	0	—	—	—	—
		16.09	0	0	0	—	—	—	—
Pelegrin (78 m)	1974.	14.08	0	1	0	21.08	18.59	38.02	38.20
		22.09	0	2	1	23.36	22.98	38.23	38.26
	1975.	13.08	0	0	0	20.97	18.51	38.56	38.61
		16.09	0	0	0	22.68	22.58	38.60	38.64
Stončica (107 m)	1974.	13.08	0	0	0	23.43	19.88	38.24	38.29
		21.09	26	0	0	23.35	21.82	37.92	38.14
	1975.	12.08	2	0	0	22.38	19.31	38.58	38.64
		13.09	0	0	2	23.07	20.77	38.56	38.65
No. 11 (170 m)	1974.	18.09	4	0	0	23.93	21.05	38.31	38.37
	1975.	11.09	0	0	0	23.23	20.45	38.23	38.30
No. 12 (110 m)	1974.	17.09	0	0	0	23.59	20.15	38.31	38.40
	1975.	11.09	41	0	0	23.42	20.45	37.90	38.10

diameter values indicate that these eggs were sardine eggs since the eggs diameter of sardine from the central Adriatic varies between 1.30 and 1.80 mm (K a r l o v a c, J., 1967). Means of diameters of eggs and oil globes which we supposed belonged to gilt sardine were, therefore, compared to the corresponding sizes of sardine eggs found at the same stations in October of 1974 and 1975. Means of diameter values were calculated for all the stations together since it was previously established that walues did not vary much from station to station. The results obtained are given in Table 2.

Table 2

Size of eggs and oil globes diameter in gilt sardine and sardine (in mm).

Year		*Sardinella aurita* N	Range	X	s	*Sardina pilchardus* N	Range	X	s
1974	eggs	140	1.13—1.39	1.24	±0.06	100	1.39—1.80	1.60	±0.08
	oil globe	138	0.08—0.15	0.11	±0.02	89	0.11—0.19	0.15	±0.02
1975	eggs	46	1.13—1.43	1.31	±0.06	225	1.39—1.77	1.59	±0.07
	oil globe	46	0.11—0.15	0.13	±0.02	224	0.11—0.19	0.16	±0.02

Difference in arithmetic means of diameters of eggs and oil globes was tested for each year separately. Following results were obtained:

a) Eggs diameter

1974 $X_1 - X_2 = 0.36$ $S_{\bar{x}_1} - S_{\bar{x}_2} = 0.009471$ $t = 38.01$ $P < 0.05$

1975 $X_1 - X_2 = 0.28$ $S_{\bar{x}_1} - S_{\bar{x}_2} = 0.009995$ $t = 28.01$ $P < 0.05$

b) Oil globes diameter

1974 $X_1 - X_2 = 0.04$ $S_{\bar{x}_1} - S_{\bar{x}_2} = 0.002683$ $t = 14.90$ $P < 0.05$

1975 $X_1 - X_2 = 0.03$ $S_{\bar{x}_1} - S_{\bar{x}_2} = 0.003209$ $t = 9.35$ $P < 0.05$

Result of t-test indicate that these eggs belong to different species. This is also evident from the frequency curves of the gilt sardine and sardine eggs size values which show minimum overlapping in both years (Fig. 2).

Table 2 demonstrates that the gilt sardine eggs diameter ranged from 1.13 to 1.43 mm. We may also add that eggs with a diameter of 1. 18 to 1.29 mm were found in the Split channel in 1952 (K a r l o v a c, J., 1967). However, these eggs were recorded in March and April when gilt sardine is unlikely to spawn. According to the same author, these eggs probably belonged to a young sardine which spawned for the first time.

Gilt sardine eggs found in 1975 appeared to be somewhat larger (Table 2, Fig. 2) than those found in 1974.

Range of values of gilt sardine eggs and oil globes daimeter agrees broadly with the data of D' A n c o n a (1933) who found eggs diameter of gilt sardine from the Gulf of Naples to range from 1.20—1.40 mm, and a mean values of oil globes to be about 0.121 mm. In addition, the eggs we found seem to be larger than those found at Balearic islands, since O l i v e r y N a v a r r o (1952) found their size range between 1.01 and 1.32 mm with a mean of 1.16 mm.

All the found larvae had oil globe in the middle of yolk sac and therefore is no doubt they belonged to gilt sardine. Length ranged between 3.04 and 3.75 mm with a mean of 3.53 mm. No one larva had completely absorbed yolk sac. These larvae, as well as eggs, are larger than those found at Balearic islands, since O l i v e r y N a v a r r o (1952) found yolk sac completely absorbed at 3.5 mm in body length. On the other hand, in October of 1974 and 1975 length of sardine larvae with almost the same rate of absorption of yolk sac varied from 3.00 to 4.95 mm, mean 4.09 mm.

Two of three found gilt sardine post-larvae were damaged. Length of the third post-larva was 4.43 mm.

Temperature and salinity at which gilt sardine plankton stages were recorded are given in Table 1. Temperature and salinity means were calculated for surface layers 0—10 m and 0—30 m. Only surface temperature and salinity were taken into consideration since earlier investigations showed

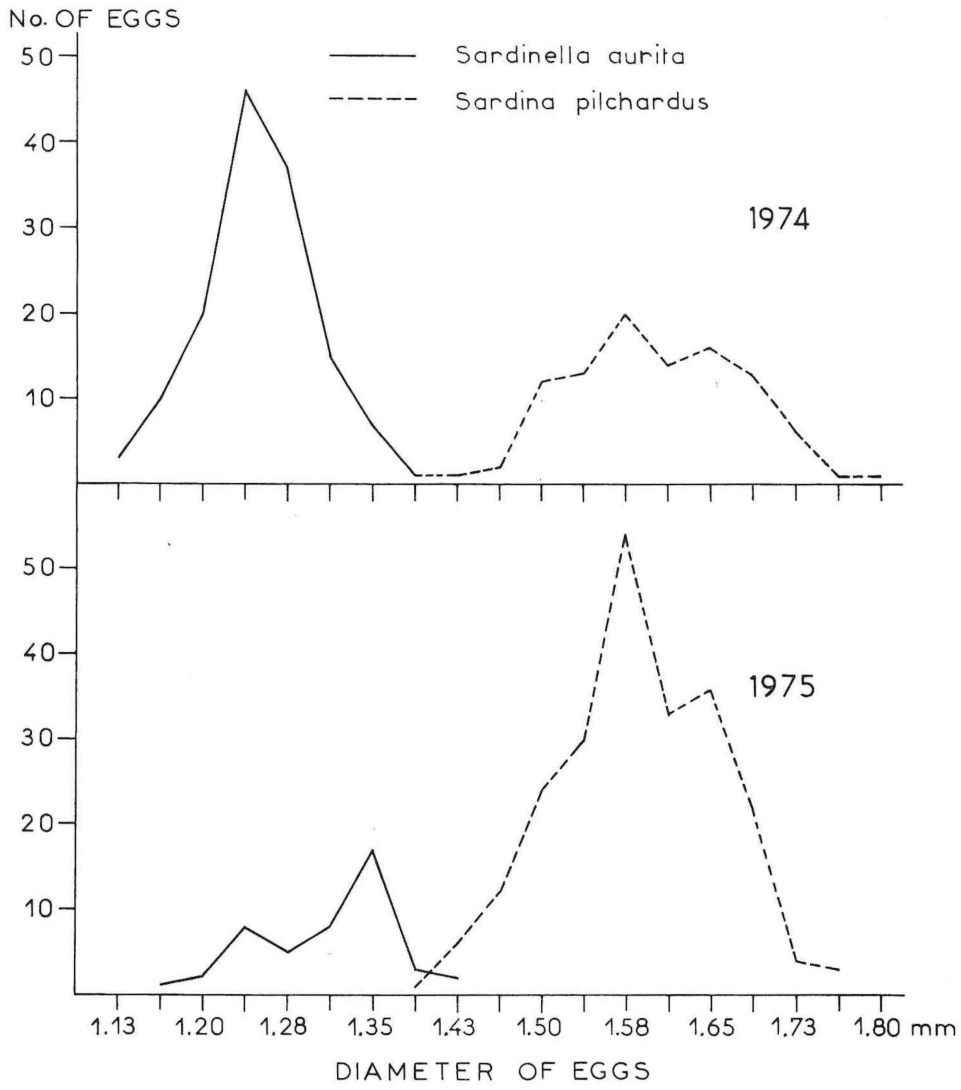

Fig. 2 Frequency curves of the egg size of gilt sardine and sardine

(F a g e, 1920) that gilt sardine plankton stages could be found not deeper than 25 m.

In 1974 the gilt sardine eggs were found between 22.75—23.93°C (21.05—-—21.53°C) — the figures within brackets refer to depths between 0 and 30 m. In 1975 eggs were found at temperatures of 22.33—23.42°C (19.31—21.64°C). In 1974 the largest number of eggs was taken from the Bay of Kaštela at temperature 23.42°C (20.45°C). One gilt sardine egg was found in the Bay of Kaštela in 1972 at temperature of 23.47°C (19.79°C).

Temperatures at which larvae and post-larvae were found varied within almoust the same range within which varied temperatures at which eggs were found. The only exception is the larva from Station Pelegrin found in August of 1974, at somewhat lower temperature of 21.08°C (18.59°C). According to Ben Tuvia (1959) these temperatures are consistent with those indicated by other authors like Fage (1920), Navarro (1932) and Anadon and Rodrigues—Roda (1951). Also, they do not differ from those indicated for the Adriatic by Gamulin (1975) except for the temperature of the upper layers varying from 16—17°C which be recorded in spring.

Temperature of 0—30 m depth layers seem to be very important for the occurrence of gilt sardine eggs. Thus, even though temperature at the surface was rather high on some occasions (Table 1), eggs were not found until temperature of the 0—30 m layer exceeded 20°C. The only exception was in August of 1975 when eggs were taken from Station Stončica at temperature of this layer of 19·31°C.

From the above it appears that gilt sardine eggs were found within relatively high temperature limits. This, together with eggs size and position of oil globe in larvae may be a further evidence that gilt sardine spawned in this area. Sardine eggs, however, occur in the central Adriatic at temperatures between 11.4 and 18.9°C in channels, and between 11.6 and 19.3°C in the open sea (Karlovac, J., 1967). Furthermore, temperatures between 20.63 and 21.83°C (19.15 and 20.42°C), at which the occurrence of sardine eggs was recorded in the area of investigations in September 1968, 1971 and 1973, were lower than those at which gilt sardine eggs occur.

Gilt sardine eggs were found in 1974 at salinity ranging between 36.95 and 38.31‰ and in 1975 between 36.98 and 38.58‰. Larvae and post-larvae were found within the same salinity range (Table 1).

These records of gilt sardine plankton stages in the central Adriatic support the observations done by Kačić (1974, 1975) who reported the occurrence of a considerable quantities of this fish in the commercial catches realized in this area in 1974. Moreover, the decrease in eggs number recorded in 1975 coincides well with what fishermen said that they caught much less gilt sardine in 1975 than they did in 1974 (Kačić, personal communication).

The length distribution of samples of commercial catches from the Bay of Kaštela taken in May and June of 1974 showed 12—15 cm gilt sardine groups with 13 cm modal lengths (Kačić, 1974 and 1975). Since it is known that gilt sardine from the eastern Mediterranean reach their first maturity at this length (Ben Tuvia, 1959) Kačić concluded that young fish, about one year old, occurred in the central Adriatic. According to him, this would mean that gilt sardine spawned somewhere in the Adriatic a year before. We cannot prove this supposition since in 1973 there were no gilt sardine plankton stages recorded from the area under our control. This, certainly, admits the possibility that gilt sardine spawned somewhere else, probably more southward. Comparing the data on gilt sardine length distribution with the eggs size which we found less in 1974 in relative to 1975 (Table 2, Fig. 2, we may suppose that it was predominantly young gilt sardine which spawned in the Central Adriatic in 1974. Namely, it is well known that younger and smaller individuals of many of the fish species produce smaller eggs (Nikolski, 1963). Some fishermen reported that specimens they caught in 1975 were mainly larger than those caught in 1974 (Kačić, personal communication).

This, together with our discovery of larger eggs in 1975, speaks in favour of the above statement. Since, however, the investigations on adult gilt sardine stopped in June 1974 and no data have been collected on the eventual gonad maturation in smaller fish, this statement remains at the level of supprosition.

Even though the incthyoplankton investigations have been carried out at the profile Bay of Kaštela — Palagruža for many years now, we have no records of gilt sardine plankton stages previous to 1974. The exception is the egg found in the Bay of Kaštela in 1972. Thus, the occurrence of gilt sardine eggs in 1974 and 1975 may be considered unusual, and all the more so,since the number of eggs we recorded exceeded a lot that recorded by Gamulin (1975). Some environmental changes which probably took place in the central Adriatic may be the cause of not only the increase in quantity of gilt sardine and their migration towards the northern Adriatic, but also of their spawning at sites where they either didn't spawn at all or spawned very rarely. Since, however gilt sardine have never been more intensively investigated in the Adriatic, the cause of changes in their geographical distribution and behaviour will be particularly difficult to explain.

Nevertheless, there are some evidences that some hydrographic changes took place in this area shortly before, and during the period of occurrence of gilt sardine and their plankton stages. One of these hydrographic changes was considerable increase in nitrate quantity recorded from the central Adriatic in 1973 (Stojanoski, personal communication). Furthermore, salinity was considerably high in this area in 1973 and particularly in 1975, what was probably due to the new ingression of Mediterranean water into the Adriatic (Buljan, personal communication). These changes, which otherwise positively affect the organic production in the Adriatic, are likely to have acted upon gilt sardine, as well. However, even though have occurred several ingressions of Mediterranean water since 1962, gilt sardine plankton stages have never been recorded. This indicates that this new ingression period in itself was not the cause of gilt sardine occurrence in the central Adriatic, but that some biological changes took place in the wider area of the Adriatic.

CONCLUSIONS

1) The occurence of gilt sardine plankton stages was recorded from the central Adriatic in August and September of 1974 and 1975, which was an unusual phenomenon in this area.

2) The occurrence of rather high concentrations of gilt sardine eggs, particularly in the coastal regions, in 1974 agrees well with the capture of considerable quantities of this fish in the central Adriatic. Smaller number of eggs found in 1975 coincides with the poorer catches realised in 1975.

3) The diameter of eggs appeared smaller in 1974 than in 1975. The eggs from 1974 seem to belong to smaller and younger fish which were cought in the same area during the spring of that year.

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KRATAK SADRŽAJ

Planktonski stadiji srdele goleme bili su do sada nalaženi u manjem broju, tokom ljetnih mjeseci, pretežno u južnom Jadranu. Međutim, u augustu i septembru 1974. i 1975. godine nađeni su planktonski stadiji ove ribe u srednjem Jadranu u relativno velikom broju. Kako se na ovome području već duži niz godina kontrolira sastav i količina ihtioplanktona, a da planktonski stadiji ove ribe nisu bili zapaženi, njihova se pojava može smatrati neuobičajenom.

Jaja, larve i postlarve srdele goleme nađeni su kod površinskih temperatura od 22.33 do 23.93°C i saliniteta od 36.95 do 38.58‰. Planktonski stadiji bili su brojniji u 1974. nego u 1975. godini. Njihova pojava koincidira sa pojavom relativno velikih količina odrasle srdele goleme na istom području.