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INTRODUCTION

In view of the important part played by the hake (*Merluccius merluccius* /L./) as a predator, especially of pelagic fishes, an attempt was made to analyse the relation of the hake to its main prey species using horizontal distribution data.

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1. MATERIAL AND METHODS

The trawling data from the Fishery Biological Expedition »Hvar« in the Adriatic carried out in 1948 and 1949 have been used in this study of the distributional relations between the hake and some other fishes.

General data on the »Hvar« Expedition, as well as the data on all the more important catches of fishes and edible invertebrates were given by O. Karlovac (1956, 1959a). The most important of these data are summarized here in addition to other calculated data.

The Expedition performed the observations in the period extending from 26 February 1948 to 31 March 1949.

The catches were made by a commercial trawl, the trawling speed ranging from 2.5 to 3 knots. Long lines were used only twice.

For various reasons the observations were not uniformly distributed in time. They were not made in October, while in December 1948 and February 1949 only a few observations were carried out; in February 1948 and January 1949 their numbers were insignificant.

The observations were performed almost entirely in the open Adriatic and, to a very small extent, in the northernmost eastern Ionian, the minefields and depths exceeding 400 m excepted. Of the 171 stations (Figs. 6—11), the most uniformly distributed and the densest stations were those of the central Adriatic.

For trawlings between two stations both stations were taken in the analysis of the species distributions.

Trawlings were carried out twice at all the stations, those along the Albanian coast excepted.

Mean depths between the initial and final trawling depths of each haul were used.

From a total of 297 trawl catches (some catches not used before being included) 8 catches were defective for various reasons. However, all of the 297 trawl catches were used when considering the species distributions.

One-hour hauls were the most frequent. When dealing with quantitative data only one-hour hauls, i.e. those lasting 60—70 minutes were used.

The trawl catches were carried out at depths ranging from 20 to 382 m (mean trawling depths) and at a mean depth of 125 m. From 297 catches 266 or 89.6% were made at depths lower than 200 m.

This fish nomenclature of CLOFNAM (Hureau and Monod, eds., 1973) was used.

The total length of the fish was taken during the Expedition and in the sardine commercial catch sampling. Lower class limits were used and the mean lengths were corrected. For other data the length used is not indicated. It was presumed that the total length was also taken by other authors.

The elementary data used are kept by the authors.

2. OBSERVATIONAL DATA

2.1. HORIZONTAL DISTRIBUTION OF THE HAKE

The hake has a wide horizontal distribution in the eastern Atlantic and Mediterranean. It is a deep water fish. According to Hickling (1935), the hake may occur at more than 300 fms (549 m) and in payable quantities even at 450 fms (823 m). Its main habitat is at the edge of the continental shelf and on the slope (Graham, 1956). According to Belloc (1929a and b), the hake is most frequently caught in waters whose depths range from 100 to 500 m. In Moroccan waters the immature fish were found near the coast, the older fish moving offshore (Maurin, 1954). Later investigations showed that the adult hake concentrations occur in waters whose depths range from 100 to 200 m, the oldest coming from greater depths and the youngest from various depths of the continental shelf (Maurin, 1968).

At depths on the Moroccan continental shelf less than 200 m the immature fish range from 5 to 29 cm represented 88% of the hake catches; at depths from 200 to 400 m the proportion of immature fish from 9 to 20 cm long was only 45% (Maurin, 1968).

Many hake spawning places have been identified along the British and Irish coasts (Hickling, 1935). According to Hickling (1935), the hake spawning starts in deep waters, »beyond the 100-fathom line« (183 m), and continues in shallower waters.

The following data may illustrate the horizontal distribution and the relation to depth of the Mediterranean hake.

The observations carried out in the 1952—1953 trawling season showed that the hake were well-represented on the continental slope of the Balearic Islands at depths ranging from 300 to 600 m (Oliver, 1953). According to later observations, the hake were also frequent at lesser and greater depths, i.e. at those ranging from 200 to 400 m and from 400 to 800 m as shown by Oliver (1959). The author also found a reduction in the proportion of fish with increasing depth, this proportion being, however, reduced by the fishing itself. Massuti (1971) recorded in 1964 a reduction in the number of hakes on the continental shelf of the Balearic Islands due to the fishing. The author also found exceptionally large hake in unexploited southern waters (Alboran I.).

According to Bas (1959), the hake is one of the most important fishes in the trawl fishery on the eastern Spanish continental shelf, the old individuals occurring on the continental slope.

A Group of Experts of the General Fisheries Council for the Mediterranean (1970) showed that in the western Mediterranean the hake is caught at depths exceeding 500 m too. According to these data, in waters off the Hammamet Bay (southern Mediterranean), at depths ranging from 200 to 300 m, small and large hake were found, while at depths exceeding 500 m only large individuals (up to 70 cm) occurred. However, on the northern African coast young hake were also recorded at depth of 400 m.

In Sardinian waters, at 150 m depth, hake of mean length 29.4 cm were recorded in the 1954—1955 trawling season, while in the Corsican waters, at depths ranging from 400 to 500 m, hake of mean length 43.4 cm occurred (Ghirardelli, 1959).

In the meso-abyssal zone of Sardinia, at depths ranging from 400 to 550 m, the hake showed a length ranging from 60 to 70 cm (Scaccini, 1959).

In western Sicilian waters and on the northern side of the Siculo-Tunisian bank in epibathyal waters, at depths ranging from 235 to 265 m, the hake were smaller than those occurring in mesobathyal waters, at depths ranging from 500 to 650 m (their length distributions essentially differed), (Arena and Li Greci, 1973).

In the Israeli waters, at depths ranging from 31 to 46 m, the hake of 15.5 cm were caught by trawl in the 1955—1956 trawling season (Gotlieb and Oren, 1957).

According to fishery statistics for 1963, 1966 and 1968, and experimental trawling in 1966—1967, the hake were well-represented off the Israeli coast,

at depths ranging from 100 to 500 m, and were larger than those occurring in shallower waters (Oren et al., 1971).

The hake is also a very widely distributed species in the Adriatic as shown mainly by the data of the »Hvar« Fishery Biological Expedition which, in 1948 and 1949, carried out extensive trawlings in open waters up to the depth of 400 m (Karlovac, O., 1957, 1959a), as well as by the data from parts of the open Adriatic (Matta, 1954; Ghirardelli, 1959; Županović, 1959, 1961a, 1968; Piccinetti, C. and G. Piccinetti Manfredin, 1971; Kirinčić and Lepetić, 1955; Jukić, 1975) and those from channels and very coastal waters of the eastern Adriatic (Kotthaus and Zei, 1938; Zei and Sabioncello, 1940; Zei, 1940, 1949; Karlovac, O., 1959a; Crnković, 1959; Županović, 1953, 1961a; Lepetić, 1965; Jukić, 1972).

In spite of being recorded, during the »Hvar« Expedition, in the northern, central and southern Adriatic hake were badly represented, by numbers (2.4%) and weight (6.6%), in the trawl catches carried out in the northern Adriatic; in the southern Adriatic they were fewer (5.1%) than in the central Adriatic (13.2%) at the similar proportion by weight (13.6%, in the central Adriatic 16.0%), (Karlovac, O., 1957), this pointing to the larger size of the south Adriatic individuals.

The Yugoslav commercial trawl catch of the hake in the shallowest northernmost part of the Adriatic does not seem to be important either. In the 1951 trawling season, *Merlangius merlangus euxinus* Nordm. was found to be fairly common in that part of the Adriatic, while the hake was the dominant gadid species in all other parts of the Yugoslav fishing area (Županović, 1953).

In the northernmost Adriatic the Italian commercial catch of the hake is very small as shown by the official fishery statistics.

In the southern deeper Adriatic the hake caught by long line were the most frequent at 300 m; the frequency rapidly decreased at greater depths, especially at depths exceeding 600 m (Kirinčić and Lepetić, 1955).

In the shallow northern Adriatic, at depths ranging from 25 to 30 m, the hake showed, in 1953, a mean length of 21.7 cm (Matta, 1954). In the central Adriatic, at depths ranging from 20 to 50 m, a mean length of 23.6 cm was recorded (Ghirardelli, 1959).

In the central Adriatic Županović (1961b) found small and large hakes at depths ranging from 100 to 210 m (the large ones mostly at depths 100—150 m) and the medium ones in shallower waters. The individuals analysed reached a total length of 84 cm, but those exceeding 50 cm were very rare.

The hake from the southern deeper Adriatic, caught by long lines at depths ranging from 100 to 800 m, was much larger, i.e. showed a total length ranging from 29 to 95 cm and a mean length of 58.6 cm (Kirinčić and Lepetić, 1955). Moreover, an increase in the hake size with the depth was recorded. At all depths females were more numerous than the males.

A more detailed analysis of the »Hvar« Expedition data on trawl catches showed that the hake was found at nearly all the stations, i.e. on 169 or

Table 1. Data on the »Hvar« Expedition trawl stations and catches numbers, and depths at catches for the analysed species, 1948 and 1949.

Species	Stations		Catches		Depths at catches, m		
	n	%	n	%	Min.	Max.	\bar{X}
<i>Sardina pilchardus</i> (Walb.)	38	22.2	41	13.8	24.5	180.5	89.2
<i>Sprattus sprattus</i> (L.)	14	8.2	16	5.4	30.0	105.0	68.7
<i>Engraulis encrasicolus</i> (L.)	35	20.5	39	13.1	31.5	210.0	97.9
<i>Scomber scombrus</i> L.	79	46.2	94	31.6	29.0	224.0	124.2
<i>Boops boops</i> (L.)	85	49.7	108	36.4	20.0	220.0	100.0
<i>Trachurus trachurus</i> (L.)	117	68.4	153	51.5	20.0	341.0	143.8
<i>Trachurus mediterraneus</i> <i>mediterraneus</i> (Std.r.)	114	66.7	151	50.8	24.5	216.0	105.6
<i>Spicara smaris</i> (L.)	65	38.0	87	29.3	20.0	213.0	98.9
<i>Spicara maena flexuosa</i> (Raf.)	96	56.1	133	44.8	20.0	256.0	89.1
<i>Argentina sphyraena</i> L.	134	78.4	225	75.8	61.0	382.0	144.7
<i>Glossanodon leioglossus</i> (Val.)	18	10.5	19	6.4	143.0	316.0	193.7
<i>Merluccius merluccius</i> (L.)	169	98.8	291	98.0	20.0	382.0	125.7

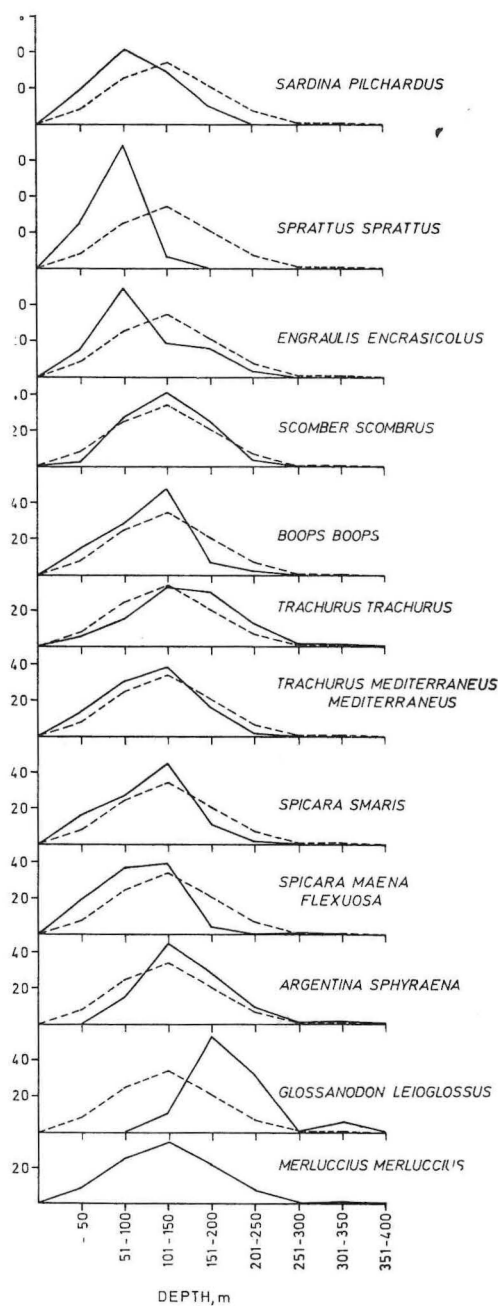


Fig. 1. Depth distributions of the »Hvar« Expedition trawl catches of the analysed species (solid line) and of all the Expeditions trawl catches, 1948 and 1949.

Table 2. Depth distributions of the »Hvar« Expedition trawl catches of the analysed species, 1948 and 1949 (in parentheses the percentage data).

Species	D e p t h, m								Total
	—50	51—100	101—150	151—200	201—250	251—300	301—350	351—400	
<i>Sardina pilchardus</i> (Walb.)	8 (19.5)	17 (41.5)	12 (29.3)	4 (9.8)	—	—	—	—	41
<i>Sprattus sprattus</i> (L.)	4 (25.0)	11 (68.8)	1 (6.3)	—	—	—	—	—	16
<i>Engraulis encrasicolus</i> (L.)	6 (15.4)	19 (48.7)	7 (17.9)	6 (15.4)	1 (2.6)	—	—	—	39
<i>Scomber scombrus</i> L.	2 (2.1)	26 (27.7)	39 (41.5)	24 (25.5)	3 (3.2)	—	—	—	94
<i>Boops boops</i> (L.)	16 (14.8)	31 (28.7)	52 (48.2)	7 (6.5)	2 (1.9)	—	—	—	108
<i>Trachurus trachurus</i> (L.)	9 (5.9)	24 (15.7)	51 (33.3)	46 (30.1)	19 (12.4)	2 (1.3)	2 (1.3)	—	153
<i>Trachurus mediterraneus mediterraneus</i> (Std r.)	21 (13.9)	46 (30.5)	58 (38.4)	24 (15.9)	2 (1.3)	—	—	—	151
<i>Spicara smaris</i> (L.)	14 (16.1)	24 (27.6)	39 (44.8)	9 (10.3)	1 (1.1)	—	—	—	87
<i>Spicara maena flexuosa</i> (Raf.)	26 (19.5)	49 (36.8)	52 (39.1)	5 (3.8)	—	1 (0.8)	—	—	133
<i>Argentina sphyraena</i> L.	—	34 (15.1)	101 (44.9)	63 (28.0)	21 (9.3)	2 (0.9)	3 (1.3)	1 (0.3)	225
<i>Glossanodon leioglossus</i> (Val.)	—	—	2 (10.5)	10 (52.6)	6 (31.6)	—	1 (5.3)	—	19
<i>Merluccius merluccius</i> (L.)	25 (8.6)	75 (25.9)	100 (34.5)	62 (21.4)	22 (7.6)	2 (0.7)	3 (1.0)	1 (0.4)	290

98.8% of stations and in 291 or 98.0% of catches (Table 1, Figs. 6—11). They were recorded in the northern, central and southern Adriatic and in the northernmost Ionian, at depths ranging from 20 to 382 m and at a mean depth of 125.7 m. The Expedition stations at which the hake was caught are shown, together with the stations positive for other fishes, in Figures 6—11. The hake were also caught by long line at greater depths (443 and 765 m). It follows that the mean depth at which the hake trawl catches were carried out would have been greater if the Expedition had trawled at greater depths, the mean trawling depth of the Expedition being only 125 m.

The largest number of the hake catches by trawl during the »Hvar« Expedition, i.e. 238 or 81.8%, was recorded within the depth intervals of 51—100, 101—150 and 151—200 m (Table 2, Fig. 1).

180 from a total of 291 hake trawl catches (61.9%) taken during the »Hvar« Expedition contained less than 40 individuals, 57 catches (19.6%) less than 10 individuals and 27 catches (9.3%) less than 5 individuals.

22 or 7.6% more abundant catches (100—199 individuals) by one-hour trawling took place at depths ranging from 45 to 220 m and at a mean depth of 162.8 m. 13 or 4.5% the most abundant one-hour catches (200 individuals and more) were recorded at depths ranging from 135 to 256 m and at a mean depth of 178 m.

More abundant one-hour hake catches (100 individuals and more) were carried out mainly in the central Adriatic, i.e. in the Jabuka Pit and southerly, but also in the southern Adriatic along the north-eastern edge of the south Adriatic pit; in the southernmost part of the Expedition area they were extremely rare (observations were carried out there mostly only once, at the end of May and in June).

The most abundant catches (200 individuals and more) were taken nearly exclusively in the Jabuka Pit and almost all in its eastern part.

More abundant catches (100 individuals and more) were obtained, during the »Hvar« Expedition, in various months of the year, i.e. in cold and warm periods.

At the experimental trawling in the Mid-Dalmatian channels, at mean depths ranging from 29.5 to 104.0 m, in 1957 and 1958, the hake catches containing on average 28 individuals and more were taken in the Split, Brač and Hvar Channels and especially in the Neretva Channel; the catches obtained outside of the Šolta Island, in the Vis and Korčula Channels were smaller and contained on average 15 individuals and less (from the monthly data of Županović, 1961a). The difference was not connected with a difference in the depth.

The total length of all the hakes caught during the »Hvar« Expedition showed a very wide range, i.e. from 2 to 86 cm. Most of the catches also showed a rather wide length range, i.e. exceeding 20 cm. Moreover, the length range showed some relation to the depth. The length range of the hake caught at depths up to 80 m fell mostly in the 20—24, 25—29 and 30—34 cm classes and mainly did not exceed the 40—44 cm class (Fig. 2). Conversely, at depths exceeding 120 m the length range was mostly larger. This agrees with the observations of Županović (1961b) who found small and large hakes at

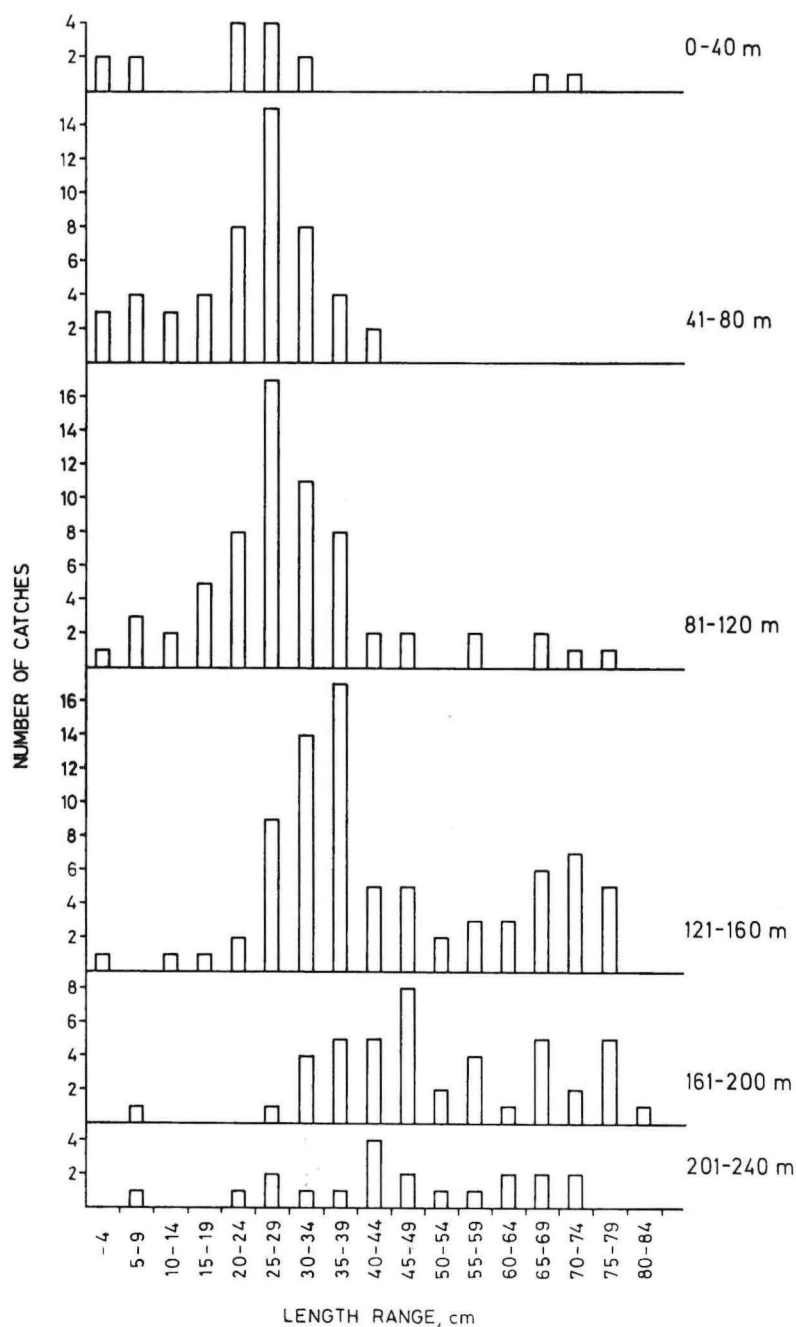


Fig. 2. Relation between the length range and the trawling depth in the hake as shown by the »Hvar« Expedition data, 1948 and 1949.

depths ranging from 100 to 210 m. In addition, in the central Adriatic, at a depth of 220 m, small, medium and large hake were caught by an Italian trawl (GFCM Group of Experts, 1970).

The hake from the »Hvar« Expedition trawl catches were generally small. Most of the larger catches showed asymmetric length distribution with a single or dominant mode at a total length not greater than 20 cm (Karlovac, J. and O. Karlovac, unpublished data). In 117 out of the 291 hake trawl catches (40.2%) only individuals with a total length less than 40 cm were recorded. Further 167 catches (57.4%) also contained such individuals besides the larger ones. Only in 63 out of the 291 catches (21.6%) individuals exceeding 59 cm, alone or with smaller fish, occurred. It may be mentioned that the male hake reach first sexual maturity at a length of 22–30 cm and the females at a greater length (Zei, 1949). According to Županović (1968), the length range for males is 20–28 cm, and for females 26–33 cm. It may also be mentioned that, according to Larrañeta (1970), Mediterranean hake smaller than 40 cm behave like the pelagic or at least semi-pelagic fishes.

Some of the »Hvar« trawl catches contained very young hakes. 73 out of the 291 (25.1%) hake catches did contain also specimens ranging from 2 to 5 cm (lower class limit was used) inclusively. These catches were taken in the Jabuka Pit and southward, at depths ranging from 57.0 to 238.5 m and at a mean depth of 158.2 m, all the year round (Karlovac, J. and O. Karlovac, unpublished data).

In the open central part of the eastern Adriatic hakes smaller than 4 cm were recorded earlier (Županović, 1961b, 1968).

The 4.0 and 5.5 cm lengths were also recorded in the hake from the north Adriatic channels (Kotthaus and Zei, 1938; Crnković, 1959).

The area in which the hake larvae and postlarvae were caught during the »Hvar« Expedition, in 1948 and 1949, and other surveys carried out in 1947, 1952 and 1953, extended between the coordinates 42° and 44°N and 14° and 17°E, but predominantly in the eastern part of the Adriatic (Karlovac, J., 1965). The larvae and postlarvae appeared from October to June, with a maximum in January and February (Karlovac, J., 1965). The largest mean number of the hake larvae and postlarvae per catch was recorded in upper layer of waters of depths ranging from 50 to 100 m (Karlovac, J., 1965). However, it must be taken into account that one part of the additional larval stages surveys were carried out within the 100-metre contour.

At such depths the spawning of hake is to be expected and, consequently, also concentrations of spawners and juvenile hakes. However, if knowledge of the general ecology of the hake (Hickling, 1935) is applicable to the Adriatic, then in shallow waters ranging from 50 to 100 m only one phase of the spawning, in which young spawners would participate, should take place. In that case another earlier spawning phase with the participation of older spawners in deeper waters has to be postulated and, therefore, their concentrations too. Mature hake were recorded at the eastern edge of the Jabuka Pit, at depths ranging from 100 and 150 m (Županović, 1968). However, they have to be expected at greater depths too.

Local differences in the mean length of the young hake were found in the central eastern Adriatic by Županović (1968).

C. Piccinetti and G. Piccinetti Manfrin (1971) found a marked difference in the size of hake between closely situated small areas in the northern Adriatic from various parts of the year (in March and November modal lengths of 33 and 18 cm respectively). In these areas the depth did not exceed 100 m.

The greatest lengths of Adriatic hake, of 68 cm in a male, and 95 cm in a female, were recorded in fish caught by long line in the southern Adriatic, in the 1950—1952 period (Kirinčić and Lepetić, 1955). As according to Taylor (1959) the ratio of the maximum length L_{max} to the asymptotic length L_{∞} is about 0.95, the asymptotic length in the Adriatic hake would be about 85.8 cm. The ratio of the length at first maturity L_m , found to be 30.5 cm (28 cm in males and 33 cm in females from the central Adriatic as shown by Županović, 1968), to the asymptotic length L_{∞} would be 0.36. This value is lower than those (0.45—0.66) recorded in gadiforms from other seas (Beverton and Holt, 1959). It is also lower than that (0.52) found by Larrañeta (1970) in female hake from the east Spanish waters (the Castellón area).

If the greatest length of hake trawled during the »Hvar« Expedition, i.e. 54 cm in a male and 86 cm in a female would be used, then a L_m/L_{∞} value of 0.41 would be obtained.

It may be mentioned that the length at which Adriatic hake enter the catch L_c is much less than the maturation length L_m . The length distribution in the hake from the eastern central Adriatic, in the 1956—1966 period, showed a dominant mode at 9 cm (Županović, 1968). The exploited phase of the Adriatic hake is obviously large. A need for a more careful regulation emerges, especially in conditions of increasing exploitation rate, mostly within the shelf waters.

Conclusions

The hake shows a very wide and continuous distribution in the Adriatic as shown by the »Hvar« Expedition data for the open waters, these data completing, to a large extent, the earlier partial data applying to some areas of the open Adriatic, channels and coastal waters of the eastern Adriatic.

During the »Hvar« Expedition hake were found at depth ranging from 20 to 382 m and at a mean depth of 125.7 m. These depths were almost equal to the Expedition trawling depths and, therefore, do not conflict with the depths found to be preferred by hake in general, which is considered as a species of deeper waters. In the Expedition area more abundant catches were found at greater mean depths (100—199 individuals at 162.8 m, 200 individuals and more at 178 m).

The highest density of the hake population was recorded in the Jabuka Pit and southward, as well as along the north-eastern edge of the south Adriatic pit.

The hake caught during the »Hvar« Expedition were rather small (in 40.2% of the catches only individuals smaller than 40 cm; only in 21.6% of the catches individuals of 60 cm and more).

Most of the hake catches showed a wide length range (> 20 cm). The catches carried out at mean depths exceeding 120 m showed mostly a wider length range than those recorded at lesser depths.

The values of 0.36 and 0.41 were obtained for the ratio of the length of the hake at first maturity to the asymptotic length.

The ratio of the length at first maturity L_m (from the data of Županović, 1968) to the asymptotic length L_∞ gave values of 0.36 and 0.41, the asymptotic length being estimated from the long line data (Kirinčić and Lepetić, 1955) and from the »Hvar« Expedition trawling data respectively. The L_m/L_∞ values are lower than those found in gadiforms from other seas (Beverton and Holt, 1959) and that recorded in the hake from the eastern Spanish coast by Larrañeta (1970).

The length at which the Adriatic hake enter the catch L_c is much lower (data of Županović, 1968) than the L_m , this pointing to a large exploited phase and a need of a more careful hake fishery regulation.

2.2. FOOD OF THE HAKE

It is well-known that the hake is very voracious. The hake is able to take relatively large prey. One hake of total length of 12 cm swallowed one sardine of 14 cm total length (lower class limits used), (from the data of O. Karlovac, 1961).

The large hake from the northern Atlantic feed on fishes and cephalopods, the most important prey being the blue whiting (*Micromesistius poutassou* /Risso/) and then mackerel, smaller hake, horse mackerel, cephalopods and herring, while the small hake take Euphausiids (Hickling, 1935). In winter and spring when the hake live mostly in deep waters, at 90 to 300 fathoms (165 to 549 m) depths and more, they take only blue whiting, smaller hake and cephalopods; in summer and autumn the hake, being in shallower waters, feed on herring, mackerel, horse mackerel, smaller hake and some other fishes. The hake feed in midwater (bottom-living fishes being rarely taken) and for feeding they leave the bottom at night and probably scatter over all depth levels (Hickling, 1935).

In Moroccan waters hake feed on fish — nearly exclusively on the anchovy (*Engraulis encrasicolus* L.), crustaceans and cephalopods (Maurin, 1954).

According to the data of Larrañeta (1970) for the eastern Spanish coast, in the food of the small hake up to 10 cm pelagic crustaceans were predominant; in specimens ranging from 11 to 19 cm these crustaceans represented 50% of the food taken and in specimens of 20 cm and more fish were predominant. Among crustaceans small specimens of *Macrura* Natantia, larvae of Decapoda and Euphausiacea predominated. Among fishes the main species were *Sardina pilchardus* (Walb.) and *Engraulis encrasicolus* (L.),

although other fish were also represented, such as the benthic *Trisopterus minutus capelanus* (Lac.), *Callionymus maculatus* Raf. (according to CLOFNAM/Hureau and Monod, eds., 1973/ it might also be *Callionymus reticulatus* Val.), *Gobius auratus* Risso, *Deltentosteus quadrimaculatus* (Val.) and *Cepola macrophthalma* (L.) and the bathypelagic *Trachurus trachurus* (L.). From the benthic fish were only temporarily found *Conger conger* (Art./L.), *Mullus barbatus* L., *Arnoglossus laterna* (Walb.) and *Serranus hepatus* (L.), from the bathypelagic fish *Boops boops* (L.), *Scomber scombrus* L., *Spicara meana flexuosa* (Raf.), *S. smarís* L. and the hake itself, and from the pelagic fish *Sardinella aurita* Val. From cephalopods *Sepia officinalis* L., *Sepiola rondeleti* Leach. and *Loligo vulgaris* Lam. were represented in the hake's food (Larrañeta, 1970).

Hake from the eastern Spanish waters ranging from 20 to 40 cm took predominantly pelagic fish (the sardine and anchovy) and the larger specimens especially the benthic and, to some extent, bathypelagic fishes (Larrañeta, 1970).

According to the data for the Adriatic, collected mostly during the »Hvar« Expedition, in 1948 and 1949, hake with a total length exceeding 16 cm fed mainly on fish (the largest individuals only on fish), although crustaceans, especially the decapods, were also represented; the smaller individuals took crustaceans (Karlovac, O., 1959b). *Sardina pilchardus* (Walb.) had an outstanding role as the food of hake (recorded in 19% individuals analysed by the stomach content); the anchovy (*Engraulis encrasicolus* /L./) and the mackerel (*Scomber scombrus* L.) were much worse and almost equally represented (in 8 and 7% individuals respectively); the hake itself, the bogue (*Boops boops* /L./) and horse mackerel (*Trachurus* sp.) were even more poorly represented (in only 3.3, 2.6 and 1.3% specimens respectively), (Karlovac, O., 1959b).

In the stomachs of hake caught in the southern deeper Adriatic, at depths ranging from 100 to 800 m, in 1951 and 1952, crustaceans (*Nephrops norvegicus* /L./ and *Parapenaeus longirostris* /H. Lucas/), cephalopods (*Ommatostrephes sagittatus* /Lam./ and *Octopus vulgaris* Lam.) and fishes (*Scomberesox saurus* /Walb./, *Scomber scombrus* L., *Trachurus* sp. and the hake itself) were found (Kirinčić and Lepetić, 1955).

In the stomachs of hake of mean length 25.6 cm taken in the north Adriatic channels, in 1956 and 1957, the sprat (*Sprattus sprattus* /L./) was well-represented (Crnković, 1959).

Županović (1961b) confirmed the difference in the food composition of different-sized hake recorded by O. Karlovac (1959b). Županović found only crustaceans (Euphausiacea, especially *Nyctiphanes couchi* were the best represented; the proportion of Decapoda and Mysidacea being small) in the food of small hake (up to 0.10 kg) from the open central Adriatic (Blitvenica). In the channel area the hake fed mostly of fish, especially on *Sardina pilchardus* (Walb.) and *Sprattus sprattus* (L.), (Županović, 1961b).

Of the 640 hake caught in the Mid-Dalmatian channels which were analysed by the stomach content in the 1959—1961 period, 3.1% of them contained red mullet (*Mullus barbatus* L.), (Haidar, 1970).

C. Piccinetti and G. Piccinetti Manfrin (1971) found fish dominating (in 56.3% stomachs) in the food of the north Adriatic hake ranging in length from 14.0 to 42.5 cm and showing modal lengths of 18 and 33 cm. Among them the sprat (4.5%), anchovy (3.5%), sardine (2.0%) and horse mackerel (*Trachurus* sp.), (2.5%) were identified. The authors recorded a higher proportion of crustaceans in smaller hakes than in the larger ones. Among crustaceans the most frequent were Decapoda Natantia. The data on food composition agree, therefore, with these of O. Karlovac (1959b). However, even in the food of the smallest hake (14.0 to 16.9 cm) C. Piccinetti and G. Piccinetti Manfrin (1971) found a much greater proportion of fish by weight than of crustaceans.

Jukić (1975) who worked in the open Mid-Adriatic, at depths ranging from 110 to 262 m and at a mean depth of 175.6 m, and in part in the channels also confirmed observations of O. Karlovac (1959b) showing that the small hake up to 16 cm feed mainly on crustaceans and the larger ones nearly exclusively on fish.

In the food of hake exceeding 16 cm from open waters Jukić (1975) found mainly fishes: *Trachurus trachurus* (L.), *Boops boops* (L.), *Argentina sphyraena* L., *Spicara smaris* (L.), *Spicara maena flexuosa* (Raf.) and, nearer to the mainland coast, also *Sardina pilchardus* (Walb.), but none of them predominated (crustaceans *Alpheus glaber* /Olivi/, *Penaeus* sp. and *Lophogaster typicus* M. Sars were also recorded; cephalopods were poorly represented).

According to Jukić (1975) the larger hake from the Mid-Adriatic channels take the fishes *Engraulis encrasicolus* (L.), *Cepola macrophthalma* (L.), *Sardina pilchardus* (Walb.), *Spicara smaris* (L.) and *Boops boops* (L.), (the crustaceans *Stylocheiron* sp., *Penaeus* sp. and *Paramysis helleri* /G. Sars/ and cephalopods *Loligo marmorae* Ver. and *Sepiola owegiana* D'Orb. were also taken).

In an earlier study Jukić (1972) found that the hake from the most inshore waters (Kaštela Bay) feed mostly on fishes, especially on the anchovy and sardine.

Data of O. Karlovac (1961) on sardines found in the stomachs of hake which were caught mostly during the »Hvar« Expedition showed that the 84 measurable individuals were rather small, the total length ranging from 5 to 16 cm (lower class limits used) and a mean length amounting to 13.7 cm (the original data of O. Karlovac on the sardine total length were used, as during the printing of the paper they were partly left out), (Fig. 3a). The total lengths of the 82 hake containing measurable sardines ranged from 12 to 75 cm, with a mean total length of 28.5 cm (all the 209 hakes with the sardine in the stomachs showed total lengths ranging from 12 to 86 cm and a mean total length of 26.8 cm).

A comparison of the length distribution in sardines from the hake stomachs (Fig. 3a), (from the original data of O. Karlovac) with those recorded in the sardines from the commercial catches, carried out in the coastal and open Mid-Dalmatian waters in the 1948 fishing season (Fig. 3b and c), (the data of Mužinić, 1954), shows that the relatively small hake

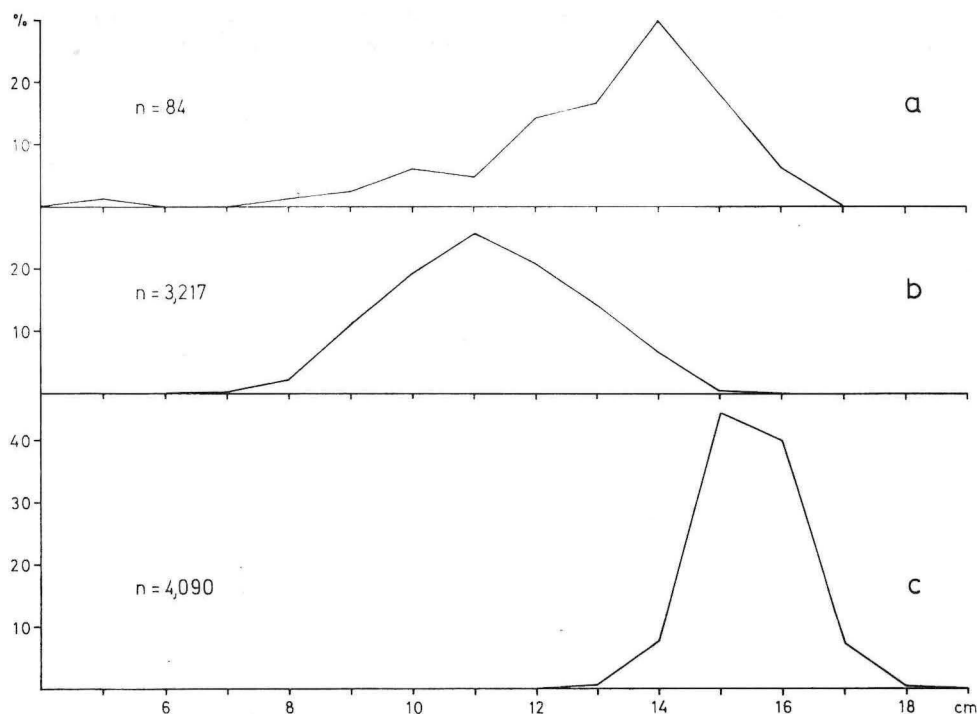


Fig. 3. The total length distribution in the measurable sardines taken by hake analysed mostly during the »Hvar« Expedition, 1948 and 1949 (a), and in those from the 1948 commercial catches carried out in the coastal (b) and open Mid-Dalmatian island waters (c), (lower class limits used), (see the text).

used for food composition studies by O. Karlovac (1959b, 1961) fed on sardines mainly in the shallower part of the Expedition area. This is confirmed by a comparison of the depth distribution in the trawl catches with the hake containing the sardines in the stomachs with that in all the Expedition trawl hake catches (Fig. 4).

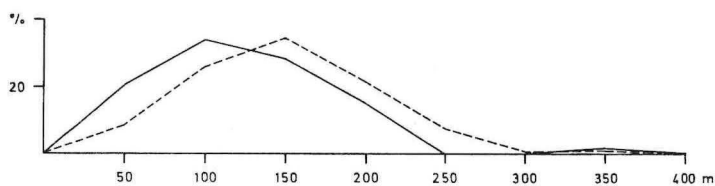


Fig. 4. Depth distributions of the »Hvar« Expedition trawl catches containing hake feeding on sardines (solid line) and of all the Expedition hake trawl catches, 1948 and 1949 (see the text).

Some dependence of the prey size on the hake size appears from the length data for the hake and measurable sardines in their stomachs (Fig. 5),

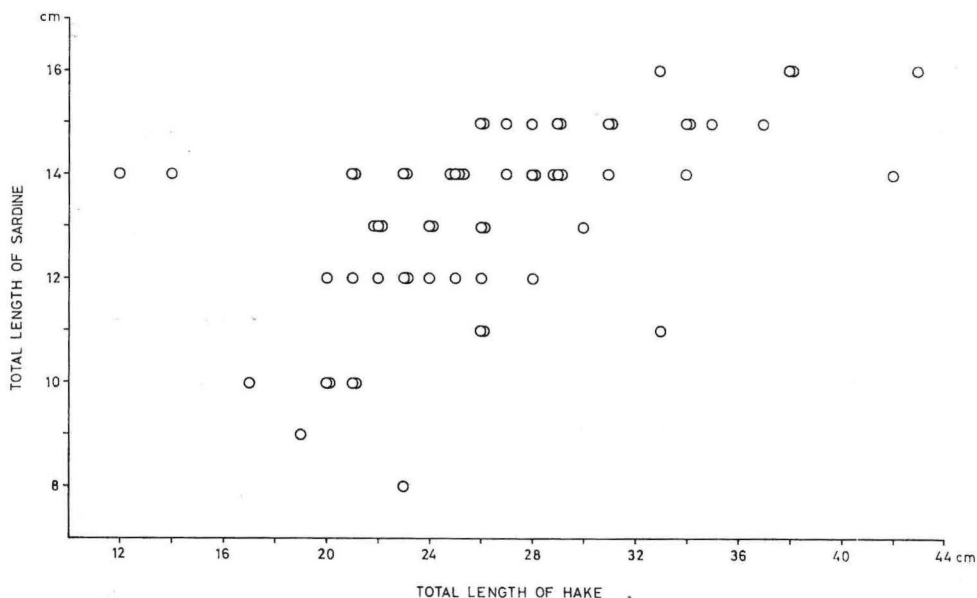


Fig. 5. Relation of the total length of the hakes and sardines found in their stomachs (lower class limits used), (from the data of O. Karlovac, 1961), (see the text).

(from the data of O. Karlovac, 1961). As the small sardines were relatively more frequent in the southernmost part of the »Hvar« Expedition area (Karlovac, O., 1961) and even the large hake had to feed there on them, the data for that part of the Expedition area were left out in Figure 5 (one very aberrant value was also omitted).

Rather abundant catches of the hake, especially of smaller individuals, in the north-eastern Adriatic channels, were due to the presence of the sprat (Crnković, 1970). As the maximal length of the sprat recorded in the Adriatic was 15 cm (Zavodnik, N. and D. Zavodnik, 1962), the sprat on which the hake fed in that area were smaller.

The appearance of the larger crustaceans in the food of the hake from the southern deeper Adriatic was probably due to large size of the hake recorded by Kirinčić and Lepetić (1955).

Sardine, anchovy and mackerel were found in the hake stomachs, mostly during the »Hvar« Expedition, nearly all the year round (from the data of O. Karlovac, 1959b, 1961). Conversely, Larrañeta (1970) recorded a greater proportion of Clupeiformes in the hake's food in winter than in other seasons and a preference for the anchovy in that part of the year.

Conclusions

The smaller hake showing a modal length of 27.5 cm, mostly caught during the »Hvar« Expedition, fed mainly on pelagic and bathypelagic fishes as shown by O. Karlovac (1959b). This is mainly in agreement with the results of a food composition analysis carried out on hake from the central eastern Adriatic (depths not exceeding 100 m), (C. Piccinetti and G. Piccinetti Manfrin, 1971), as well as with those obtained on the west Mediterranean hake (Larrañeta, 1970). In contrast, observations in the open waters of the central eastern Adriatic (depths ranging from 110 to 262 m and a mean depth of 175.6 m) showed that the hake fed mainly on bathypelagic and benthic fishes (Jukić, 1975).

The sardine recorded in the hake stomachs were small (a mean total length of 13.7 cm), (from the data of O. Karlovac, 1961). This was due to a rather small size of the hake themselves (modal length of 27.5 cm) which were caught in the shallower part of the »Hvar« Expedition area.

From a study of the food composition in the larger hake from the southern deeper Adriatic it follows that they prey on large benthic crustaceans, bathypelagic fishes and cephalopods (Kirinčić and Lepetić, 1955). Such a different food composition could be in part explained by the larger size of the hake.

2.3. HORIZONTAL DISTRIBUTION OF THE PREY SPECIES

2.3.1. *Sardina pilchardus* (Walb.)

The horizontal distribution of the sardine in the Adriatic was studied earlier (Mužinić, 1972, 1973b). The »Hvar« Expedition trawl catches, 1948 and 1949 (the data of O. Karlovac, 1961, unpublished material), those from the Mid-Dalmatian channels, 1957 and 1958 (the data of Županović, 1961a), and those from some parts of the central and southern Adriatic, from the 1954-1955 trawling season (the data of Mužinić, 1956) were used in the study.

The proportion of the trawl catches containing sardine was greater (19.8%) in the Mid-Dalmatian channels, the trawling being carried out at the depths which did not exceed 104 m, than the proportion of the »Hvar« Expedition trawl catches (13.8%), the Expedition having worked at a mean depth of 125 m (Mužinić, 1973b, from the data of O. Karlovac, 1961, unpublished material, and Županović, 1961a). In addition, the sardine was often found in the coastal waters (in the eastern part of the Neretva Channel and in the Mali Ston Channel, where a sardine nursery ground exists).

The sardine was well-represented in the catches carried out in some parts of the central and southern Adriatic, at depths not exceeding 120 m, in the 1954-1955 trawling season (they were recorded in nearly all the localities analysed and in 27 out of the 35 catches with pelagic fish), (Mužinić, 1956, 1973b). Large sardines were found at that time only at depths exceeding 70 m.

The existence of the sardine fishing grounds mostly near the islands and mainland coasts, the shallow northernmost Adriatic excluded (Grubišić, 1964, 1968), is in full agreement with the data from the three sources previously mentioned.

In spite of its occurrence in the northern (in the northernmost Adriatic the observations were very scarce), central and southern Adriatic, the horizontal distribution of the sardine within the »Hvar« Expedition area was found to be limited — it occurred at only 38 or 22.2% of the Expedition trawl stations (Table 1, Fig. 6), (Mužinić, 1973b, from the data of O. Karlovac, 1961, unpublished material). The sardine was recorded neither in the Jabuka Pit, nor at the edges of the south Adriatic pit and only exceptionally between the two pits except near the Palagruž Island. The depth was presumed to be a factor limiting the horizontal distribution of the sardine (Mužinić, 1973b). During the Expedition the sardine were recorded at depths ranging from 24.5 to 180.5 m and at a mean depth of 89.2 m (Table 1). 70.8% of the sardine catches were carried out within the depth intervals of 51 to 100 and 101 to 150 m (Table 2, Fig. 1).

The »Hvar« catches contained sardine ranging from 8 to 19 cm, i.e. in part immature fish (lower class limits used). However, in most of these catches the sardine ranged from 12 to 16 cm.

The data on the distribution of the commercial annual sardine catch in the Yugoslav fishing area, in the 1947—1971 period, mostly agreed with the data on the horizontal distribution of the sardine obtained during the »Hvar« Expedition (Mužinić, 1973b). This was shown firstly by the minimum catch of the former Šibenik District, i.e. close to the greater depths of the Jabuka Pit. The maximum catch of the former Split District was not in agreement with the data on the sardine horizontal distribution of the »Hvar« Expedition. However, the Expedition made the observations in May and June, i. e. at the time of one sardine catch maximum, mostly in the southernmost Adriatic. Moreover, the Expedition carried out the observations almost exclusively in the open waters. One part of the adult sardine population does migrate at the beginning of spring from the open to coastal Mid-Dalmatian waters (Mužinić, 1950, 1952, 1954).

Important sardine egg concentrations were recorded off Dugi otok and more to the north, among the islands of the Mid-Dalmatian area, in the Palagruž waters and farther to the south near the mainland coast (Gamulin, 1954), as well as in the Albanian waters (Rakaj, 1962). Larvae were recorded in the whole »Hvar« Expedition area and even in the Yugoslav southernmost waters (Karlovac, J., 1955, 1958), as well as off the Albanian littoral (Karlovac, J., 1955, 1958; Rakaj, 1962).

During the spawning period the adult sardine were also found in waters whose depths did not exceed the maximum depths recorded for the sardines from the »Hvar« Expedition. According to Gamulin (1954), sardine spawning takes place at depths ranging from 60 to 120 m or to a maximum of 150 m. Larger concentrations of sardine eggs were later found in part extending beyond the 150 m contour (Hure, 1960, 1961; Karlovac, J., 1969).

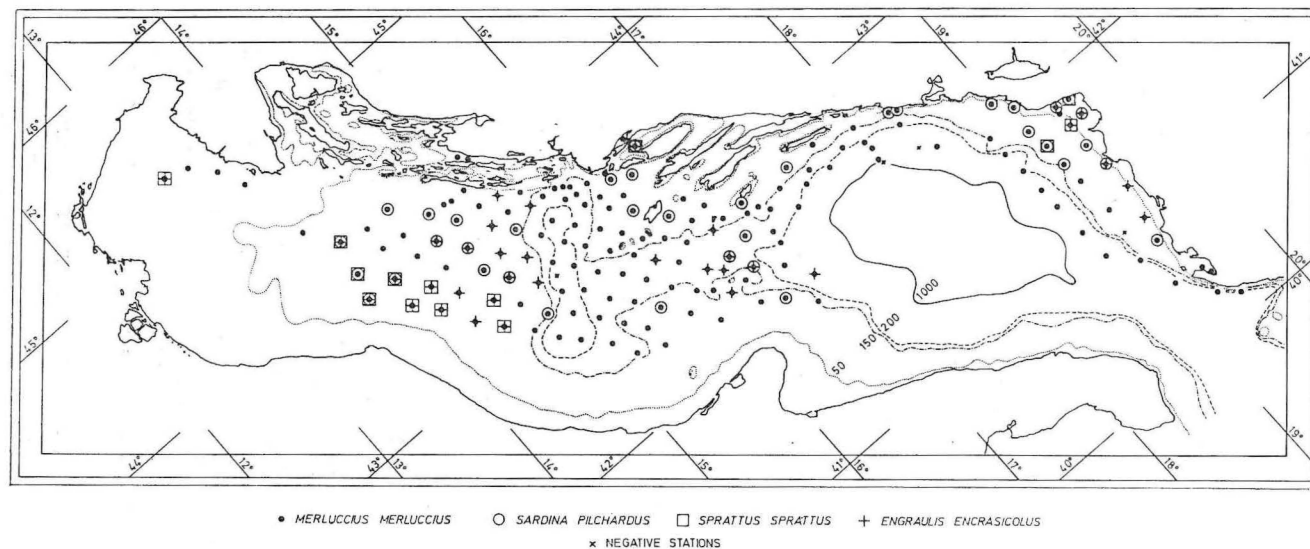


Fig. 6. Distribution of the hake (*Merluccius merluccius* /L./), and of the sardine (*Sardina pilchardus* /Walb./), sprat (*Sprattus sprattus* /L./) and anchovy (*Engraulis encrasicolus* /L./) in the Adriatic as shown by the »Hvar« Expedition data, 1948 and 1949.

Outside of the spawning period the adult sardine keep in part in shallower waters (Mužinić, 1954, 1969).

Small sardines keep in the coastal waters with lower salinities. During their life history they gradually migrate to the open sea (Mužinić, S., 1936; Mužinić, 1954). The distribution pattern due to such a migration is complicated by two coastward partial migrations (or at least two peaks in one continuous migration) of adult sardines in connection with the intensive feeding and prematuration — the last one is followed by an opposite spawning and wintering migration (Mužinić, 1954, 1973c).

2.3.2. *Sprattus sprattus* (L.)

The horizontal distribution of the sprat in the Adriatic was analysed earlier (Mužinić, 1973b). Trawl catches from the »Hvar« Expedition (data of O. Karlovac, unpublished material) and those from the Mid-Dalmatian channels, 1957 and 1958 (data of Županović, 1961a), were used in the analysis.

It was shown that the proportion of the experimental trawl catches including the sprat was by far larger (21.4%) in the Mid-Dalmatian channels, where the greatest mean depth at trawling did not exceed 104 m, than in the »Hvar« Expedition area (5.4%), (the Expedition trawled at a mean depth of 125 m).

It was also shown that, in spite of their occurrence in the northern, central and southern Adriatic, the horizontal distribution of sprat was very localized — they occurred at only 14 or 8.2% of the »Hvar« Expedition trawl stations (Table 1, Fig. 6), (Mužinić, 1973b, from the unpublished data of O. Karlovac). North of the Jabuka Pit sprat were more frequently recorded at the stations closer to the Italian coast. However, the observations of the »Hvar« Expedition were very scarce just in the northernmost Adriatic, where the sprat is the object of intensive fishing in open waters. The depth was presumed to be a factor limiting the horizontal distribution of the sprat (Mužinić, 1973b). During the »Hvar« Expedition sprat were recorded at depths ranging from 30 to 105 m and at a mean depth of 68.7 m (Table 1). More than two thirds (68.8%) of the sprat catches were carried out within the depth interval of 51 to 100 m (Table 2, Fig. 1).

The »Hvar« catches contained sprat ranging from 4 to 13 cm, i.e. in part immature individuals (lower class limits used). However, in all these catches, with one exception, the smallest sprat reached at least 9 cm.

During the trawling in the Mid-Dalmatian channels, in 1957 and 1958, sprat were recorded in inshore and nearby waters, although very irregularly and mostly in the warmer part of the year (from the data of Županović, 1961a).

The data on the distribution of the commercial annual catch of sprat in the Yugoslav fishing area, in the 1947—1971 period, showed one area of greater abundance of the sprat in the more northern Adriatic (Mužinić, 1973b).

In the first spawning phase the sprat keep in the open shallow northernmost Adriatic (35—38 m) as shown by the studies of their eggs distribution

(Štirn, 1969; Zavodnik, N. and D. Zavodnik, 1969; Zavodnik, D., 1970).

An analysis of the distribution of the commercial annual catch of sprat within the northernmost part of the Yugoslav fishing area showed that the sprat probably migrate, later during the spawning period, to southern deeper waters (Mužinić, 1967).

2.3.3. *Engraulis encrasicolus* (L.)

The horizontal distribution of the anchovy in the Adriatic has been studied before (Mužinić, 1972, 1973b), by an analysis of the trawl catches from the »Hvar« Expedition (the unpublished data of O. Karlovac), those from the Mid-Dalmatian channels, 1957 and 1958 (the data of Županović, 1961a), and those from some parts of the central and southern Adriatic, from the 1954—1955 trawling season (the data of Mužinić, 1956).

The proportion of the experimental trawl catches containing anchovy was greater (19.1%) in shallower Mid-Dalmatian channels, where the mean trawling depth did not exceed 104 m, than the share of such catches in the »Hvar« Expedition area (13.1%), (the Expedition trawled at a mean depth of 125 m). Moreover, anchovy were frequent in the coastal waters (in the eastern part of the Neretva Channel and in the Mali Ston Channel, where an anchovy nursery ground is present).

Anchovy were less frequently recorded than sardine in some parts of the central and southern Adriatic, at depths not exceeding 120 m, in the 1954—1955 trawling season (in 15 out of the 35 catches including pelagic fish), (Mužinić, 1956, 1973b). Large anchovies were caught at that time only at depths exceeding 70 m.

In the »Hvar« Expedition area anchovy occurred in the northern, central and southern Adriatic, although in limited areas, at 35 or 20.5% of the trawl stations (Table 1, Fig. 6), (Mužinić, 1973b, from the unpublished data of O. Karlovac). The horizontal distribution of anchovy was rather similar to that of sardine. The anchovy, as well as the sardine, occurred exceptionally between the Jabuka Pit and the south Adriatic pit, except in Palagruž waters. The depth was presumed to be a factor limiting the horizontal distribution of anchovy as it was also supposed for sardine and sprat (Mužinić, 1973b). Anchovy were recorded at depths ranging from 31.5 to 210.0 m and at a mean depth of 97.9 m (Table 1). Nearly one half (48.7%) of the »Hvar« Expedition anchovy trawl catches was carried out within the depth interval of 51 to 100 m (Table 2, Fig. 1).

A similarity in the late autumn and winter horizontal distribution of sardine and anchovy was recorded earlier (Mužinić, 1972).

Anchovy from the »Hvar« catches ranged from 10 to 20 cm, but nearly all from 11 to 17 cm (lower class limits used).

In the central Adriatic an abundant catch of large anchovies (18 cm) was obtained by an Italian trawl in April, at the depths up to 220 m (GFCM Group of Experts, 1970).

The data on the distribution of the commercial annual catch of anchovy in the Yugoslav fishing area, in the 1947—1971 period, mostly agree with the »Hvar« Expedition data on the horizontal distribution of anchovy. A minimum in the anchovy catch was shown by the former Šibenik District, i. e. close to greater depths of the Jabuka Pit (Mužinić, 1973b).

During the reproductive phase anchovy keep in the open central and northern Adriatic (Karlovac, J., 1963; Vučetić, 1964; Štirn, 1969, 1970; Zavodnik, D., 1970; Regner, 1972) but also in the coastal waters (Gamulin, 1940; Varagnolo, 1964, 1965; Vučetić, 1971; Regner, 1972). Anchovy spawning was also recorded in the Crna Gora Littoral (Merker, personal communication). Large concentrations of anchovy larvae were found mainly in the open central Adriatic in upper layer of waters of depths ranging from 90 to 250 m, with a maximum of those ranging from 150 to 200 m (Karlovac, J., 1963). In the Mid-Dalmatia anchovy larvae were more numerous, in 1968 and 1969, in the intermediate area than in the very coastal and open waters, the eggs were the most numerous in the open area (Regner, 1972).

2.3.4 *Scomber scombrus* L.

The horizontal distribution of mackerel in the Adriatic was the object of separate and comparative studies (Mužinić, 1973a and b). Trawl catches carried out in the »Hvar« Expedition area (the data of O. Karlovac, unpublished material), those from the Mid-Dalmatian channels, 1957 and 1958 (the data of Županović, 1961a), and those from some parts of the central and southern Adriatic, from the 1954—1955 trawling season (the data of Mužinić, 1956), were used in the studies.

Contrary to the sardine and anchovy, and especially to the sprat, mackerel were found in greater number in the »Hvar« Expedition trawl catches (31.6%), (the Expedition trawled at a mean depth of 125 m) than in the trawl catches carried out in the Mid-Dalmatian channels at a maximum depth of 104 m (19.1%). The mackerel were sometimes caught in coastal waters of the Mid-Dalmatian channel area (in the eastern part of the Neretva Channel and in the Mali Ston Channel), in 1957 and 1958, but the catches usually contained only one or two individuals. In contrast, in the 1954—1955 trawling season mackerel were not found at all in the coastal waters (Split and Neretva Channels).

In the catches from some parts of the central and southern Adriatic having taken place at depths not exceeding 120 m, in the 1954—1955 trawling season, the mackerel were less frequent than the sardine (in 17 out of the 35 catches containing pelagic fish), (Mužinić, 1956, 1973a and b). All the catches containing the mackerel were carried out at depths exceeding 70 m.

In the »Hvar« Expedition area the mackerel were found to be widely distributed — they were recorded at 79 or 46.2% of the trawl stations (Table 1) — especially in the central Adriatic (in the northern Adriatic the observations were scarce), except in the Jabuka Pit, where they were extremely rare; they were also rare at the edges of the south Adriatic pit and in the

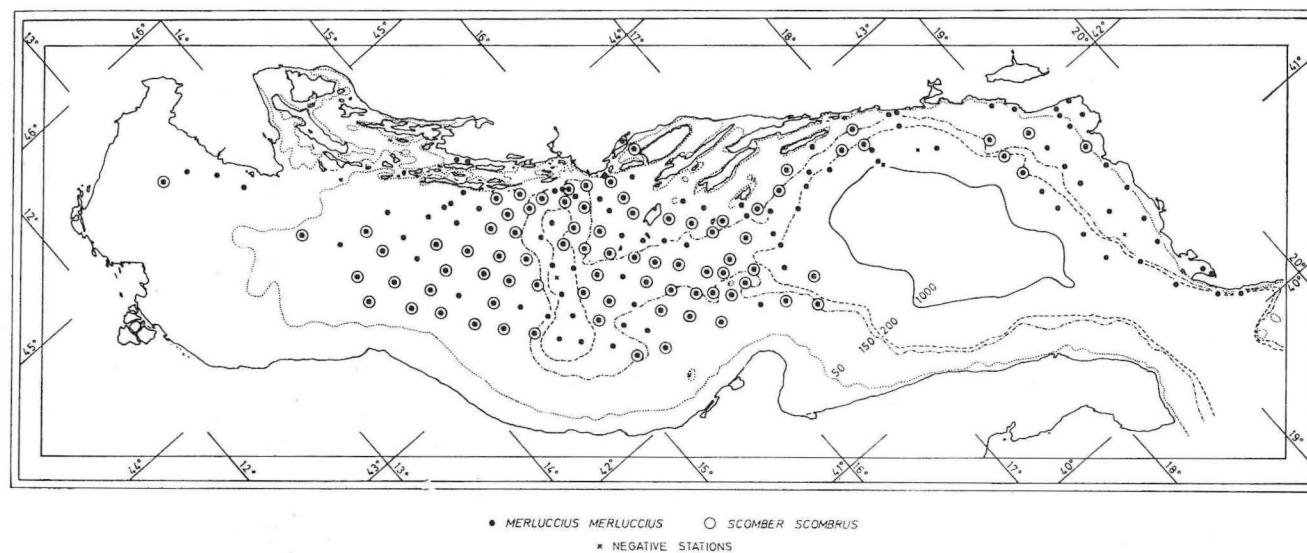


Fig. 7. Distribution of the hake (*Merluccius merluccius* /L./) and mackerel (*Scomber scombrus* L.) in the Adriatic as shown by the »Hvar« Expedition data, 1948 and 1949.

southernmost part of the area; between the Jabuka Pit and the south Adriatic pit the mackerel were well represented (Fig. 7), (Mužinić, 1973a and b, from the unpublished data of O. Karlovac). The opinion was expressed that the depth was at least one of the factors determining the horizontal distribution of the mackerel. The Expedition recorded mackerel at depths ranging from 29 to 224 m and at a mean depth of 124.2 (Table 1). Nearly all (94.7%) of the mackerel catches took place within the depth intervals of 51 to 100, 101 to 150 and 151 to 200 m (Table 2, Fig. 1). Almost complete absence of mackerel in the catches from the Jabuka Pit and their rarer occurrence in the catches from the southernmost Adriatic were presumed to be due to their preference for somewhat shallower waters (Mužinić, 1973a).

The »Hvar« catches contained mackerel ranging from 13 to 32 cm (lower class limits used). However, in most of these catches the mackerel ranged from 14 to 27 cm.

Larger mackerel (total length 20 cm and more) were caught at somewhat greater depths in the »Hvar« Expedition area than those at which smaller individuals were taken (Mužinić, 1973a).

In the central Adriatic mackerel were caught in April, at a depth of 220 m, by an Italian trawl (GFCM Group of Experts, 1970).

According to CLOFNAM (Hureau and Monod, eds., 1973), the mackerel occur to 200 or 250 m.

The data on the distribution of the commercial annual catch of mackerel in the Yugoslav fishing area, in the 1947—1971 period, are in agreement with the data on the horizontal distribution of mackerel obtained during the »Hvar« Expedition. These data show two areas of the mackerel greater abundance, one, the larger, north of the Jabuka Pit and the other, south of the Pit (Mužinić, 1973a).

For spawning the mackerel need waters whose depths exceed 90 m as shown by the data of the egg surveys (Lissner, 1939; Gamulin, 1954; Hure, 1960, 1961) and of the analysis of commercial trawl catches from the winter months (Mužinić, 1956, 1973a). The data showed mackerel spawning grounds in the north Adriatic channels (Gauss-Garady quoted by Lissner, 1939), in the Palagruž area (Gamulin, 1954; Mužinić, 1956; Hure, 1960, 1961) and at the eastern edge of the Jabuka Pit (Mužinić, 1973a). During plankton surveys in the northernmost Adriatic, in 1965, no mackerel eggs were recorded (Štirn, 1969, 1970).

2.3.5. *Boops boops* (L.)

The horizontal distribution of the bogue was the object of an earlier study using the »Hvar« Expedition data (Karlovac, J. and O. Karlovac, 1974). This species was found to be rather widely distributed in the »Hvar« Expedition area. However, the largest number of stations where bogue were caught was recorded in the central Adriatic, the Jabuka Pit excepted (Karlovac, J. and O. Karlovac, 1974).

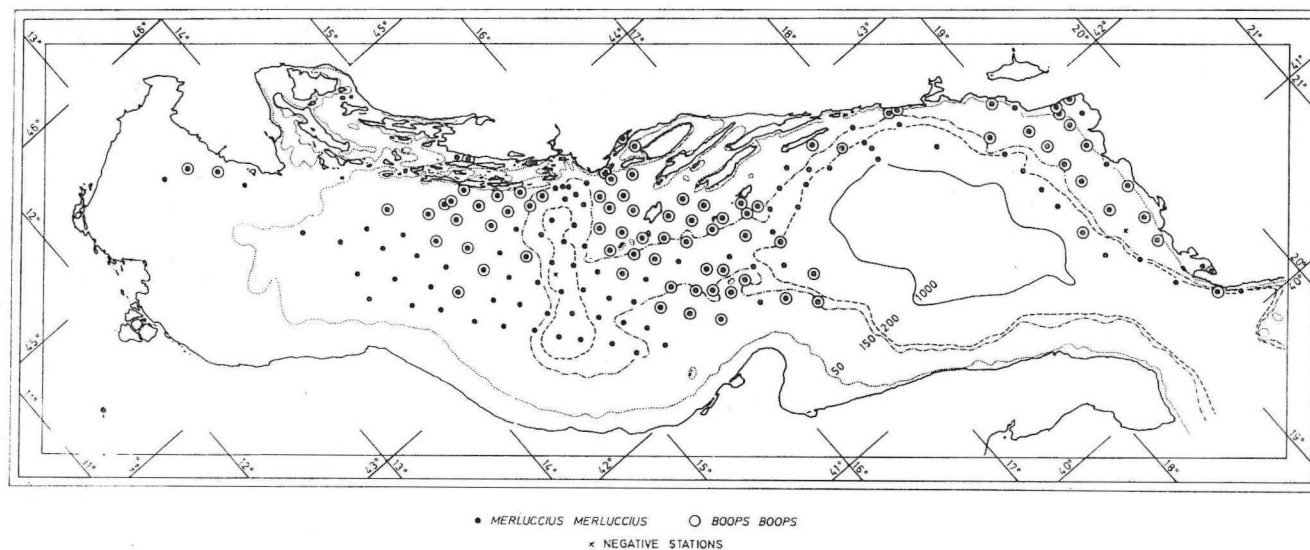


Fig. 8. Distribution of the hake (*Merluccius merluccius* /L./) and bogue (*Boops boops* /L./) in the Adriatic as shown by the »Hvar« Expedition data, 1948 and 1949.

Bogue were caught by trawl on 85 or 49.7% of the »Hvar« Expedition stations and in 108 or 36.4% of the trawl catches, at depths ranging from 20 to 220 m (means between the initial and final depths were used here) and at a mean depth of 100 m (Table 1, Fig. 8). About three quarters (76.9%) of the bogue catches were taken within the depth intervals of 51–100 and 101–150 m (Table 2, Fig. 1). Although rather widely distributed in the Expedition area, the bogue were more frequently recorded in the eastern Adriatic, the Palagruž area excepted (Fig. 8).

Bogue trawled during the »Hvar« Expedition ranged from 7 to 24 cm, but mostly from 11 to 21 cm (lower class limits used).

During experimental trawlings in the Mid-Dalmatian channels, at the depths which did not exceed 104 m, in 1957 and 1958, the largest mean catch of the bogue (374 individuals) was taken in the coastal waters (the Mali Ston Channel); from the remaining catches the largest mean catches (75 and 74 individuals) were recorded in the offshore waters (the Vis and Korčula Channels), (from the data of Županović, 1961a).

In contrast, experimental trawling in the Kaštela Bay, in 1963 and 1964, gave a low mean catch (11 individuals), (Jukić, 1973).

In the central Adriatic, at a depth of 220 m, bogue were caught by an Italian trawl (GFCM Group of Experts, 1970).

According to CLOFNAM (Hureau and Monod, eds., 1973), bogue occur to 150 m at least.

Larval stages of the bogue were found in 51 of the 307 (16.6%) »Hvar« Expedition ichthyoplankton samples, mostly in the central Adriatic, in upper layer of waters of depths ranging also from 50 to 150 m, even in its western part (Karlovac, J. and O. Karlovac, 1974). However, the spawning of the bogue was found to be more intensive in the eastern Adriatic, this being in agreement with the horizontal distribution of the bogue in general (Karlovac, J. and O. Karlovac, 1974).

2.3.6. *Trachurus trachurus* (L.) and *T. mediterraneus mediterraneus* (Std.r.)

The genus *Trachurus* is widely distributed in the Adriatic as shown by the »Hvar« Expedition data. However, a very wide horizontal distribution was recorded only in *Trachurus trachurus* (L.) (Karlovac, J. and O. Karlovac, 1971) and *T. mediterraneus mediterraneus* (Std.r.), (Fig. 9), (*T. picturatus* /Bowd./ occurred only once).

T. trachurus was found in a great part of the Adriatic and in the northernmost part of the eastern Ionian, at 117 or 68.4% out of the Expedition trawl stations and in 153 or 51.5% of the trawl catches (Table 1, Fig. 9), (Karlovac, J. and O. Karlovac, 1971). The catches were taken at depths ranging from 20 to 341 m (means between the initial and final depths were used) and at a mean depth of 143.8 m (Table 1). Nearly two thirds (63.4%) of the *T. trachurus* catches were taken within the depth intervals of 101 to 150 and 151 to 200 m (Table 2, Fig. 1).

T. mediterraneus mediterraneus occurred at 114 or 66.7% out of the Expedition trawl stations and in 151 or 50.8% of the trawl catches, at depths ranging from 24.5 to 216.0 m and at a mean depth of 105.6 m (Table 1, Fig. 9). About two thirds (68.9%) of the *T. mediterraneus mediterraneus* catches took

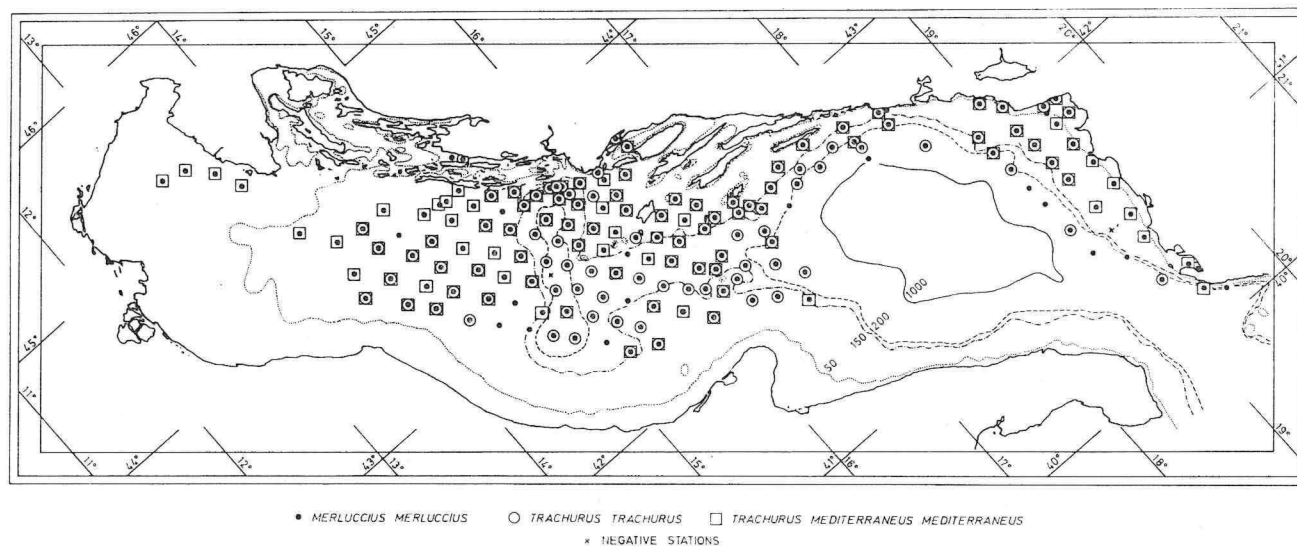


Fig. 9. Distribution of the hake (*Merluccius merluccius* /L./) and of the horse mackerels (*Trachurus trachurus* /L./ and *T. mediterraneus mediterraneus* /St d r./) in the Adriatic as shown by the »Hvar« Expedition data, 1948 and 1949.

place within the depth intervals of 51 to 100 and 101 to 150 m (Table 2, Fig. 1). It follows that *T. mediterraneus mediterraneus* occurred at much lower depths than those at which *T. trachurus* was found. In the Jabuka Pit *T. trachurus* was recorded at nearly all the stations while *T. mediterraneus mediterraneus* rarely occurred there (Fig. 9).

The »Hvar« catches contained *Trachurus trachurus* ranging from 4 to 41 cm and *T. mediterraneus mediterraneus* from 6 to 40 cm (lower class limits used). However, the catches with small (< 10 cm) *T. mediterraneus mediterraneus*, alone or mixed with larger individuals, were rarer than the catches containing small *T. trachurus*; the catches with *T. mediterraneus mediterraneus* exceeding 24 cm were extremely rare.

Both *Trachurus trachurus* and *T. mediterraneus mediterraneus* were very poorly represented in the experimental trawl catches carried out in the Mid-Dalmatian channels, at the depths not exceeding 104 m, in 1957 and 1958 (from the data of Županović, 1961a).

The larvae and postlarvae of *Trachurus trachurus* were found in the northern, and especially in the central and southern Adriatic, with some discontinuities in the Jabuka Pit area and to the south of it, as well as at level of the south Adriatic pit; they occurred in upper layer of waters of depths ranging from 32 to 355 m, but the largest catches took place in waters of depths ranging from 100 to 200 m (Karlovac, J. and O. Karlovac, 1971). Therefrom, these authors concluded that the spawning of *T. trachurus* took place mostly between the 100 and 200 m contours. The individuals ranging from 4 to 6 cm showed a more southern distribution, as they were trawled mostly in the southern Adriatic (Karlovac, J. and O. Karlovac, 1971).

There are no published data on spawning areas of *Trachurus mediterraneus mediterraneus*. However, this species, like *T. trachurus*, was also trawled during the »Hvar« Expedition in all the months and, consequently, during the spawning period, too.

2.3.7. *Spicara smaris* (L.) and *S. maena flexuosa* Raf.

Spicara smaris occurred at 65 or 38.0% of the »Hvar« Expedition trawl stations and in 87 or 29.3% of the trawl catches, at depths ranging from 20 to 213 m and at a mean depth of 98.9 m (Table 1, Fig. 10). Nearly three quarters (72.4%) of the Expedition trawl catches including *S. smaris* took place within the depth intervals of 51 to 100 and 101 to 150 m (Table 2, Fig. 1). *S. smaris* was more frequent in the eastern part of the Adriatic, the Palagruž area excluded.

In contrast, *Spicara maena flexuosa* was more widely distributed. It was recorded at 96 or 56.1% of the Expedition trawl stations and in 133 or 44.8% of the trawl catches, at depths which ranged from 20 to 256 m and at a mean depth of 89.1 m (Table 1, Fig. 10). Three quarters (75.9%) of the trawl catches containing *S. maena flexuosa* were carried out within the depth intervals of 51 to 100 and 101 to 150 m (Table 2, Fig. 1).

Spicara smaris trawled by »Hvar« Expedition ranged from 3 to 18 cm and *S. maena flexuosa* from 6 to 17 cm (lower class limits used). However,

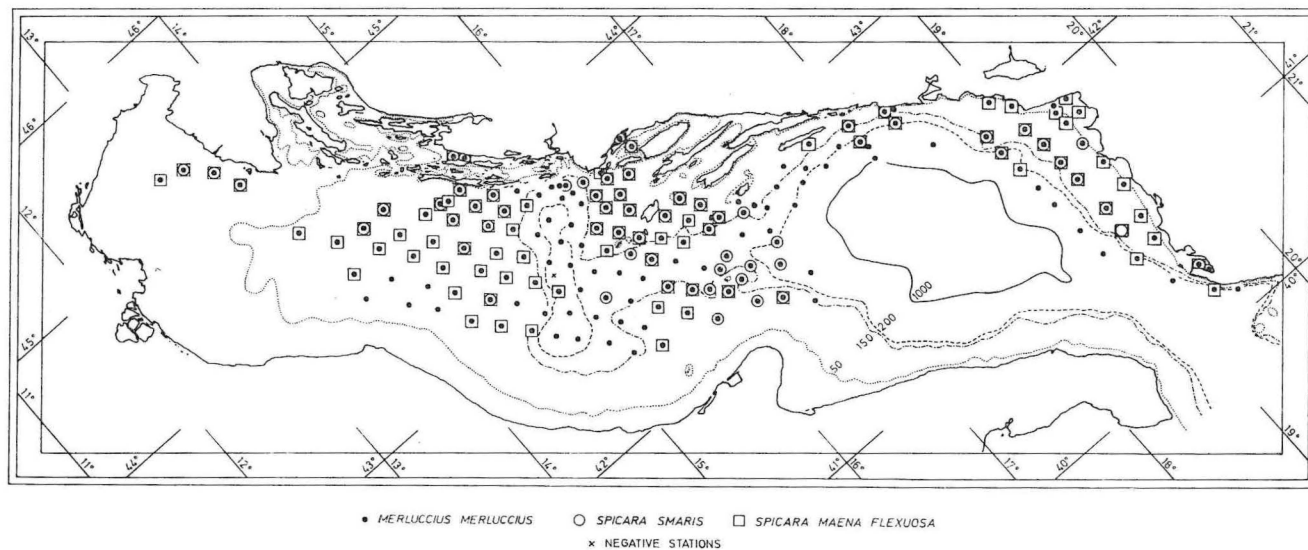


Fig. 10. Distribution of the hake (*Merluccius merluccius* /L./) and of the picarels (*Spicara smarís* /L./ and *S. maena flexuosa* /Raf./) in the Adriatic as shown by the »Hvar« Expedition data, 1948 and 1949.

the catches with small (< 10 cm) *S. maena flexuosa* were more frequent than the catches with small *S. smarís*.

In the experimental trawl catches carried out in the Mid-Dalmatian channels, at the depths not exceeding 104 m, in 1957 and 1958, *Spicara smarís* was mostly well-represented, the largest mean catches being obtained in the Vis Channel (148 individuals) and in the outer part of the Korčula Channel (161 individuals), (from the data of Županović, 1961a). The largest mean catches of *S. maena flexuosa* were carried out in the Korčula Channel (442 and 685 individuals) and in the Split Channel (313 individuals), but especially in the very coastal waters, i. e. in the Mali Ston Channel (1,354 individuals), (from the data of Županović, 1961a).

According to CLOFNAM (Hureau and Monod, eds., 1973), both *Spicara smarís* and *S. maena flexuosa* are littoral, the latter occurring to about a depth of 130 m.

2.3.8. *Argentina sphyraena* L. and *Glossanodon leioglossus* (Val.)

The horizontal distribution of *Argentina sphyraena* in the »Hvar« Expedition area is extensive and continuous, although this species rarely appear in the northern Adriatic (Fig. 11). *A. sphyraena* was found at 134 or 78.4% of the trawl stations and in 225 or 75.8% of the trawl catches, at depths ranging from 61 to 382 m and at a mean depth of 144.7 m (Table 1, Fig. 11). Nearly three quarters (72.9%) of the catches containing *A. sphyraena* were carried out within the depth intervals of 101 to 150 and 151 to 200 m (Table 2, Fig. 1).

In contrast, *Glossanodon leioglossus* showed a very limited horizontal distribution (Fig. 11). It occurred only in the southern Adriatic and at greater depths, these ranging from 143 to 316 m and at a mean depth of 193.7 m (Table 1). Most (84.2%) of the *G. leioglossus* catches took place within the depth intervals of 151 to 200 and 201 to 250 m (Table 2, Fig. 1).

Argentina sphyraena from the »Hvar« catches ranged from 4 to 26 cm, but nearly all from 4 to 17 cm, and *Glossanodon leioglossus* ranged from 5 to 14 cm (lower class limits used). However, most of the catches with *Argentina sphyraena* contained small individuals (< 10 cm), although mixed with larger fish. It was the same with the catches containing *Glossanodon leioglossus*.

Argentina sphyraena was also recorded in the trawl catches carried out in the Mid-Dalmatian channels, in 1957 and 1958, even inshore, the most abundant and exceptionally large catch of 5,904 specimens occurring at a depth of 104 m (from the data of Županović, 1961a).

Judging from the available data, the ecology of both *Argentina sphyraena* and *Glossanodon leioglossus* was not adequately studied. The horizontal distribution of their postlarvae, mostly in the »Hvar« Expedition area, was analysed by J. Karlovac (1949). The postlarvae of *Glossanodon leioglossus* showed a more southern distribution than that recorded in the postlarvae of *Argentina sphyraena*. From the 11 stations in the open Adriatic at which *Glossanodon*

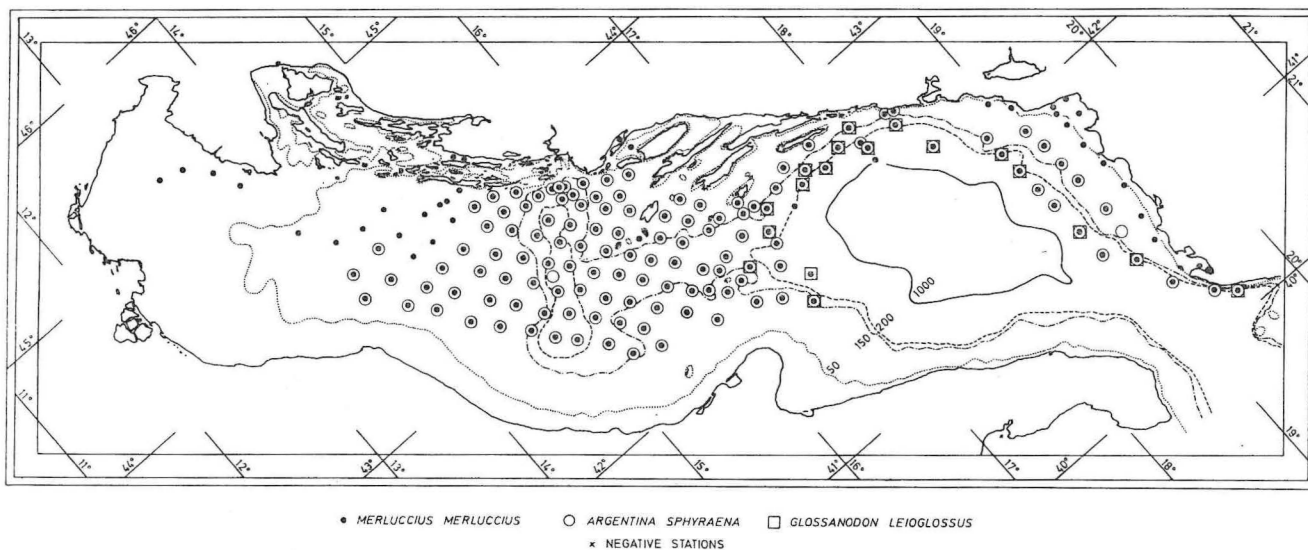


Fig. 11. Distribution of the hake (*Merluccius merluccius* /L./), and of *Argentina sphyraena* L. and *Glossanodon leioglossus* (V a l.) in the Adriatic as shown by the »Hvar« Expedition data, 1948 and 1949.

leioglossus occurred 10 were recorded in the southern deeper Adriatic (south of the Jabuka Pit).

Larvae and postlarvae of *Argentina sphyraena* were found only in the coastal area during the observations on the sardine planktonic phase in the Mid-Dalmatian waters, in 1952 and 1953 (Karlovač, J., 1967).

Conclusions

Some of the species analysed from the point of the hake food preferences showed a limited distribution in the »Hvar« Expedition area, such as *Sprattus sprattus* (L.) and *Glossanodon leioglossus* (Val.), the first one occurring in the shallowest waters (mean depth 68.7 m) and the latter in the deepest waters (mean depth 193.7 m).

Other six species, i.e. *Sardina pilchardus* (Walb.), *Engraulis encrasicolus* (L.), *Boops boops* (L.), *Trachurus mediterraneus mediterraneus* (Sdr.), *Spicara smaris* (L.) and *S. maena flexuosa* (Raf.), appeared in relatively shallow waters of similar mean depths ranging from 89.2 to 105.6 m and showed some discontinuity in the distribution, being due to the Jabuka Pit depths.

Further two species, i.e. *Trachurus trachurus* (L.) and *Argentina sphyraena* L., were recorded in deeper waters of the Expedition area of nearly the same mean depths of 143.8 and 144.7 m and showed a continuous horizontal distribution in the area.

Scomber scombrus L. had mainly a central position appearing at a mean depth of 124.2 m as shown before (Mužinić, 1973a), this being nearly equal to the mean Expedition trawling depth (125 m). However, *Scomber scombrus* showed a discontinuous distribution in the Expedition area like the previously mentioned six species.

It had to be taken into account that the availability to trawling might not have been the same in the species analysed at time when most of the Expedition trawl catches were carried out and in the areas in which they took place.

When considering the relation of the species to the depth it must also be kept in mind that there were few »Hvar« Expedition stations in the northernmost Adriatic and in the coastal waters.

3. DISCUSSION

From a comparison of the horizontal distribution of the hake on one hand and the species which, according to the data of O. Karlovač (1959b), were well-represented in the food of the hake larger than 16 cm (mostly originating from the »Hvar« Expedition area), such as the sardine (*Sardina pilchardus* /Walb./), anchovy (*Engraulis encrasicolus* /L./) and mackerel (*Scomber scombrus* L.) on the other hand it follows that the horizontal distribution of

the hake is, in the Expedition area, by far wider than that of the sardine and anchovy (Fig. 6). In contrast, the mackerel is more widely distributed in the area (it occurred at 46.2% of the stations), although it was nearly absent in the trawl catches carried out in the Jabuka Pit (Fig. 7), (Mužinić, 1973a and b). The distributional relations in these species are also confirmed by the mean depths at which they appeared. While the hake was recorded at a mean depth of 125.7 m, the sardine, anchovy and mackerel occurred at mean depths of 89.2, 97.9 and 124.2 m respectively (Table 1).

It follows that the horizontal distribution of the mackerel in the »Hvar« Expedition area is in a better agreement with the horizontal distribution of the hake than it is with the sardine and anchovy. The mackerel might be, therefore, fairly available to the hake.

However, from the data of O. Karlovac (1959b) the sardine seemed to be the preferred food of the rather small hake (mean length 26.8 cm) in the »Hvar« Expedition area. Notwithstanding, the hake with sardines in the stomach was recorded at the »Hvar« Expedition trawl stations with the depths ranging from 20 to 175.5 m, with one exceptional station at 341 m, and at a mean depth of 101.5 m (the only one catch outside of the Expedition area was excluded), i.e. at depths lower than those which showed stations negative as to the presence of the sardine in the hake stomach (from 23.5 to 382.0 m, mean depth 131 m). The difference between the trawling depth distribution for the »Hvar« Expedition hake catches with sardines in the stomach and for the »Hvar« Expedition hake catches in general is shown in Figure 4.

Obviously, the sardine is not able to keep its position in the hake feeding in the whole Expedition area.

It must be taken into account that relatively much bigger numbers of hake from deeper waters of the Expedition area had everted stomachs (Karlovac, O., 1959b). Such hake were probably in part larger and might prefer larger prey. Mackerel and some other species might, therefore, be of greater importance in the food of the larger hake from deeper Expedition waters than that shown for somewhat shallower waters by the data of O. Karlovac (1959b).

Mackerel were also recorded in the food of the larger hake caught by long line in the southern deeper Adriatic (Kirinčić and Lepetić, 1955). As mackerel are rare in waters exceeding 200 m (Figs. 1 and 7) and their commercial catch in deeper southern Adriatic is accordingly small (Mužinić, 1973a and b), it might point to some preference of larger hake for the mackerel and larger prey in general.

The bogue (*Boops boops* L.) were much more poorly represented in the food of the hake mostly originating from the »Hvar« Expedition area (shallower part), (Karlovac, O., 1959b). The horizontal distribution of the bogue is narrower than that of the hake (Fig. 8). However, the bogue was rather well-represented in the Expedition area, as it occurred at 49.7% of the stations. The bogue occurred more frequently in the eastern part of the Adriatic, the Palagruž Island waters excepted. During the »Hvar« Expedition it was recorded at a mean depth of 100 m, this being similar to those at which the sardine and anchovy occurred (Table 1).

From other species represented in the food of the hake in some parts of the Adriatic the sprat (*Sprattus sprattus* /L./), (Crnković, 1970) and horse mackerels (*Trachurus* sp.), (Kirinčić and Lepetić, 1955; Piccinetti, C. and G. Piccinetti Manfrin, 1971; Jukić, 1972), as well as the picarel (*Spicara smaris* /L./), this in both the open and channel waters of the central Adriatic, and the argentine (silver smelt), (*Argentina sphyraena* L.), (Jukić, 1975) should be mentioned.

The horizontal distribution of the sprat is rather localized (Fig. 6), (Mužinić, 1973b) and, therefore, this species can not have any more general significance for hake feeding except in shallow waters.

Two species of the genus *Trachurus*, i. e. *Trachurus trachurus* (L.) and *T. mediterraneus mediterraneus* (Std.r.) are widely distributed in the Adriatic as shown by the »Hvar« Expedition data (they occurred at 68.4 and 66.7% of the trawl stations respectively), (Fig. 9). In *T. trachurus* such distribution was shown earlier (Karlovac, J. and O. Karlovac, 1971). *T. trachurus* occurred at a greater mean depth (143.8 m) than *T. mediterraneus mediterraneus* (105.6 m). *T. trachurus* also appears at greater depths of the Jabuka Pit, where other fish species well-represented in the food of the hake originating from shallower Expedition waters do not appear. However, the genus *Trachurus* was poorly represented in the food of the hake caught mostly in the Expedition area (Karlovac, O., 1959b). As there is no evidence so far that the horse mackerels would not be available to the hake, they might not be a preferred prey of the hake.

Of the two *Spicara* species *Spicara maena flexuosa* (Raf.) was much better represented in the »Hvar« Expedition area (56.1% of the stations) than *S. smaris* (L.), (38.0% of the stations), (Fig. 10). They occurred in shallower waters of the area, at similar mean depths (89.1 and 98.9 m respectively). Nevertheless, an essential difference in the horizontal distribution appeared between the two species. *S. maena flexuosa* was more uniformly distributed than *S. smaris* which was more frequent in the eastern part of the Adriatic, with the exception of the Palagruž Island waters. The horizontal distribution of *S. smaris* in the Expedition area showed a high overlap with the horizontal distribution of the bogue. At 48 from the 65 stations (73.9%) positive as to the *S. smaris* the bogue was also found. However, *S. smaris* and the more widely distributed *S. maena flexuosa* were very poorly represented in the hake food analysed mostly during the »Hvar« Expedition (Karlovac, O., 1959b). It seems, therefore, that *Spicara* species are also not preferred by the hake.

Judging from an extremely limited horizontal distribution of *Glossanodon leioglossus* (Val.) in the »Hvar« Expedition area (it occurred at only 10.5% of the trawl stations), this species does not seem to have any importance for hake feeding in the area controlled. In contrast, *Argentina sphyraena* L. was found to be the most widely distributed species (it occurred at 78.4% of the trawl stations) of all the species analysed.

Both *Argentina sphyraena* L. and *Glossanodon leioglossus* (Val.) rarely appeared in the hake food analysed mostly during the »Hvar« Expedition (shallower part of the area), (Karlovac, O., 1959b). They were also not

recorded in smaller areas of the Adriatic investigated so far (Kirinčić and Lepetić, 1955; Crnković, 1959; Piccinetti, C. and G. Piccinetti Manfrin, 1971). They did not appear either in the food of the hake from the eastern Spanish coast (Larrañeta, 1970). However, *Argentina sphyraena* was found in the hake food in the central eastern Adriatic by Jukić (1975).

A comparison of the catch distributions of the analysed species as to the depth with the trawling depth distribution of the »Hvar« Expedition itself (Fig. 1) shows that *Sardina pilchardus* (Walb.), *Engraulis encrasicolus* (L.), *Spicara maena flexuosa* (Raf.) and especially *Sprattus sprattus* (L.), generally preferring lower depths, were not fully available to the Expedition trawling. On the other side, *Trachurus trachurus* (L.), in part *Argentina sphyraena* L. and especially *Glossanodon leioglossus* (Val.), being the species with more or less greater depth preferences, were also, therefore, not fully available to the Expedition. The hake itself is to be found in shallower and deeper waters than those covered by the Expedition as shown by many observations in the eastern Adriatic channels and coastal area, as well as those in the southern deeper Adriatic (Kirinčić and Lepetić, 1955). It is also shown by an agreement of the hake catch distribution as to the depth with the Expedition trawling depth distribution (Fig. 1). In shallower and deeper waters some other species might play greater part in the hake feeding than that recorded for the shallower part of the Expedition area by O. Karlovac (1959b).

From all the mentioned fishes appearing in the hake food only *Trachurus* sp., especially *T. trachurus* (L.) and *Argentina sphyraena* L. were caught during the »Hvar« Expedition in the Jabuka Pit (Figs 6—11). In such deeper waters the hake must feed on fishes other than the sardine, anchovy, mackerel, bogue and picarels (the *Spicara* species) which are typical fishes of the continental shelf, partly of the higher one. *Trachurus trachurus* (L.) and *Argentina sphyraena* L. were found to be represented in the food of the hake caught in the open central Adriatic, at depths ranging from 110 to 262 m and at a mean depth of 175.6 m (Jukić, 1975).

The experimental trawlings in the Mid-Dalmatian channels in 1957 and 1958 (Županović, 1961a) supplied monthly data on the distribution of the fish species in shallow coastal and channel waters of the eastern Mid-Adriatic. Larger mean catches of the hake (28 individuals and more) in the Split, Brač and Hvar Channels, and especially in the Neretva Channel coincided with large mean catches of at least one of the following three species — sardine, sprat and anchovy — valuable for the hake feeding in shallower »Hvar« Expedition waters, but also mostly with relatively small or no catches of *Spicara smaris* (L.), mostly with relatively small catches of *S. maena flexuosa* (Raf.) and with no or insignificant catches of *Argentina sphyraena* L. (from the monthly data of Županović, 1961a). Conversely, small hake mean catches (up to 15 specimens inclusively) off the Šolta Island, in the Vis and Korčula Channels coincided with poor mean catches of the sardine, sprat and anchovy taken together, but also mostly with the large mean catches of the bogue and the *Spicara* species. Small mean catch of the hake off the Šolta Island also coincided with a extremely large mean catch of *Argentina*

sphyraena (454 individuals), (from the monthly data of Županović, 1961a). The trawl catches from the Mid-Dalmatian channels positive for the mackerel included mostly single specimens with only two exceptions. The highest number of the mackerel catches and the largest mackerel catch (33 individuals) as well were recorded in the Neretva Channel (from the monthly data of Županović, 1961a).

These comparative data based on the elementary monthly data on the trawl catches from the Mid-Dalmatian channels supplied by Županović (1961a) might also support the hake preferences for the sardine and anchovy in shallower »Hvar« Expedition waters recorded by O. Karlovac (1959b), as well as that for the sprat in the north-eastern Adriatic channels found by Crnković (1959).

The differing data on the food composition of the hake from the open central Adriatic analysed by Jukić (1975) could probably be explained by the greater depths (110—262 m, mean 175.6 m). However, at least some of the species recorded in the food composition by this author do not seem to be preferred by the hake.

The presence of the Norway lobster (*Nephrops norvegicus* /L./) in the food of the hake caught by long line in the southern Adriatic (Kirinčić and Lepetić, 1955) seems to be exceptional. According to other available data, the Norway lobster was never recorded in the hake food.

The Norway lobster is a rather frequent species in the Adriatic as shown by the »Hvar« Expedition and some complementary data (Karlovac, O., 1953). The largest catches were recorded in the open central Adriatic, at depths ranging from 150 to 250 m. However, in shallower north Adriatic channels an even denser Norway lobster population was recorded (Karlovac, O., 1953).

The hake and the Norway lobster showed a markedly overlapping distribution in some parts of the »Hvar« Expedition area. They both were well-represented in the Jabuka Pit and between the Jabuka Pit and the south Adriatic pit. In addition, the Norway lobster and the hake were, in 1956 and 1957, the best represented species in the north-eastern Adriatic channels, the numerical shares amounting to 38.9 and 14.2% respectively (Crnković, 1959).

The Norway lobster is obviously not preferred by the hake. Its presence in the hake food might be due to poor feeding conditions for the hake in deeper southern waters. However, it should be mentioned that the Norway lobster population is not fully available all the year round, as the females carrying external eggs remain buried (Poulsen, 1949).

It must be pointed out that the food preferences of the Adriatic hake were presumed from the data on the food composition and the comparative distributional data, fully aware that more data on behaviour would also be very useful.

In the food of the hake from eastern Spanish waters the sardine and anchovy were most important (Larrañeta, 1970). The gilt sardine (*Sardinella aurita* Val.), the bogue, mackerel, picarels (*Spicara maena flexuosa* /Raf./ and *S. smaris* /L./), red mullet (*Mullus barbatus* L.) and some

other species occurred only temporarily in the digestive tractus of the hake. Moreover, while in hake ranging from 20 to 40 cm the pelagic fishes (the sardine and anchovy) predominated, in the larger hake benthic and bathypelagic species were predominant (Larrañeta, 1970). This observation might perhaps also point out to the fact that the larger hake keep in deeper waters where small pelagic fishes do not occur and possibly also that at least some of these larger fish do not migrate to shallower waters.

4. SUMMARY

The trawling data collected during the »Hvar« Fishery Biological Expedition, mostly in the open Adriatic, at depths ranging from 20 to 382 m and at a mean depth of 125 m, in 1948 and 1949, showed a wide and continuous distribution of hake in the Expedition area. The data completed, to a large extent, earlier very incomplete knowledge on hake distribution in the Adriatic.

During the Expedition the hake was recorded at depths ranging from 20 to 382 m and at a mean depth of 126 m. These depths are almost equal to the Expedition trawling depths and are not in disagreement with the generally known depth preferences of the hake.

Within the Expedition area larger catches of the hake were obtained at greater depths. The highest population density was recorded in the Jabuka Pit and southwards, as well as along the north-eastern edge of the south Adriatic pit.

During the Expedition rather small hake were caught, 40.2% of the catches contained only individuals smaller than 40 cm and only 21.6% contained individuals of 60 cm and more.

The length range in individual hake catches was mostly rather wide (> 20 cm). The catches from greater depths showed wider length ranges than those from lesser depths.

The ratio of the length of the hake at first maturity to the asymptotic length (L_m/L_∞) gave values of 0.36 and 0.41 (data of Kirinčić and Lepetić, 1955, Županović, 1968, and of the »Hvar« Expedition used), these being lower than those recorded in gadiforms from other seas (Beverton and Holt, 1959) and that found in the eastern Spanish hake (Larrañeta, 1970).

A review of the data on food composition in the Adriatic hake showed that the rather small hake from the »Hvar« Expedition area exceeding 16 cm and showing a modal length of 27.5 cm fed mainly on pelagic fish (the sardine and anchovy) and bathypelagic fish (the mackerel, bogue and horse mackerels), (Karlovac, O., 1959b). These data are in agreement with the data for the shallower northern Adriatic (Piccinetti, C. and G. Piccinetti Manfrin, 1971) and those for the eastern Spanish coast (Larrañeta, 1970). In contrast, according to the data of Jukić (1975), the hake caught in the open central Adriatic, at depths ranging from 110 to 262 m and at a

mean depth of 176 m, took mainly bathypelagic and benthic fishes from which none was found to be predominant.

The hake preyed on the sardine in the shallower part of the »Hvar« Expedition area (at a mean depth of 102 m). It had also to feed on other fishes recorded in the food of the hake mainly in shallower waters (at greater depths the hakes mostly had everted stomachs as shown by O. Karlovac, 1959b). At depths exceeding those sampled during the food composition study by O. Karlovac (1959b) the hake might have had different food preferences or perhaps no marked preferences at all. The differing data on the hake food composition given by Jukić (1975) might be due to difference in the trawling depths between the two series of observations.

The rather small hake (mean length of 28.5 cm) from the »Hvar« Expedition area (shallower part) fed on small sardines (mean length of 13.7 cm), (from the data of O. Karlovac, 1961).

Data on the horizontal distribution of the fish species analysed from the point of the hake food preferences, in the »Hvar« Expedition area, partly studied earlier, showed a localized distribution of the sprat, in the shallowest waters (mean depth 69 m), (Mužinić, 1973b) and a distribution limited to the deepest waters of the area (mean depth 194 m) in *Glossanodon leioglossus* (Val.). The other six species, i.e. *Sardina pilchardus* (Walb.), *Engraulis encrasicolus* (L.), *Boops boops* (L.), *Trachurus mediterraneus mediterraneus* (Std.r.), *Spicara smaris* (L.) and *S. maena flexuosa* (Raf.), were recorded in rather shallow waters of the Expedition area of mean depths ranging from 89 to 106 m and showed a discontinuous distribution, due to the Jabuka Pit.

Trachurus trachurus (L.) and *Argentina sphyraena* L. occurred at greater and similar mean depths, 144 and 145 m, and had a continuous horizontal distribution in the Expedition area.

Scomber scombrus L. was found at a mean depth of 124 m (almost equal to the mean Expedition trawling depth) and showed a discontinuous horizontal distribution in the investigated area as shown earlier (Mužinić, 1973a).

An analysis of the distributional data for the hake on one hand and the prey fish species on the other in the »Hvar« Expedition area showed that the hake had a horizontal distribution wider than that of any of the other fishes considered, but especially of *Sprattus sprattus* (L.), *Sardina pilchardus* (Walb.), *Engraulis encrasicolus* (L.), *Boops boops* (L.), *Trachurus mediterraneus mediterraneus* (Std.r.), *Spicara smaris* (L.) and *S. maena flexuosa* (Raf.). None of these species could, therefore, have an importance for the hake feeding in the whole Expedition area.

From the data on the hake food composition and the comparative distributional data on the species it appears that *Sardina pilchardus* (Walb.), *Sprattus sprattus* (L.) and *Engraulis encrasicolus* (L.) may be the prey species preferred by the hake only in shallower waters. The hake seems to prefer mackerel in somewhat deeper waters. The hake showing a preference for mackerel is probably larger. In contrast, *Trachurus* and *Spicara* species, as well as *Argentina sphyraena* L. might not be the preferred prey of the hake. However, more behavioural data are needed when considering these predator-prey relations.

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O PREFERENCIJAMA JADRANSKOG OSLIĆA, *MERLUCCIUS MERLUCCIUS* (L.), U ODNOSU NA HRANU

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KRATAK SADRŽAJ

Podaci o vučarenju za vrijeme Ribarstveno-biološke ekspedicije »Hvar«, u 1948. i 1949. najvećim dijelom u otvorenom Jadranu, na dubinama od 20 do 382 m i na srednjoj dubini od 125 m, pokazuju da oslić ima u području rada ekspedicije široku i kontinuiranu rasprostranjenost.

Tijekom ekspedicije oslić je zabilježen na dubinama od 20 do 382 m i na srednjoj dubini od 126 m. Te su dubine skoro jednake dubinama vučarenja ekspedicije i stoga nisu u suprotnosti s opće poznatim preferencijama oslića u odnosu na dubinu.

U području rada ekspedicije lovine oslića s većim brojem primjeraka ostvarene su na većim dubinama. Najveća gustoća njegove populacije zabilježena je u kotlini Jabuke i južno od nje, kao i duž sjeveroistočnog ruba južno-jadranske kotline.

Za vrijeme ekspedicije ulovljen je razmjerno mali oslić — 40,2% lovina sadržavalo je samo primjerke manje od 40 cm, a samo 21,6% primjerke od 60 cm i više.

Raspon dužine oslića u pojedinim lovinama bio je prilično širok (> 20 cm). Lovine iz većih dubina pokazale su veći raspon dužine nego one iz manjih dubina.

Odnos između dužine oslića pri prvoj spolnoj zrelosti i asimptotične dužine (L_m/L_∞) dao je vrijednosti od 0,36 i 0,41 (korišteni su podaci Kirinčića i Lepetića, 1955, Županovića, 1968, te podaci ekspedicije »Hvar«). Te su vrijednosti niže od onih koje su ustanovljene kod gadiforma iz drugih mora (Beverton i Holt, 1959), kao i od one koja je nađena kod oslića u istočnim španjolskim vodama (Larrañeta, 1970).

Iz razmatranja podataka o sastavu hrane jadranskog oslića proizlazi da su se razmjerno mali oslići iz područja rada ekspedicije koji su pokazali dužinu veću od 16 cm i modalnu dužinu od 27,5 cm hranili pelagičnim (srdela i brgljun) i batipelagičnim ribama (skuša, bukva i šnjuri), (Karlovac, O., 1959b). Ti su podaci u skladu s podacima za plići sjeverni Jadran (Piccinetti, C. i G. Piccinetti Manfrin, 1971) i s onima za istočnu španjolsku obalu (Larrañeta, 1970). Naprotiv, prema podacima Jukića (1975), oslić ulovljen u srednjem Jadranu, na dubini od 110 do 262 m i na srednjoj dubini od 176 m, hranio se uglavnom batipelagičnim i bentoskim ribama od kojih ni jedna nije dominirala.

Oslić se hranio srdelom u plićim vodama područja rada ekspedicije »Hvar« (na srednjoj dubini od 102 m). On se morao hraniti i drugim ribama,

koje su ulazile u sastav njegove hrane, također uglavnom u plićim vodama (u većim dubinama oslići su većinom imali posuvraćene želuce, kako je ustanovio O. Karlovac, 1959b). Na dubinama većim od onih na kojima je O. Karlovac (1959b) izvršio opažanja o sastavu hrane oslić bi mogao imati ili drugačije ili čak nikakve izrazite preferencije u odnosu na hranu. Različiti podaci o sastavu hrane oslića, što ih daje Jukić (1975), mogli bi potjecati od razlike u dubini vučarenja.

Razmjerno mali oslići (srednja dužina od 28,5 cm) iz područja rada ekspedicije »Hvar« (plići dio) hranili su se malom srdelom (srednja dužina od 13,7 cm), (iz podataka O. Karlovca, 1961).

Podaci o horizontalnoj rasprostranjenosti vrsta riba analiziranih sa staništa preferencija oslića u području rada ekspedicije »Hvar«, dijelom izučavani ranije, pokazali su lokaliziranu rasprostranjenost papaline u najplićim vodama (srednja dubina od 69 m), (Mužinić, 1973b) i rasprostranjenost vrste *Glossanodon leioglossus* (Val.) ograničenu na najdublje vode (srednja dubina od 194 m). ostalih šest vrsta, tj. *Sardina pilchardus* (Walb.), *Engraulis encrasicolus* (L.), *Boops boops* (L.), *Trachurus mediterraneus mediterraneus* (Std.r.), *Spicara smaris* (L.) i *S. maena flexuosa* (Raf.), zabilježeno je u razmjerno plitkim vodama područja rada ekspedicije »Hvar« na srednjoj dubini od 89 do 106 m, a pokazalo je diskontinuiranu rasprostranjenost zahvaljujući kotlini Jabuke.

Vrste *Trachurus trachurus* (L.) i *Argentina sphyraena* L. susretale su se na većim i sličnim srednjim dubinama, od 144 i 145 m, i imale su kontinuiranu rasprostranjenost u području rada ekspedicije.

Iz analize podataka o rasprostranjenosti oslića s jedne strane i riba koje predstavljaju njegov plijen s druge strane u području rada ekspedicije »Hvar« proizlazi da oslić ima širu rasprostranjenost od svih tih analiziranih vrsta riba, ali osobito od vrsta *Sprattus sprattus* (L.), *Sardina pilchardus* (Walb.), *Trachurus mediterraneus mediterraneus* (Std.r.), *Spicara smaris* (L.) i *S. maena flexuosa* (Raf.). Prema tome, ni jedna od tih vrsta riba ne može imati važnost za ishranu oslića u cijelom području rada ekspedicije »Hvar«.

Iz podataka o sastavu hrane oslića i usporednih podataka o rasprostranjenosti vrsta proizlazi da *Sardina pilchardus* (Walb.), *Sprattus sprattus* (L.) i *Engraulis encrasicolus* (L.) mogu predstavljati preferirani plijen oslića samo u plićim vodama. Čini se da oslić pokazuje preferenciju za skušu u nešto dubljim vodama. Oslić koji preferira skušu vjerojatno je krupniji. Naprotiv, vrste rodova *Trachurus* i *Spicara*, kao i vrsta *Argentina sphyraena* L. ne bi mogle predstavljati preferirani plijen oslića. Međutim, pri razmatranju tih odnosa između grabežljivca i plijena potrebno je raspolagati i s više podataka o ponašanju riba.

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