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A CONTRIBUTION TO THE STUDY OF BIOLOGY AND POPULATION DYNAMICS OF THE ADRIATIC HAKE, *MERLUCCIUS MERLUCCIUS* (L.)

PRILOG IZUČAVANJU BIOLOGIJE I DINAMIKE POPULACIJE JADRANSKOG OSLIĆA, *MERLUCCIUS MERLUCCIUS* (L.)

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Hake is one of commercially most important fish species in the Adriatic Sea. However, nevertheless they count among commercially important species, our knowledge on their rates of fishing and natural mortalities of the exploitable stock, and their variation with changes in the intensity of exploitation and natural factors are relatively scare.

Therefore the authors here have tried to present some of the results of studies of biology and population dynamics of the hake, *Merluccius merluccius* (L.), in the Adriatic.

INTRODUCTION

The first data on biology and exploitation of hake in the channel area of the middle Adriatic may be found in a treatise on harmful effects of intensive trawling written in the second half of the XVIII century (Moller, 1775).

The decrease in hake catches this author attributed to trawls capturing »the adolescent and small« fish.

This problem of the decrease in the average catch and size of specimens within populations of economically important species was until lately considered one of the fundamental indications of overfishing. In this connection an intensive development of trawling in the Adriatic, particularly in XX century, posed the problem of relationship between fishing intensity and fishery resources. This problem of the effects of fishing intensity on the Adriatic fishery resources was dealt with by a number of authors between the two wars (Gast, 1918, 1925; D' Ancona, 1926; Kotthaus, 1938; Kotthaus and Zei, 1938; Zei, 1940; Zei and Sabioncello, 1940).

A large amount of more intensive work was carried out after World War II, dealing with the relationship between fish populations and fishing intensity (Zei, 1949; D' Ancona, 1949—1950; Županović, 1953, 1956a, b, 1959, 1961a, b, c, 1963, 1964, 1968, 1971, 1974; Karlovac, O., 1957, 1959; Crnković, 1959, 1970; Lepetić, 1965; Scaccini and Piccinetti, 1968, 1969; Merker and Ninčić, 1973; Jukić and Crnković, 1974; Jukić, 1975; Jukić and Piccinetti, 1979, 1981, 1985; Froglia and Gramitto, 1986; Bello *et al.*, 1986).

Biology, population dynamics, exploitation and stock assessment of the hake, that is hake in relation to other demersal species were also investigated by a number of authors after World War II (Matta, 1953, 1954; Karlovac, O., 1959; Ghirardelli, 1959; Županović, 1964, 1968; Karlovac, J., 1965; Piccinetti and Piccinetti-Manfrin, 1971; Jukić, 1972, 1975; Levi and Gianetti, 1972; Froglia, 1973; Mužinić and Karlovac, O., 1975; Jardas, 1976; Jukić and Piccinetti, 1978; Granić *et al.*, 1980; Granić and Jukić, 1982; Alegrîa Hernández *et. al.*, 1982; Flamigni, 1983; Giovanardi *et al.*, 1986).

The relationship between hake behaviour and applied gear was described in several papers published also after World War II (Županović and Grubišić, 1958; Županović, 1963, 1969; Levi *et al.*, 1971; Jukić, 1975; Jukić and Piccinetti, 1985; Froglia and Gramitto, 1986).

Catch of hake suddenly increased in the Adriatic between 1970 and 1980 with maximum in 1975—1977. The question is posed by the exploitation of hake fishery in the Adriatic, to what extent is the said trend of catch increase associated with better biological conditions in recruitment or year class strength, resulting from more favorable hydroclimatic factors. It is evident from the question posed that sufficient knowledge an continuous appraisal of the hake environment is essential.

Therefore, the determination of the rates of fishing and natural mortalities of the exploitable stock, and their variation with changes in the intensity of exploitation and in natural factors for the hake fisheries in the Adriatic requires a better knowledge of hake selectivity by trawls, length composition of catches of various fleets, the age structure of the stocks, growth rates and fishing and natural mortality rates.

Majority of these data are still unknown. However, a limited amount of data precludes an accurate assessment of the degree of exploitation of the Adriatic hake. This is especially important for an estimate of the effective pathwidth of a trawl — using hake data relating the fishing mortality (F).

MATERIALS AND METHODS

The material essential for the study of hake biology and population dynamics in the Adriatic was collected by means of 696 one-hour trawl hauls during the 1956—1967 explorations undertaken with the research vessel BIOS. Of that total 560 hauls were made in the open part of the Adriatic, and 136 in the channel area.

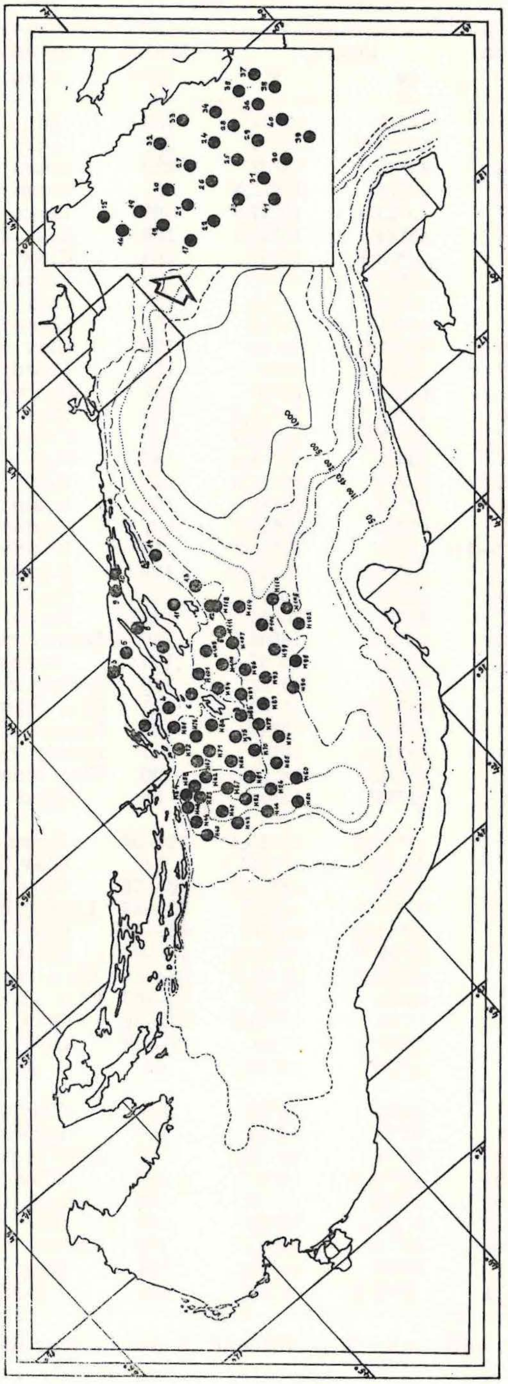


Fig. 1. Positions of sampling stations in the 1956—1967 period

Table 1. Location of stations bz regions where hake samples were taken (1956—1967)

Area	Station	Position N	Position E	Depth (m)	Structure of bottom	Trawling hauls
1. Open middle	H-40*	43°35,	15°24,	181	Clay loam	17
Adriatic	H-43	43°24,5'	15°17'	220	Loam	15
(Blitvenica,	H-44	43°35'	15°32'	220	Loam	21
Jabuka Pit)	H-46	43°14'	15°12,5'	216	Loam	17
(30 stations)	H-47	43°25,5'	15°27,5'	199	Loam clay	21
	H-48	43°34'	15°39,5'	188	Clay loam	29
	H-50	43°03,5'	15°07'	264	Clay	9
	H-52	43°17'	15°25'	193	Loamy clay	18
	H-53	43°28'	15°40'	181	Clay	22
	H-54	43°31,5'	15°45'	172	Loamy clay	17
	H-56	43°07,5'	15°20'	190	Clay loam	13
	H-57	43°19'	15°35'	157	Loamy clay	21
	H-58	43°27'	15°46'	157	Loamy clay	21
	H-60	42°58'	15°15,5'	210	Clay	1
	H-61	43°10,5'	15°32,5'	150	Loam	17
	H-62	43°22'	15°46,5'	157	Clay	24
	H-65	43°00'	15°27,5'	170	Clay	1
	H-66	43°12'	15°43'	135	Loam	22
	H-67	43°21'	15°54,5'	127	Loamy sand	27
	H-67—71	43°22'	15°53,2'	117	Loamy sand	101
		43°15,6'	15°55,6'	126	Loamy sand	
	H-70	43°03'	15°40'	110	Sand	1
	H-71	43°15'	15°54'	125	Loamy sand	27
	H-72	43°22,5'	16°03,5'	110	Loamy clay sand	14
	H-74	42°53'	15°37,5'	157	Loamy clay	1
	H-75	43°05'	15°51'	115	Loamy clay sand	1
	H-76	43°15,5'	16°03'	111	Clay loamy sand	16
	H-79	42°55,5'	15°48'	130	Loamy clay sand	1
	H-80	43°08,5'	16°02'	111	Loamy clay sand	1
	H-81	43°18,5'	16°13'	120	Clay loamy sand	14
	H-86	42°58'	15°57'	88	Sand	1
2. Channels of	1	43°30,6'	16°23,4'	12—38	Loam	12
the middle	2	43°23,3'	16°22'	53	Clay loam	13
Adriatic	3	43°22'	16°52,2'	76—78	Clay	14
(11 stations)	4	43°16,5'	16°26'	82—85	Loamy clay sand	14
	5	43°14,4'	16°56'	65—68	Clay	14
	6	43°07,5'	16°19,5'	85—87	Sand	14
	7	43°03,5'	16°44,5'	66—68	Clay loamy sand	14
	8	43°04'	17°00'	59—63	Clay sandy loam	13
	9	43°01,3'	17°24,2'	27—32	Clay	14
	10	42°57'	17°31'	27—29	Clay	13
	11	42°50'	16°58,2'	64	—	1
3. Islands —	H-91	42°53'	16°05'	136	Clay loam	1
Vis—Lastovo	H-94	42°58'	16°14'	119	Loamy clay	1
—Mljet	H-96	42°46'	16°12,5'	148	Clay sandy loam	1
(13 stations)	H-100	42°50,5'	16°22'	132	Clay loam	1
	H-101	42°59'	16°27'	99	Loamy clay sand	1
	H-107	42°42,5'	16°28'	143	Clay sand	1
	H-108	42°52'	16°33'	110	Loamy clay sand	1
	H-111	42°43'	16°36'	134	Clay	1
	H-114	42°32,5'	16°39'	188	Loamy clay	1

* Stations marked with letter H correspond to the stations of HVAR expedition 1948—1949.

Area	Station	Position N	Position E	Depth (m)	Structure of bottom	Trawling hauls
	H-118	42°38,5'	16°47'	153	Loam	1
	12	42°39,6'	16°48,8'	143	—	1
	13	42°39,6'	17°02,6'	128—130	—	1
	14	42°42,2'	17°25,4'	115	—	1
4. Island Palagruža (9 stations)	H-89	42°49'	15°55'	154	Loam	1
	H-90	42°37'	15°52'	139	Clay sand	1
	H-93	42°42'	16°02,5'	169	Loamy clay	1
	H-95	42°29,5'	16°00'	137	Clay	1
	H-99	42°33,5'	16°11'	174	Clay	1
	H-102	42°20'	16°13'	130	Clay sandy loam	1
	H-105	42°20,5'	16°23'	130	Sand	1
	H-106	42°31'	16°25,5'	190	Clay	1
	H-110	42°22'	16°32'	168	Sand	1
5. Montenegro coastal area (27 stations)	15	42°15'	18°41'	102—112	Clay and clay sandy loam are present in the whole area	1
	16	42°11,6'	18°38'	123		1
	17	42°01,4'	18°36,2'	160—172		1
	18	42°04,8'	18°39,3'	113—128		1
	19	42°08,1'	18°42,4'	80—117		1
	20	42°04,5'	18°46,8'	83—83		1
	21	42°03,8'	18°46'	105—135		1
	22	42°00,5'	18°43'	142—175		1
	23	41°53,4'	18°42,4'	110—165		1
	24	42°00'	18°58,2'	70—88		1
	25	41°56,7'	18°55'	90—100		1
	26	41°55,7'	18°51'	95—100		1
	27	41°58,6'	18°49'	85—90		1
	28	41°56,6'	19°02,7'	75—87		1
	29	41°53,2'	18°59,6'	90—92		1
	30	41°47,4'	18°54,2'	102—105		1
	31	41°50,9'	18°49,6'	102—110		1
	32	42°06'	18°55,9'	70—72		1
	33	42°02,9'	19°00'	67—70		1
	34	41°59,8'	19°00,8'	72		1
	35	41°56'	19°05,2'	72—75		1
	36	41°50,6'	19°04,9'	77—86		1
	37	41°53,3'	19°08,7'	65		1
	38	41°50,3'	19°10,8'	73—85		1
	39	41°44'	18°58,8'	85—105		1
	40	41°47,3'	19°01,8'	95		1
	41	41°49,8'	18°51,4'	95—102		1

The stations where the samples were taken are shown in Fig. 1 and Table 1.

The material was analyzed according to the size of the catches. All the individuals were tested in poor yields but only representative samples were taken from abundant catches.

The analysis involved length measuring, weighing, determination of sex and of the degree of sexual maturity, taking of otoliths and examination of stomach contents. Morphological characters were examined on fresh fish.

The age of individuals was determined from otoliths.

Trend of hake catches was analyzed from commercial catches. Data on temperature and salinity were also taken.

RESULTS AND DISCUSSION

Morphology

External morphology

Morphometric characteristics of the Adriatic hake were expressed as percentages of total length (Županović, 1968). Several most important body characteristics were measured: head length in relation to total length; length from the tip of snout to insertion of first dorsal fin; length from the tip of snout to insertion of second dorsal fin; length from the tip of snout to insertion of anal fin and diameter of the eye in relation to the head length.

A total of 213 specimens were analyzed. Of this number 121 were caught from the open middle Adriatic and 92 from the channel area of the middle Adriatic.

Mean values of analyzed characteristics of fish from these two areas examined by *t* distribution showed no significant differences in these characteristics between fish from the open middle Adriatic and channel area. They at the same time indicate that they belong to a single population of the Adriatic hake.

Matta (1954) analyzed morphometric properties of hake from the northern Adriatic and Ghirardelli (1959) from the western part of the middle Adriatic. The results of these authors generally coincide with our findings.

Vertebrae

Piccinetti and Piccinetti-Manfrin (1971) studied vertebral counts in the hake from the northern and middle Adriatic. They found that all the analyzed specimens belonged to the same population.

Comparing the vertebral count in the Adriatic hake (M = 51.99) with that in the Mediterranean hake (Maurin, 1965) it was suggested that the differences in the mean number of vertebrae between the hake from both areas were not great so that did not exist two hake populations. The Adriatic hake, after the same authors, represent something like an intermediate species between eastern and western Mediterranean. This similarity the authors tried to associate with the respective hydrographical factors in the middle Adriatic (Jabuka Pit), known as the hake spawning ground in the Adriatic (Županović, 1968). Similarity in the vertebral counts is particularly marked in the hake from the western Mediterranean (Gulf of Lyon, Corsica, Tuscany archipelago) and that from the B zone in the northern Adriatic (Piccinetti and Piccinetti-Manfrin, 1971). This similarity in the vertebral counts in the hake from the Adriatic and hake from the northern part of the western Mediterranean may be associated with the divergence zones. The same phenomenon was recorded near Banc des Esquerquis off Tunisia (Furnestin, 1960; Allain, 1960; Furnestin and Allain, 1962; Allain *et al.*, 1965; Maurin, 1965, 1968a, b).

It should be taken into consideration that fish which spend very early part of their life in cold water (like hake from the Jabuka Pit, Gulf of Lyon, etc.) will develop more myomeres, and consequently more vertebrae, than will fish which grow in warmer water (Libyan water, Sea of Marmara). This apparent negative correlation between the number of vertebrae and water temperature has been noted for many species (Marr, 1953). The same was, to a certain extent, proved by a progressive increase in the number of vertebrae in hake along the shores of north Africa (Maurin, 1968a) probably consequent to the digression inflow of the Atlantic current.

Geographical distribution

For geographical distribution of hake in the Adriatic the papers of a number of authors were used: *for the open Adriatic:* Karlovac, O., 1957, 1959; Županović, 1956, 1959, 1961a, 1968, 1971; Kirinčić and Lepetić, 1955; Matta, 1954; Ghirardelli, 1959; Piccinetti and Piccinetti-Manfrin, 1971; Merker and Ninčić, 1973; Froglia, 1973; Jukić, 1975; Jukić and Piccinetti, 1981; Flamigni, 1983; Jukić and Arneri, 1983; *for the channel area of the middle Adriatic:* Kotthaus and Zei, 1938; Zei, 1940, 1949; Zei and Sabiocello, 1940; Županović, 1953, 1956; Kirinčić and Lepetić, 1955; Karlovac, O., 1959; Crnković, 1959, 1970; Lepetić, 1965; Rijavec, 1966; Jukić, 1972, 1975; Jukić and Crnković, 1974; Hure (manuscript) and field data of the authors (1956—1967).

The available data show that hake are distributed throughout the Adriatic (Fig. 2) counting among markedly eurytopic species. Their bathymetric distribution in the Adriatic, from several metres in the coastal area to 800 metres in the South Adriatic Pit (Kirinčić and Lepetić, 1955) is another proof of this fact.

As shown by the data of HVAR Expedition, 1948—1949, hake were poorly represented in the northern, middle as well as southern Adriatic in relation to other species. In the northaern Adriatic hake made up 2.4% of the number and 6.6% of the weight; in the middle Adriatic 13.2% of the number and 16.0% of the weight and in the southern Adriatic 5.1% of the number and 13.6% of the weight (Karlovac, O., 1957). The relationship between the number and weight of hake from the southern Adriatic is indicative of larger specimens in this Adriatic part (Mužinić and Karlovac, O., 1975).

Depth preferences

After the data of HVAR Expedition (Mužinić and Karlovac, O., 1975) hake were caught by trawls at 20 to 382 m depths, and by long-lines at still greater depths (443 and 765 m). Of trawl catches 291 or 98% were positive. The highest number of hake catches, 238 or 81.8%, was realized between 51 and 100 m depths (75 or 25.9%), between 101 and 150 m (100 or 34.5%) and between 151 and 200 m (62 or 21.4%). As to the abundance of catches per an hour haul, 22 or 76% were recorded from 45 tol 220 m (mean depth 162.8 m) (with 100—199 individuals), 13 or 4.5% from 135 to 256 m (mean depth 178 m) (with 200 and more specimens).

Kirinčić, and Lepetić (1954, 1955) reported long-line hake catches in the southern Adriatic from all the depths between 100 and 800 m. These

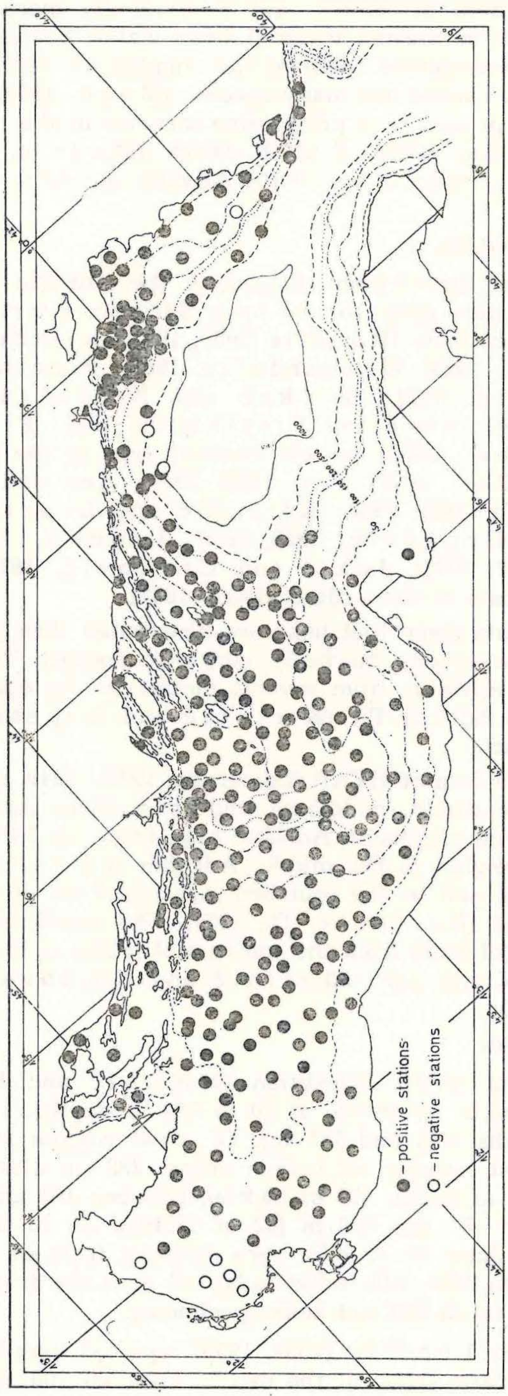


Fig. 2. Geographical distribution of hake in the Adriatic Sea

authors recorded greatest abundance at 300 m (31.8% of the number and 33.6% of the weight).

Merker and Ninčić (1973) reported hake to be caught by trawls at all the operating depths, from 10 to 500 m, in the deep southern Adriatic, with the greatest abundance at 200 m.

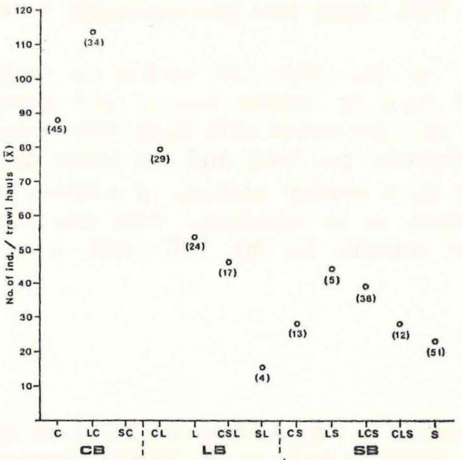


Fig. 3. Mean of the number of hake individuals per hour experimental trawl haul on bottoms of defferent granulometric composition (from fine to rough bottoms): CB — clayeay bottoms, LB — loamy bottoms, SB — sandy bottoms, C — clay, LC — loamy clay, SC — sandy clay, CL — clayey loam, L — loam, CSL — clayey-sandy loam, SL — sandy loam, CS — clayey sand, LS — loamy sand, LCS loamy-clayey sand, CLS — clayey-loamy sand, S — sand; the number of analyzed catches is given within brackets (after the data of HVAR Expedition, Karlovac, O., 1959)

After our available data for the Jabuka Pit in the 1956—1967 period hake were caught from mean depths of 104 to 219 m, that is throughout the study area. Mean value of 62 specimens per trawl haul was obtained for mean depths of 100 to 150 m, that of 152 specimens for mean depths of 151 to 200 m and that of 336 specimens at depths exceeding 201 m.

To conclude, hake are in the Adriatic most abundant in deeper areas of the continental shelf, that is at depths of about 100 m to depths slightly exceeding 200 m.

Substratum preferences

The analysis of published data of HVAR Expedition for the open Adriatic (Karlovac, O., 1959a) showed that hake abode all types of sea bed in the open Adriatic. The densest populations were recorded from fine and tenacious clayey substrata and from loamy bottoms. The lowest hake density was recorded from coarser and loose sandy bottoms (Fig. 3). Out of the total of 79 experimental trawl hauls realized on clayey bottoms 49.35% hake individuals were recorded, out of 74 hauls on loamy bottoms 27.95% and out of 119 hauls on sandy bottoms 22.70%. Hake caught from clayey bottoms made up 31.09% of the total weight of hake catch, those from loamy bottoms 38.92% and those from sandy bottoms 30.00%, that is a total of 70% from muddy bottoms.

The densest population was recorded from the narrower area of the Jabuka Pit (stations: 43 and 46—59). A total of 27 trawl hauls on clayey, loamy-clayey, loamy and clayey-loamy bottoms of the above stations gave 5,000 hake specimens or 40.1% of a total of hake specimens caught by 153 trawl hauls on muddy bottoms. However, the hake caught from the above mentioned area made up not more than 14.7% of the total hake weight of the hake caught from muddy bottoms. This means that predominantly small specimens were caught.

After our data for the Jabuka Pit for the 1956—1967 period the mean number of hake individuals per trawl haul on muddy (clayey and loamy bottoms) was higher than that on sandy bottoms mixed with mud. The former bottoms gave the average of 183.4 specimens per haul and the latter 40.6.

This clearly marked preference of hake muddy bottoms in relation to muddy-sandy bottoms and sandy bottoms, is in agreement with the data from the channel area of the middle Adriatic in the 1957—1958 period (Županović, 1961c).

Bionomics and Life-history

Maturity

Zei (1949) found male hake to mature in the Adriatic at 22 to 30 cm length. Županović (1968) analyzed stages of hake in the middle Adriatic and found that males are mature first time at 20 to 28 cm and females between 23 and 33 cm. The highest percentage of ripe males were 23—25 cm in length and of females 29—32 cm. Similar results were obtained by Jardas (1976) for the hake from the open middle Adriatic. After this author the inflexion point of allometric weight-length relationship between adolescent and adult growth phases was for males at mean length of 26.5 cm and weight of 118.1 g, and for females at mean length of 30.5 cm and weight of 201.6 g. These data also show that males weigh less and are, on the average, 4 cm shorter than females at the end of adolescent stage.

Matta (1956b) obtained the inflexion point for females at 32 cm and for males at 29 cm at the same weight-length relationship in the Mediterranean hake exceeding 16 cm in length. These values may be taken as mean length at which hake mature.

Larrañeta (1970) suggested that hake smaller than 40 cm behaved like pelagic or semi-pelagic fish. Hickling (1933), Graham (1956), Wheeler (1969), Grinols and Tillman (1970) held that European hake abode surface or intermediate layers during juvenile stage inhabiting bottom not earlier than after the second year of age, at length of 20 cm.

The relationship between growth and maturation of the hake from different areas of their geographical distribution is different. Thus after some authors (Belloc, 1929; Hickling, 1933; Hart, 1948; Svetovidov, 1948; Maurin, 1954, 1968; Bagenal, 1954; Figueras, 1955, 1964, 1965; Castro, 1955; Bas, 1964; Županović, 1968; Wheeler, 1969;

Bouhlal and Ktari, 1975) the differences between the Mediterranean and Atlantic hake are considerable.

Spawning

Županović (1968) reported a spawning ground of hake in a shallower area of the open middle Adriatic (between 100 and 150 m) in summer. Catches realized from that area in summer contained rather large number of mature individuals, in spawning or spent conditions. This author also found ripe male and female hake between the islands Vis and Palagruža in winter (Fig. 4).

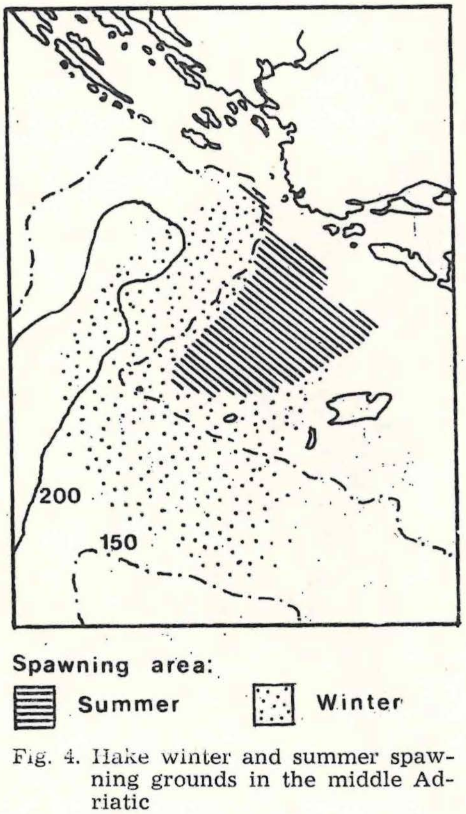


Fig. 4. Hake winter and summer spawning grounds in the middle Adriatic

The earliest spawning begins in deeper waters in winter and as the spawning season progresses hake spawn in shallower waters (spring-summer).

Maurin (1968a) established that during spawning the hake spawning stock from the Morocco waters concentrated between 100 and 200 m; older individuals coming from greater depths and younger individuals from different layers of the continental shelf.

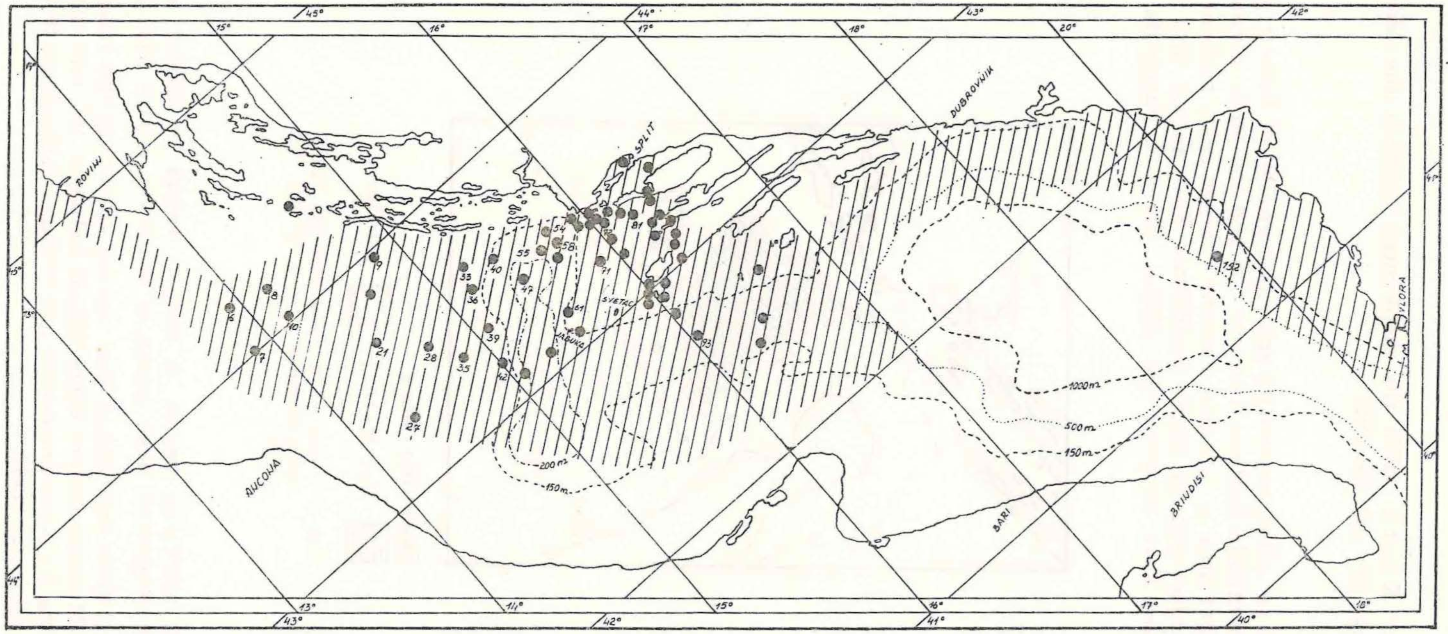


Fig. 5. Distribution of hake larvae and postlarvae in the Adriatic. Dotted areas = study area; black circles = positive stations; circles with numbers = stations of the HVAR Expedition — 1948/1949 (after J. K a r l o v a c, 1965)

Larvae

Karlovac, J. (1965) recorded young hake larvae from October through June. The highest numbers were recorded in January and February. Larvae and postlarvae were mainly distributed between 40 and 200 m, the highest number of individuals mainly caught between 50 and 100 m (Fig. 5).

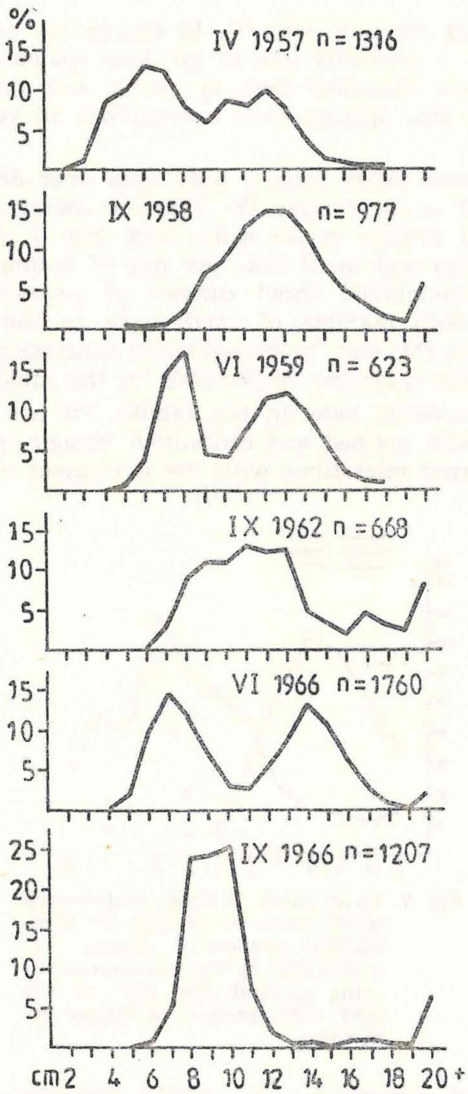


Fig. 6. Distribution of juvenile hake in the middle Adriatic in spring--autumn

Temperature ranged from 11.1° to 20.3°C. On the average, the highest number of specimens per haul was caught at temperature ranging from 12.6°C and 13.0°C and between 14.1°C and 14.5°C. Salinity varied from 37.09 to 38.75 × 10^{-3} at the same stations. Frequency of the number of specimens was highest at salinity ranging between 38.01 and 38.10 × 10^{-3} and between 38.41 and 38.50 × 10^{-3}.

Juveniles

The occurrence of juvenile hake (7—15 cm) in the population in spring and autumn (Fig. 6) is probably due to the long spawning season. Females with ripe gonads were abundant both in winter and spring in the middle Adriatic. Males with ripe sperms were encountered all year round (Županović, 1968).

Juvenile hake were taken from a wide area over deep water only, off the edge of the shelf in the Jabuka Pit. This our assumption was supported by commercial trawl catches in the same area. Fig. 7. depicts the average catch of large, medium and small hake per day of fishing in the 1956—1966 period. Maximum commercial trawl catches of juvenile hake show two pronounced peaks. Both maxima of small hake in the Blitvenica fishing ground, in the Jabuka Pit, may be brought into connexion with the intensity of summer and winter spawning respectively in the middle Adriatic.

Distribution of juvenile hake in the Jabuka Pit has always been associated with strong, well defined and continuous pelagic traces on echograms which presented diurnal migrations with the movement of DSL in the same area.

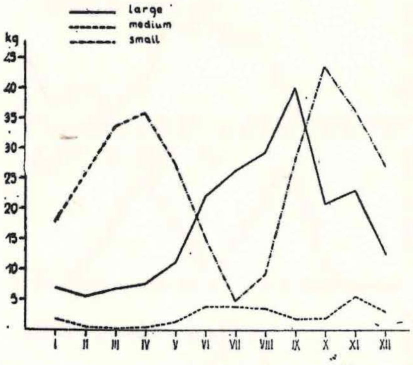


Fig. 7. Mean catch of large, medium and small hake in catches by commercial trawlers of »Jadran« organization in the Blitvenica fishing ground per day in the 1956—1966 period (arranged by months)

Flow of gradient currents in the middle Adriatic (Zore, 1956 and Zore-Armanda, 1968) in spring, summer, autumn and winter periods may have some connexion with the distribution of larval and postlarval hake (see Fig. 5) as well as with the continuous records of juvenile hake in the Jabuka Pit (Fig. 8).

Longitudinal flows are prevalent in summer and winter and transversal flows in spring and autumn. Northward directions prevail in spring and southwesternward directions in autumn along the eastern Adriatic coast. These flows in transient periods mean that the flow of the onshore direction prevails along the coast in spring causing divergence. Such a divergence is probably related to water upwelling on the bisecting line in the Jabuka Pit (Zore-Armanda, 1968)

In autumn, we have convergence instead of divergence, because the flow shows an off-coast tendency. It is probably connected with the influence of

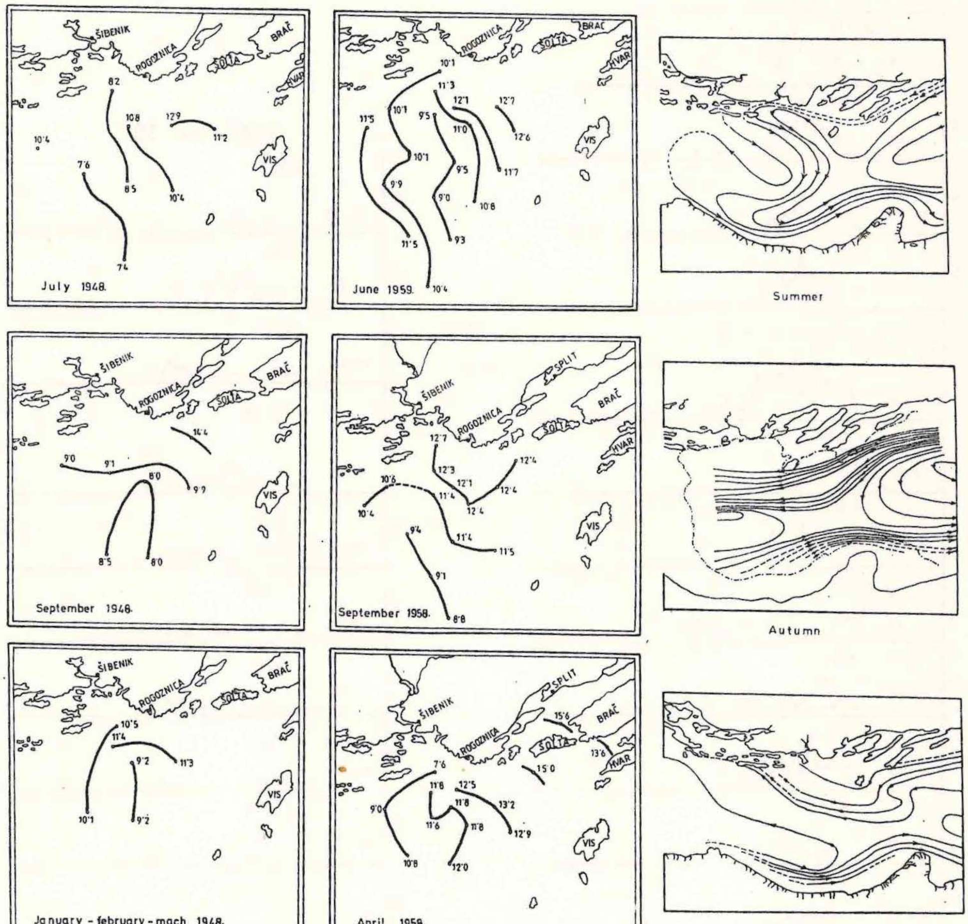


Fig. 8. Relationship between the flow of gradient currents in the middle Adriatic, referring to 50 m level (after Zore, 1956) and juvenile hake distribution in spring, summer, autumn and winter periods.

coastal water which cools down in cold periods (in autumn), sinks into the depths and flows towards the Jabuka Pit in the bottom layer (Zore-Armanda, 1968; Županović, 1969).

The occurrence of divergence and convergence in the Jabuka Pit in spring and summer, caused by offshore and onshore flows, may account for the rich catches of juvenile hake in the Jabuka Pit, particularly in the Blitvenica fishing ground. This was proved by Buljan (1974): »Possibly big catches

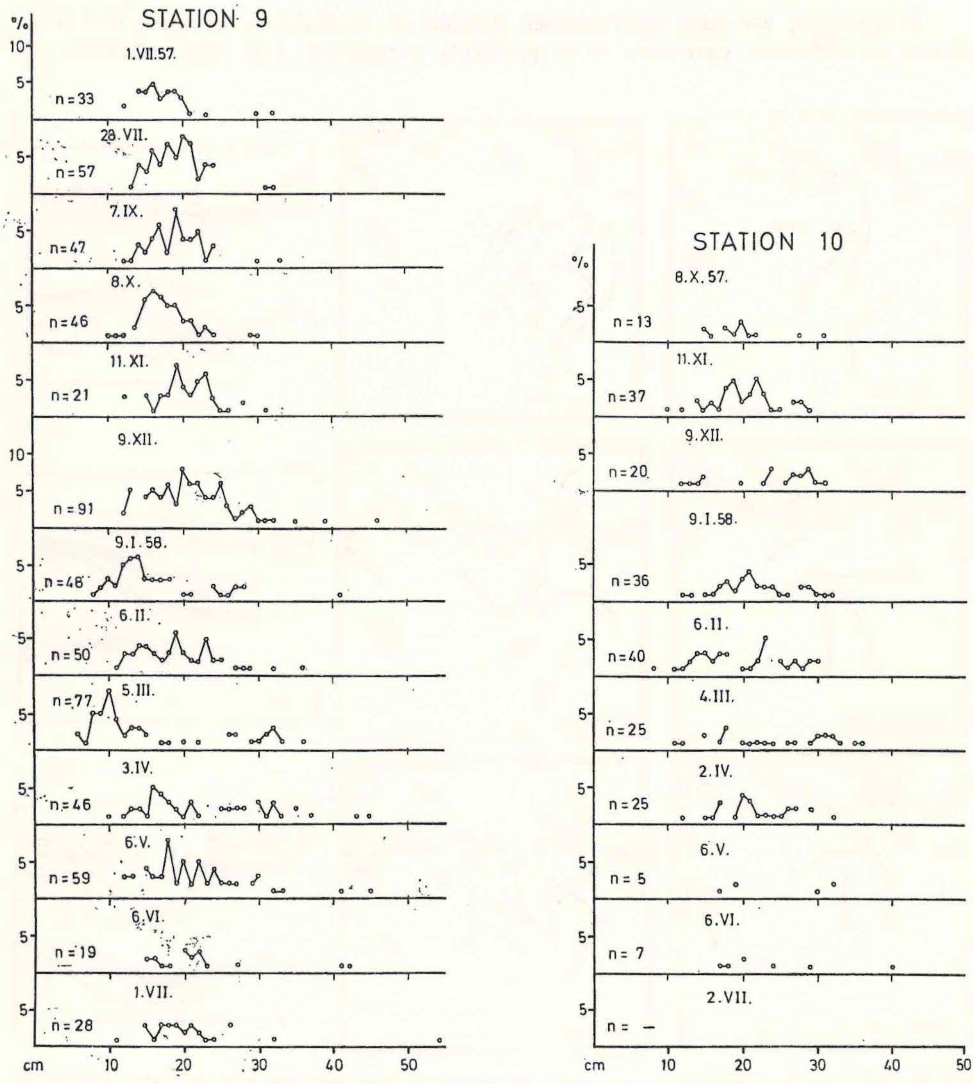
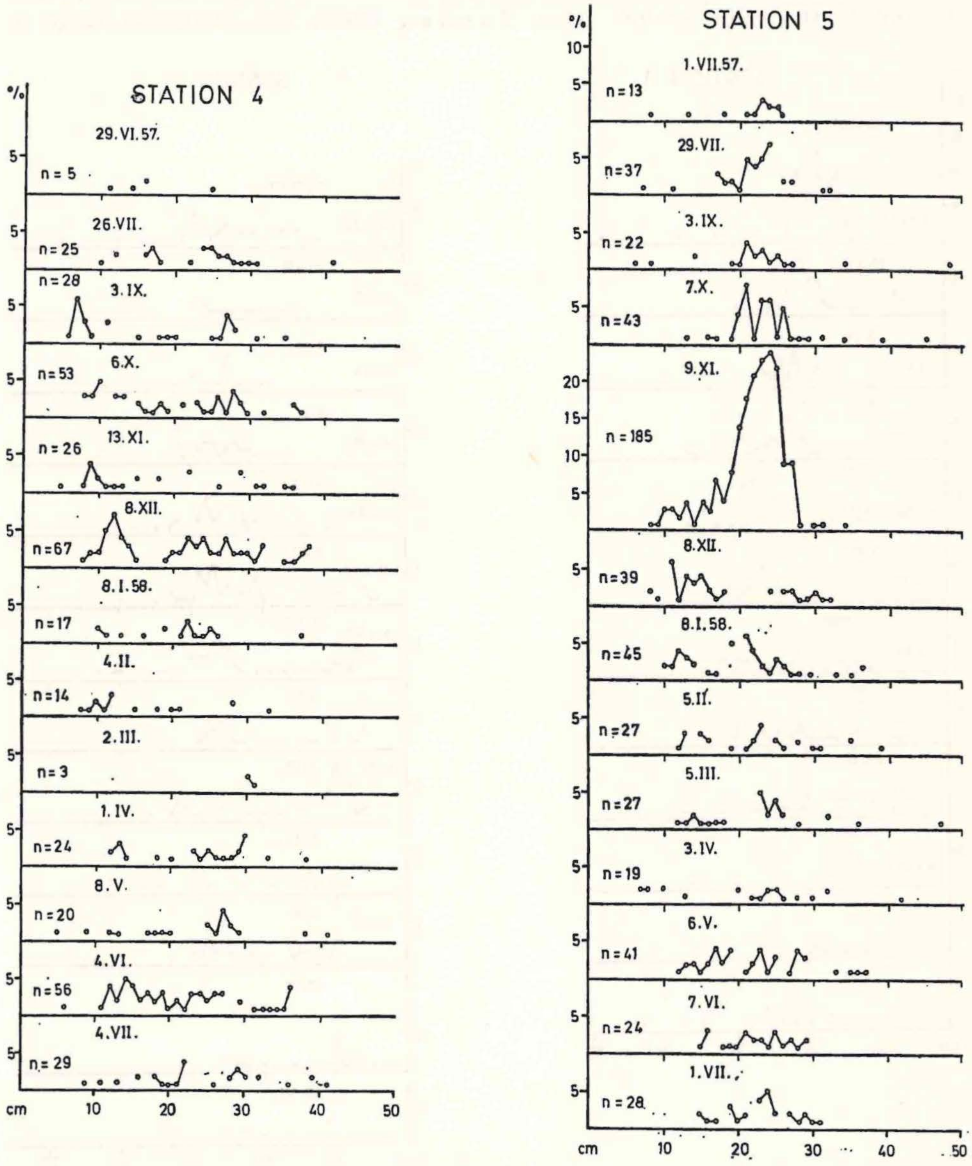


Fig. 9. Length frequency distributions of hake from the channel area of the middle Adriatic in 1957/1958, by months (mean in Fig. 9 is given by a vertical line)

in Blitvenica are due to the effects of deep water upwelling from the adjacent Jabuka Pit, which — as we have seen — is pretty nutrient rich at the bottom«.

Adolescents

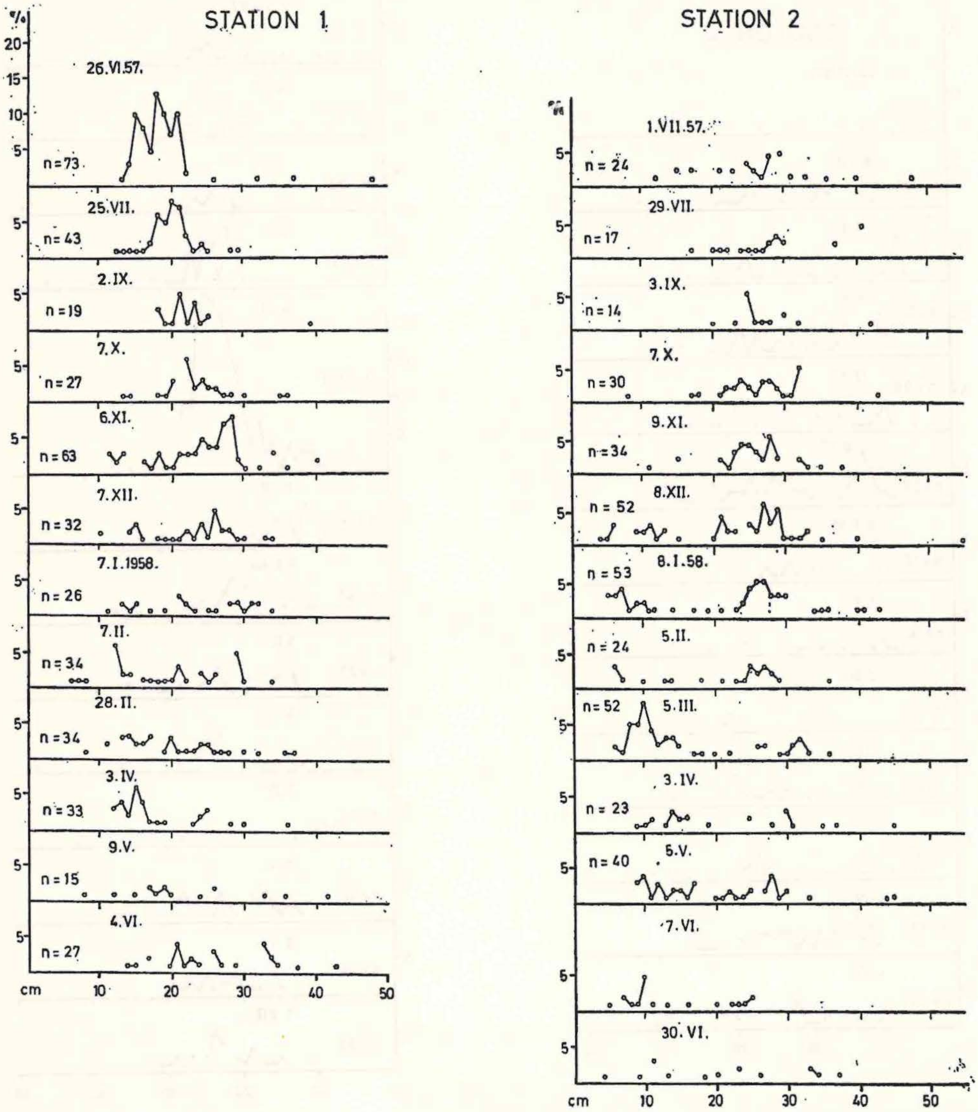
Measurements of morphometric characters of hake from the open middle Adriatic and channel area showed that they belong to a single population (Županović, 1968).



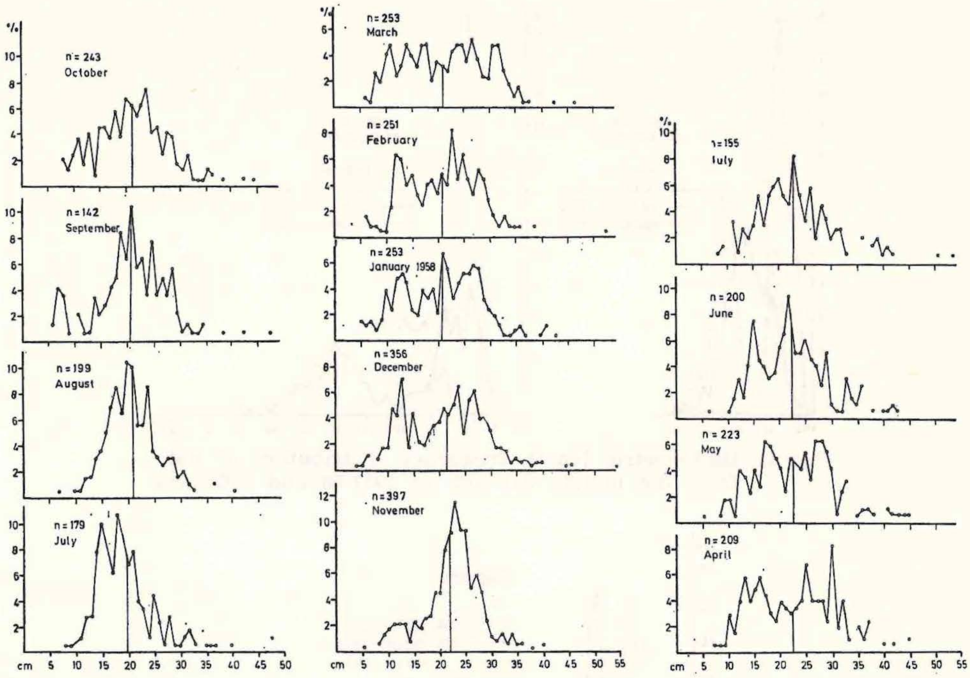
(Fig. 9)

Local movements of juvenile and adolescent hake (Figs. 9a-d and 10) not yet mature, towards shallower, channel waters of the middle Adriatic (Županović, 1961c) take place in spring and autumn (Table 2). Length frequency distribution in relation to depth is also indicative of the possibility of such a movement (Fig. 11).

On the basis of bathymetric distrbiution in Fig. 11 it is apparent that adolescent hake are present in the channel area of the middle Adriatic (below 100 m) in the same period. After Jardas (1976) the adolescent stage of



(Fig. 9)



(Fig. 9)

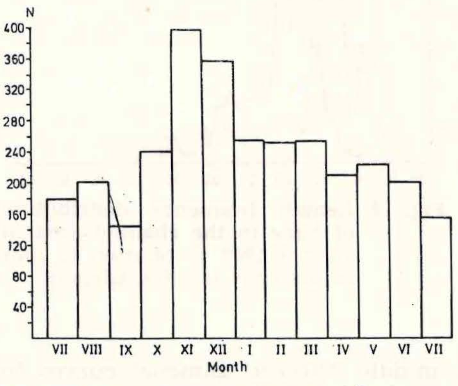


Fig. 10. Variations in hake abundance in the channel area of the middle Adriatic in 1957/1958, by months

the Adriatic hake lasts approximately from 18 to 26.5 cm in length and 25 to 118.1 g in weight for males, and up to about 30.5 cm in length and 201.6 g in weight for females.

This onshore movement of adolescent hake is better shown in Fig. 12 which depicts the movement of hake in August 1960 in the channel area in

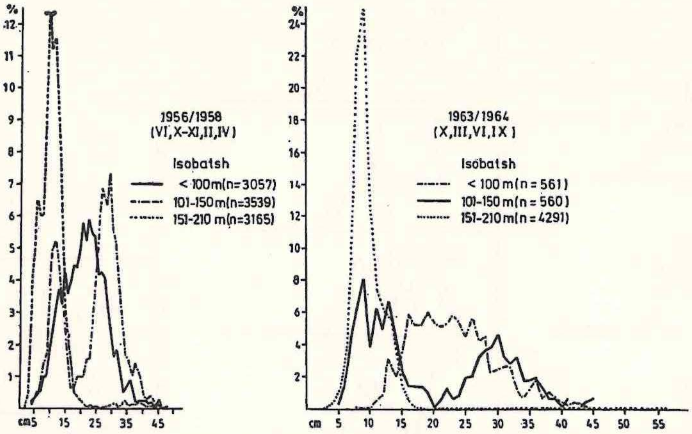


Fig. 11. Bathymetric length frequency distribution of hake from the middle Adriatic in 1957/58 and 1963/1964.

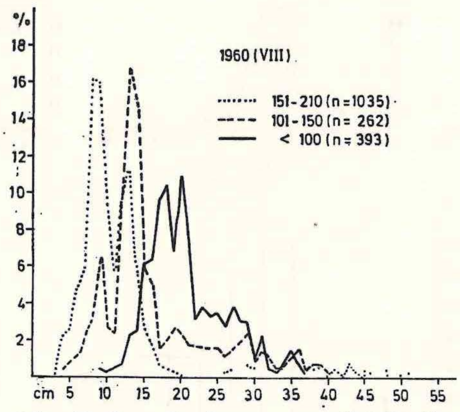


Fig. 12. Length frequency distribution of hake in the channel area in August 1960 in relation to that in the open middle Adriatic

relation to the open middle Adriatic. Bimodal curves for juvenile and adult hake and unimodality for adolescents in the channel area are best illustrative of this fact.

Adults

In general, adult and juvenile hake migrate onshore, towards shallower waters of the middle Adriatic in spring, adults for spawning and juveniles and adolescents for food. After spawning (100—150 m) adults migrate towards deeper waters in winter, wintering toghether with the juveniles in the same area (Fig. 13).

Onshore migrations of adult hake and vice versa can be seen in Table 2, as well.

Analogous movements of European hake in the waters of Great Britain and Ireland were reported by Hickling (1927).

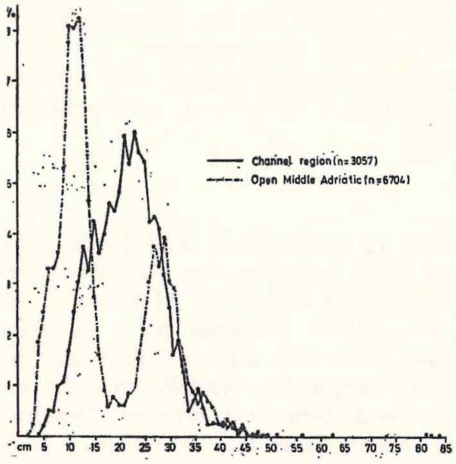


Fig. 13. Frequency poligon of male and female hake in the channel area in 1957/1958 and in the area of the open middle Adriatic in 1956, 1957 and 1958

Table 2. Hake catches in the areas of open and channel middle Adriatic (1956—1958)

Season	Area	No. of specimens	Mean length (cm)	Weigth (kg)	No. of hauls of an hour duration
Summer	Open middle Adriatic (1956)	1.479	23.95	214.13	24
	Channel area of the middle Adriatic (1957)	478	20.73	40.90	24
Autumn	Open middle Adriatic (1956)	522	25.22	93.81	24
	Channel area of the middle Adriatic (1957)	964	21.73	94.37	24
Winter	Open middle Adriatic (1957)	604	22.22	81.23	24
	Channel area of the middle Adriatic (1958)	701	21.00	68.07	24
Spring	Open middle Adriatic (1957)	518	25.12	81.04	24
	Channel area of the middle Adriatic (1958)	577	25.02	67.35	24
Total	Open middle Adriatic (1956/1957)	3.123	24.02	470.21	96
	Channel area of the middle Adriatic (1957/1958)	2.700	22.04	270.69	96

Nutrition and growth

Feeding

Jukić (1972) found feeding intensity of hake from the channel area of the middle Adriatic to show two peaks, one in winter and the other in spring. Both maxima this author brought into connexion with the occurrence of large quantities of small pelagic fish on which hake intensively feed. Temperature variations at bottom and variations in feeding intensity showed no correlation. In addition to small pelagic fish *(Sardina pilchardus* /Walb,/ and *Engraulis encrasicolus* /L./), Crustacea, with peaks in autumn and spring, are very important food.

Food

Food habits of hake in the Adriatic and Mediterranean was studied by a number of authors. Hake nutrition in the Mediterranean, Adriatic and eastern Atlantic was studied in detail by Mužinić and Karlovac, O., (1975). Karlovac, O., (1959) analyzed hake nutrition from the data of HVAR Expedition, 1948—1949. This author found that smaller hake, up to 16 cm, fed on crustacea and larger fish mainly on fish. Very important among the Adriatic hake fish food items are sardine *(Sardina pilchardus* /Walb./), followed by *Engraulis encrasicolus* (L.), *Scomber scombrus* L., *Boops boops* (L.). *Trachurus* sp., etc. Kirinčić and Lepetić (1955) found stomachs of hake caught between 100 and 800 m from the southern Adriatic in 1951 and 1952 to contain Crustacea *(Nephrops norvegicus* /L./ and *Parapenaeus longirostris* /H. Lucas/), Cephalopoda *(Ommatostrephes sagittatus* /Lam./ and *Octopus vulgaris* Lam.) and fishes *(Scomberesox saurus* /Walb./, *Scomber scombrus* L., *Trachurus* sp. and *Merluccius merluccius* /L./).

Crnković (1959) reported that stomach contents of hake caught from the northern Adriatic channels showed well represented sprat (*Sprattus sprattus sprattus* /L./).

Županović (1968) examined stomach contents of hake from the middle Adriatic. This author found fish to make up 81.80% of the total content, (mainly *Sardina pilchardus.* /Walb./ and *Sprattus sprattus spratus* /L./), Crustacea 6.51%, Cephalopoda 6.74% and unidentified species 4.59%, Analyzing stomach contents of hake from the same area Jukić (1975) proved findings of Karlovac (1959) and Županović (1968) that hake not exceeding 16 cm in length fed mainly on Crustacea and larger hake almost exclusively on fish. Food of hake exceeding 16 cm in length contained mainly the following fish species: *Engraulis encrasicolus* (L.), *Cepola rubescens* L., *Sardina pilchardus* (Walb.), *Spicara smaris* (L.), and *Boops boops* (L.); the following Crustacea species: *Stylocheiron* sp., *Penaeus* sp. and *Paramysis helleri* (G. Sars) and the following Cephalopoda species: *Loligo marmorae* Ver. and *Sepiola oweniana* D'Orb. Jardas (1976) studied qualitative-quantitative composition of the food of hake from the open middle Adriatic (Jabuka Pit). This author also found that hake food contained fish, Crustacea and Cephalopoda. Fish constituted 62.8%, Crustacea 35.7% and Cephalopoda 1.6%. Of fish *Trachurus* sp. were best represented (20.4%), of Crustacea *Alpheus glaber* (Olivi) (28.9%)

and of Cephalopoda *Alloteuthis subulata* (Lam.) and *Sepiola* sp. (100%). Fish made up 97.5% of the total weight, Crustacea 2.3% and Cephalopoda 0.4%. Obtained frequency index showed that hake prefered fish (f = 0.74), Crustacea are secondary food (f = 0.38) and Cephalopoda occasional food (f = 0.02).

The analysis of stomach contents of hake from the channels of the middle Adriatic in the 1957—1958 (Županović, 1961c) and from the same stations in August 1960 is presented by months in Table 3.

As shown by Table 3. fish (*Sardina pilchardus* /Walb./, *Sprattus sprattus sprattus* /L./, *Cepola rubescens* L., *Spicara maena flexuosa* Raf., and *Engraulis encrasicolus* /L./) were dominant. This is in broad agreement with the findings of authors who studied hake feeding in the middle Adriatic.

Piccinetti and Piccinetti-Manfrin (1971) also reported fish to dominate the food of the hake from the northern Adriatic (56.3%) at length of 14.0 to 42.5 cm. Best represented fish were *Sprattus sprattus sprattus* (L.), *Engraulis encrasicolus* (L.), *Sardina pilchardus* (Walb.) and *Trachurus* sp. These authors also reported larger quantities of Crustacea in stomachs of smaller size hake. Froglia (1973) also analyzed stomach contensts of hake from the middle Adriatic (Jabuka Pit). A year old fish mainly fed on Crustacea (Euphausiacea, Mysidacea and Amphipoda) and on mesopelagic fish *Maurolicus muelleri* (Gmelin). Larger fish ate other fish species, primarily Clupeiformes, and of Crustacea Decapoda.

Yannopoulos (1976) also reported Crustacea to be the principal food of smaller size hake from the Greek waters.

Hickling (1935) found larger hake from the northern Atlantic to prey on fish and Cephalopoda. Fish, blue whiting (*Micromesistius poutassou* /Risso/), mackerel, smaller hake, horse mackerel and herring assumed dominance as the fish grew larger while smaller hake included Euphausiacea (*Meganyctiphanes norvegica* /M. Sars/).

Larañeta (1970) was of the opinion that small hake, up to 10 cm in length, from the levantine coasts of Spain, fed mainly on pelagic Crustacea; in 11 to 19 cm fish Crustacea constituted 50% of taken food while fish larger than 20 cm fed mainly on fish of which *Sardina pilchardus* (Walb.) and *Engraulis encrasicolus* (L.) dominated in these waters as well. For larger fish small Crustacea items consumption was limited to Macrura Natantia, Decapoda larvae and Euphausiacea.

Maurin (1954) found hake from Moroccan waters to feed mainly on anchovy *(Engraulis encrasicolus* /L./), Crustacea and Cephalopoda.

Domanevski and Patokina (1981) reported for hake from the continental shelf waters of Moroccan Atlantic coast to feed mainly on fish (89.43%), Crustacea (8.07%), Cephalopoda (1.21%), Polychaeta (0.08%) and Echinodermata (0.02%). Of fish *Trachurus trachurus* (L.) (27.36%), *Scomber japonicus* Hout. (21.50%), *Engraulis encrasicolus* (L.) (15.26%) were most frequent, of Crustacea Euphausidae (5.35%) and of Cephalopoda *Alloteuthis subulata* (Lam.) (1.09%).

Table 3. Composition of hake stomach contents in the channel area of the middle Adriatic during 1957/1958.

	Month														
	VI	VII	VIII	IX	X	XI	XII	I	II	III	IV	V	VI	Total	%
Pisces:															
Sardina pilchardus (Walb.)		6	2			36	9	4	9	3		4	19	92	
Sprattus sprattus sprattus (L.)	3	8				10	2	12	10			2		47	
Cepola rubescens L.		3	1		3	7	3	1	1					19	
Spicara maena flexuosa Raf.		2	2								8		4	16	
Lesueurigobius friesii (Malm.)			14											14	
Engraulis encrasicolus (L.)	1				2	2		3	1	1	2	1		13	
Antonogadus megalokynodon (Kolombat.)		1			1	2	3		3				1	11	
Boops boops (L.)						3				3	1		2	9	
Merluccius merluccius (L.)	1					3	2	2						8	
Spicara smaris (L.)		1			2			2						8	
Trisopterus minutus capelanus (Lac.)		2		1					1				3	7	
Aphia minuta (Risso)		4							2				1	7	
Scomber (Scomber) scombrus L.		1		1	2		2							6	
Citharus linguatula L.			1		1			2	1		1			6	
Deltentosteus quadrimaculatus (Val.)						1	1	2						4	
Serranus hepatus (L.)		1				1							2	4	
Gobius sp.						1		1		1				3	
Gobius niger L.						1	1							2	

Diplecogaster sp.						2								2	
Mullus barbatus L.								1					1	2	
Syngnathus sp.			2											2	
Callionymus maculatus Raf.							1							1	
Pagellus erythrinus (L.)							1							1	
Trachinus draco L.		1												1	
Atherina sp.										1				1	
Unidentified fish		7	11				2	14	15	9	11	4	8	81	82.47
C r u s t a c e a:															
Penaeus sp.	1	1	1	1		1	2	6		3				16	
Upogebia litoralis (Risso)							3	1						4	
Alpheus glaber (Olivi)							1	1						2	
Squilla desmaresti Risso													1	1	
Unidentified		1				1		1	1		1	1		6	6.52
C e p h a l o p o d a:															
Sepiola oweniana D'Orb.		3	1				4	3	1				3	15	
Sepia elegans D'Orb.		1			1			3	1				1	7	
Loligo marmore Ver.							2							2	
Undientified					2						1			3	6.07
Rest		4	1					1		7	6	2	1	22	4.94
Total	6	47	39	3	14	71	39	60	46	28	31	14	47	445	100,00

Growth rate

Growth rate of hake shows diversity within the limits of their geographical distribution. In the Mediterranean, after Belloc (1929), hake from the northern African coasts attain mean length of 30.0 cm in 8 years. On the other hand, hake from Spanish waters attain 75.0 cm in 7 years. In the Atlantic, in the vicinity of Ireland, Scotland, the Bay of Biscay and Morocco, hake attain the lengths of 65—67.9 cm; 68 cm, 61—71 cm and 78 cm respectively in 8 years (Figueras, 1964; Inada, 1981).

Females often attain greater lengths than males which grow slower after maturation at age of 3 or 4. Bagenal (1954) held that there was no difference in growth rates between male and female hake up to 3 years of age. Jardas (1976) obtained (in the Jabuka Pit) that inflexion points between different growth phases in allometric relationship of weight and length occurred always at smaller length and weight in males than in females. At the inflection point between adolescent and adult stage this difference was 4 cm in length and 84 g in weight. This is indicative of the fact that in the maturation phase some differences in growth rate occur.

As distinct from the eastern Atlantic, the areas of hake faster and slower growth were observed in the Mediterranean. This is well evident in Fig. 14

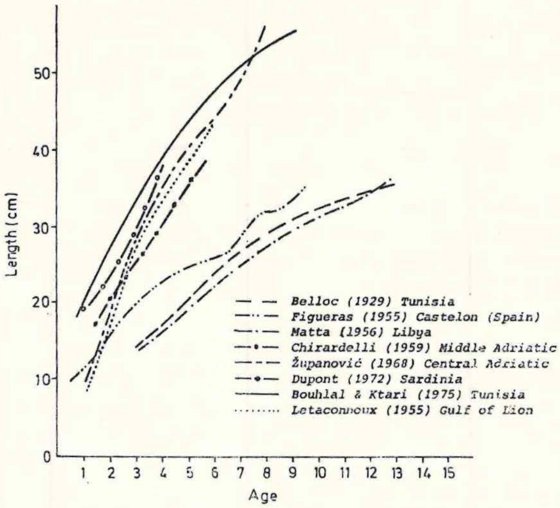


Fig. 14. Graphical presentation of hake growth in the Mediterranean

which presents hake growth rates in the Mediterranean. Belloc (1929) held that the Mediterranean hake belonged to the nain growth (36 cm for individuals of 13 years of age in relation to Atlantic 80 cm) in relation to the Atlantic hake. Matta (1956a and b) also recorded slow growth of hake from Libyan waters which is in agreement with the results of Belloc. Slow hake growth was recorded also by Kutaygil (1965) from the Marmara Sea.

On the other hand, the analyses of hake growth rate in the waters of Tunisia (Bouhlal and Ktari, 1975), for the middle Adriatic (Ghirardelli, 1959; Županović, 1968; Flamigni, 1983), for Sardinia (Dupont, 1972), and the Gulf of Lyon (Letaconnoux, 1955) pointed to a very similar growth trend. Data on hake growth on the levantine coast of Spain (Figueras, 1955, 1965) are indicative of slightly slower growth in relation to the northern Mediterranean.

Obtained values of hake growth rate in the Mediterranean are, to a certain extent, in agreement with the data on vertebral counts in respective areas (Maurin, 1965).

Behaviour

Diurnal changes in the catches of hake

Diurnal and seasonal migrations of hake can affect the catch considerably. Diurnal changes in the number of hake are often followed by corresponding changes in their size composition. Hickling (1933) stated that in catches of hake off Ireland smaller fish showed the greatest diurnal variations in the catch decrease with increase in size of fish.

Variations in size composition have been evident, not only between night and day but also within different periods of day. Woodhead (1964), analysing the trawl catches in the North Sea from dawn to dusk, showed that the average lengths of both whiting and haddock tended to increase during diurnal trawling. The greatest number of small fish was caught in the first haul after sunrise while the largest fish were obtained in the catches at dusk.

Diurnal variations in catch might also be related to the behaviour of hake in response to the gear used. The results of experiments performed in the middle Adriatic during daylight hours in summer, autumn, winter and spring periods were analyzed and the diurnal changes in the catches of hake are shown in Fig. 15 (Županović, 1969).

From the data presented it may be seen that the largest catches were obtained mainly in the first haul after sunrise. The only exception was the catch obtained in the summer period, when the greatest number of mature males and females was caught (Županović, 1968). Changes in physiological conditions probably brought about this variation in the pattern of diurnal apperance of hake in the catches. In other seasons the diurnal changes in the catches do not show essential variations.

In all the seasons there is a gradual decrease in the number of hake caught, as the day progresses. This might be due to the changes in light intensity and the visual reactions of hake to bright daylight. This is in conformity with the results of observations made by Blaxter *et al.* (1964) in tanks and at the sea, that vision is the most important factor determining the behaviour of fish in relation to fishing gear. But the visual capabilities of hake appear to be better expressed in the greater average lengths of hake in these catches which might be associated with the greater transparency of the sea water and the greater capability of smaller fish to escape through the meshes of the net especially its front part. This is probably the reason for the relatively less number of smaller fish in these catches.

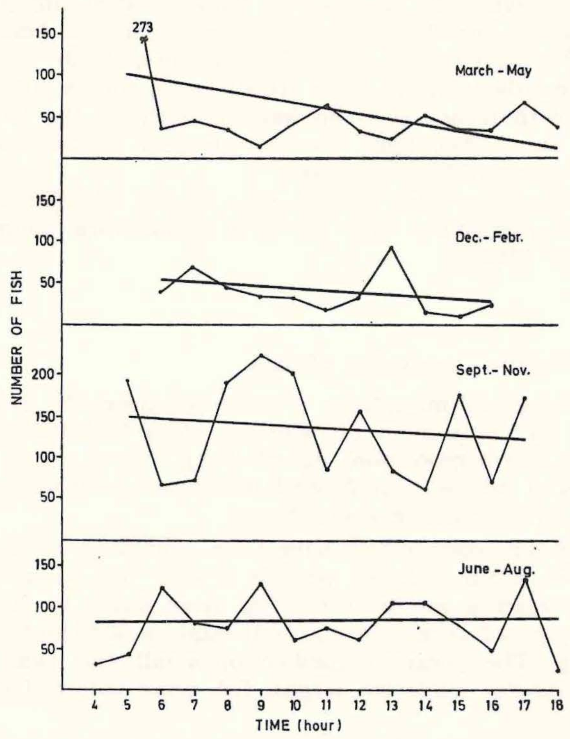


Fig. 15. Diurnal fluctuations in hake catches (from dawn to dusk) for summer, autumn, winter and spring in the middle Adriatic

Ingressions and hake catch

Le Danois (1922, 1938) established the correlation between transgressions of more saline Atlantic water and movements of many demersal fishes along the eastern Atlantic coast. This author believed that there was a correlation between the flow of more saline transgression Atlantic water at the bottom and abiding or migration of a hake population. This may be applicable to the catches of hake in the Adriatic. Salted aspect of the Adriatic caused by ingressions of more saline Mediterranean waters is associated with the temperature increase in the Adriatic as well as with an increase of primary production (Buljan, 1953, 1957; Zore-Armanda, 1963, 1969, 1984). Increased salinity and temperature in the Adriatic in individual years due to ingression probably results in a better survival of larval and postlarval stages, like in sardine, (Županović, 1985). The results are felt a few years later by better commercial catches of hake.

Such a relationship between the catch of small, medium and large hake in the area of Blitvenica and salinity variations at the bottom of the Jabuka Pit and Palagruža Sill in the 1951—1980 period is given in Fig. 16.

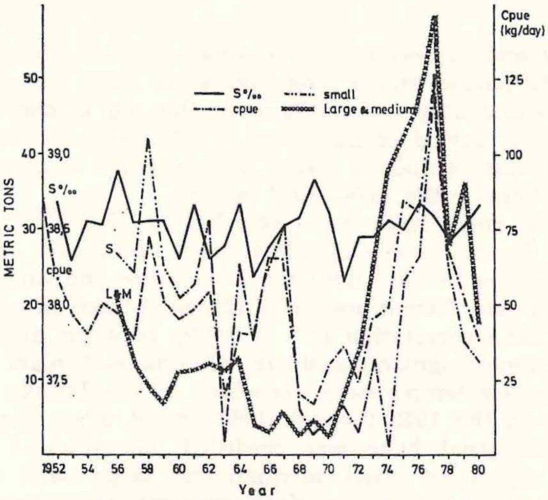


Fig. 16. Relationship between catches of large, medium and small hake in the area of Blitvenica and salinity variations at bottom in the Jabuka Pit and on the Palagruža Sill in the 1951—1980 period

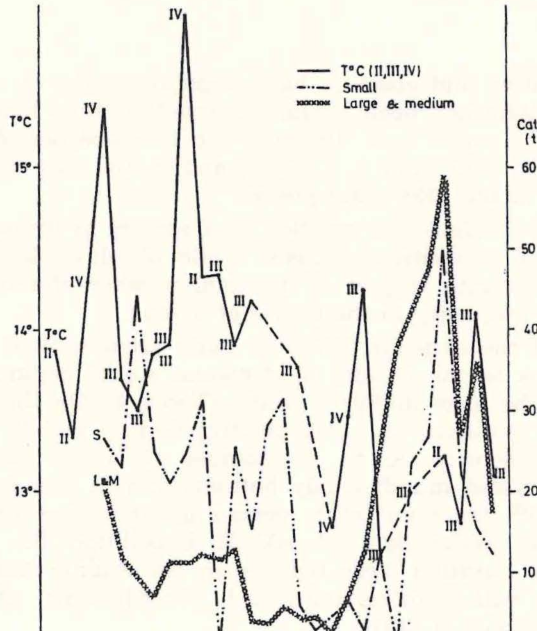


Fig. 17. Relationship between surface temperature variations in February, March and April and catch of small, medium and large hake in the area of Blitvenica in the 1953—1980 period

High salinity and the occurrence of small hake in the area of Blitvenica in the 1958—1967 period and strong ingression from the Mediterranean in 1968—1970 are presumably associated with the big catches of medium and large hake after the period of ingression (1971—1977). At the same time better survival of larval and postlarval stages was reflected as a sudden increase of catch of juvenile hake in the 1974—1977 period.

Fluctuations of small hake were recorded by Hickling (1946) as well in the waters of Seven Stones Lightship. Mass occurrence of small hake this author brought into connexion with the favourable and unfavourable surface sea water temperatures during postlarval stages of hake. Moreover, this author obtained the positive correlation ($r = \pm 0.742$) between high surface temperature at Seven Stones Lightship and hake abundance 5 years later.

Studies of surface temperature variations in the Jabuka Pit in February, March and April in the 1953 through 1980 period when the highest number of larval and postlarval hake was recorded (J. Karlovac, 1965) and observations of catches of small, medium and large hake are indicative of their interrelations (Fig. 17). High surface temperatures in February and March were mainly accompanied by better commercial catches of hake several years later and vice versa.

Population

Density

Values of relative and absolute hake population density within demersal stocks in the Adriatic has been so far observed in the channel area of the middle Adriatic (Županović, 1961c) in the 1957—58 period, open southern Adriatic (Merker and Ninčić, 1973) and in the Bay of Boka Kotorska (Lepetić, 1965) in the 1963—1964 period.

Relative density defines the position of a species by frequency in a stock during the year on a continuity basis, while absolute density defines the position of a species with respect to the total number of recorded specimens irrespective of the frequency in the course of a year.

Comparison of the data for different study areas showed hake to occupy highest positions as to the density in demersal stocks on muddy bottoms in deeper waters of the open middle Adriatic (Table 4). On these bottoms hake occupied 1^{th} to 3^{rd} positions as to the relative density and 1^{th} to 4^{th} positions as to the absolute density. As to the number of individuals hake made up 9.54—66.94%. On mixed muddy-sandy bottoms and in less deep waters hake occupied 5^{th} to 9^{th} positions with percentage presence of individuals of 2.12—5.66%. After earlier data of HVAR Expedition the most abundant catches of an hour duration were realized in the middle Adriatic, that is in the Jabuka Pit as well as more southward (Karlovac, O., 1959; Mužinić and Karlovac, O., 1975).

Hake occupied lower positions in demersal stocks of other study areas. Thus in the channel area of the middle Adriatic they occupied 4^{th} to 14^{th} positions (relative density) and 5^{th}—14^{th} positions (absolute density), with the percentage proportion of individuals of 0.18 to 6.92% (Županović, 1961c). Hake occupied higher positions, as in the middle open Adriatic, on muddy bottoms.

Table 4. Position of hake with respect to relative and absolute density within demersal stocks in the areas of Jabuka Pit and Blitvenica (1956—1967)

Station	Depth (m)	Bottom type*	Relative Position	Relative Points	MNPP**	Absolute Position	Absolute No. of indiv.	%
H-40***	115—181	c.l.	2	77	120	2	1,701	15.49
H-43	210—220	l.	1	68	80	2	1,710	31.34
H-44	199—220	l.	1	139	150	1	8,842	53.66
H-46	216—223	l.	1	87	100	1	1,947	23.68
H-47	186—199	l.c.	2	115	140	1	2,502	27.95
H-48	164—188	c.l.	1	146	160	1	5,507	33.31
H-50	241—256	c.	1	50	50	1	1,306	66.69
H-52	183—188	l.c.	2	95	120	3	1,574	20.04
H-53	166—178	c.	1	128	140	2	3,005	24.93
H-54	146—168	l.c.	3	89	110	3	1,630	17.71
H-56	168—188	c.l.	2	65	80	2	590	14.58
H-57	150—170	l.c.	2	115	140	2	1,643	18.82
H-58	137—180	l.c.	2	117	140	3	2,028	17.10
H-61	146—159	l.	3	78	100	3	820	12.18
H-62	153—170	c.	2	136	170	3	1,351	13.27
H-66	130—135	l.	3	95	140	4	1,039	9.54
H-67	126—137	l.s.	5	111	190	5	1,097	5.66
H-71	117—123	l.s.	5	75	160	5	550	3.48
H-72	97—112	l.c.s.	6	25	60	6	171	2.59
H-76	104—111	c.l.s.	6	42	110	9	293	2.12

* c. = clay, l. = loam, c.l. = clayey-loamy, l.c. = loamy-clayey, l.s. = loamy-sand, l.c.s. = loamy-clayey-sandy, c.l.s. = clayey-loamy-sandy
** Maximum no. of points possible
*** Stations marked with letter H correspond to the stations of HVAR expedition 1948—1949

Merker and Ninčić (1973) established that hake occupied 2^{nd} to 9^{th}(12^{th}) positions (relative density) and 2^{nd} to 11^{th} positions (absolute density) with percentage presence of 1.47 to 9.49% between 100 and 200 m depths in demersal stocks ranging from 10 to 500 m. At greater depths (200—500 m) hake occupied 11^{th} to 19^{th} positions (relative density) and 9^{th} to 20^{th} positions (absolute density) with the percentage presence of 0.27 to 2.10%.

Hake showed lowest densities in the bay of Boka Kotorska occupying 10^{th} to 15^{th} positions (relative density) and 10^{th} to 18^{th} positions (absolute density), with percentage presence of 0.24—0.77% (Lepetić, 1965).

These data clearly show that positions of hake in stocks with respect to density and percentage presence are more clearly marked in the open middle Adriatic than in other study areas as well as on muddy bottoms than on other ones (muddy-sandy and sandy bottoms) as well as at depths of about 200 m. These data are also indicative of optimum ecological factors relevant to hake distribution.

Sex ratio

Sexual dimorphism of hake is given in Fig. 18. Male/female hake ratio showed males from the channel area of the middle Adriatic to be more abundant at smaller lengths, and females at greater lengths. Maximum male length was 37 cm and that of female 55 cm.

Age composition

Hake from the middle Adriatic was aged using otoliths. Standard otolith types showed clearly distinct hyaline zones from the opaque zones. Fig. 19. shows several specimens of standard otolith types in hake caught from the Jabuka Pit in October 1963 and July 1965. Given otoliths are from 0 to third age group.

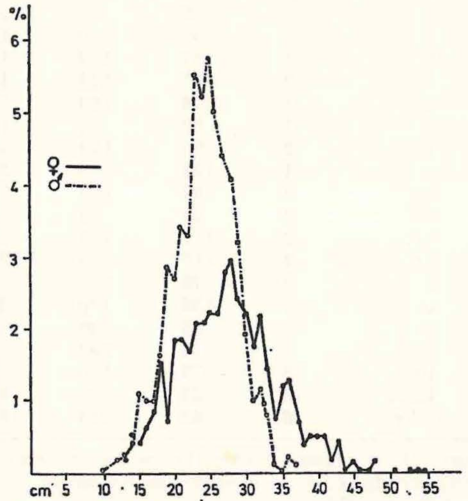


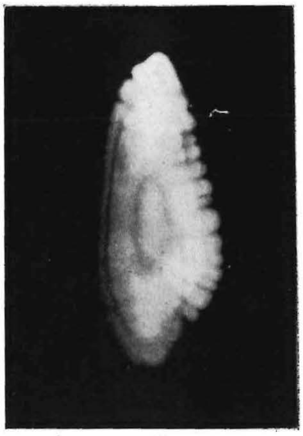
Fig. 18. Length frequencies of male and female hake in the channel area of the middle Adriatic in 1957/1958

Central zone or nucleus consisted of opaque substance in a majority of otoliths. Other opaque zone appeared on several occasions as double or multiple structure, consisting of two or more thin tapes separated from one another by that thin hyaline tapes. Those »false rings« in summer period between age 2 and 3 are presented in Fig. 19.7. They may be due to some sudden changes of environmental factors or to some physiological changes (spawning) during a normal year. »False rings«, consisting of several unfinished and closely arranged sclerites may also be the result of some changes in the way of life of juvenile fish. Two this type otoliths of 0 age group of hake are given in Fig. 19 (8a and b). Narrow concentric and unfinished annuli round

Fig 19. 1. Otolith of the hake L = 10.0 cm, group I, October 23, 1963
2. Otolith of the hake L = 10.9 cm, group I, October 23, 1963
3. Otolith of the hake L = 13.6 cm, group II, October 23, 1963
4. Otolith of the hake L = 15.2 cm, group II, October 22, 1963
5. Otolith of the hake L = 27.4 cm, group II, June 26, 1965
6. Otolith of the hake L = 30.0 cm, group III, June 26, 1965
7. Otolith of the hake L = 31.8 cm, gropu III, October 4, 1965
8. a) Otolith of the hake L = 6.7 cm, group 0, October 23, 1963
b) Otolith of the hake L = 7.7 cm, group 0, October 26, 1963


1


2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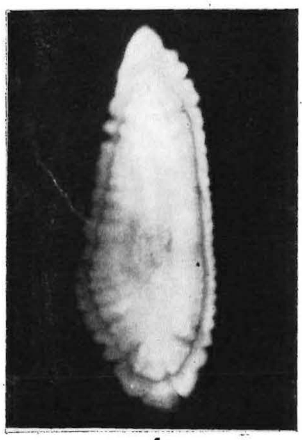
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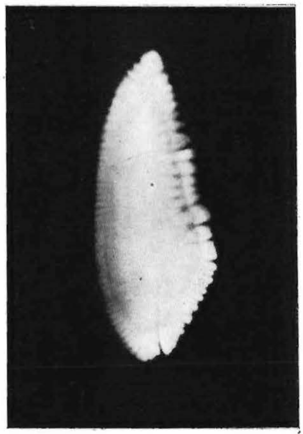
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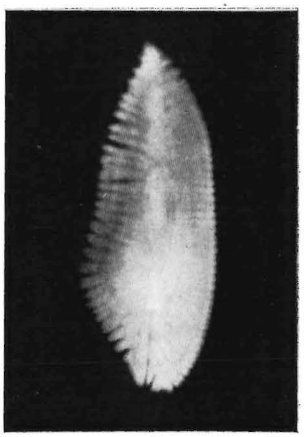
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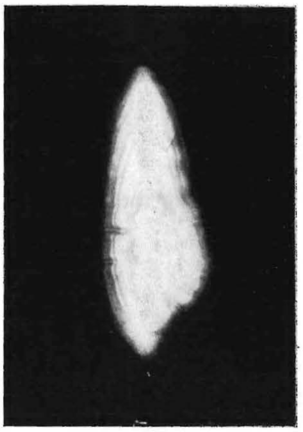
7


8a


8b

nucleus in the summer period are probably indicative of habitat changes, that is from pelagic to demersal way of life, associated with the changes in food habits. This phenomenon is rather frequent in up to 6 months old hake from the Jabuka Pit in summer-autumn period. In some otoliths the first opaque zone was much wider than normal, its center consisting of an indistinct mass of hyaline and opaque zone. No clear opaque zone could be distinguished in the central part in this case. One possible explanation may be very marked indentation of otoliths during the first year of age of hake. The first opaque zone, consequently, appears much wider than in normal otoliths.

Percentage age composition of hake from the middle Adriatic (1963—1966) is shown in Fig. 20. A total of 1487 specimens was analyzed. The maximum age recorded was 9 years.

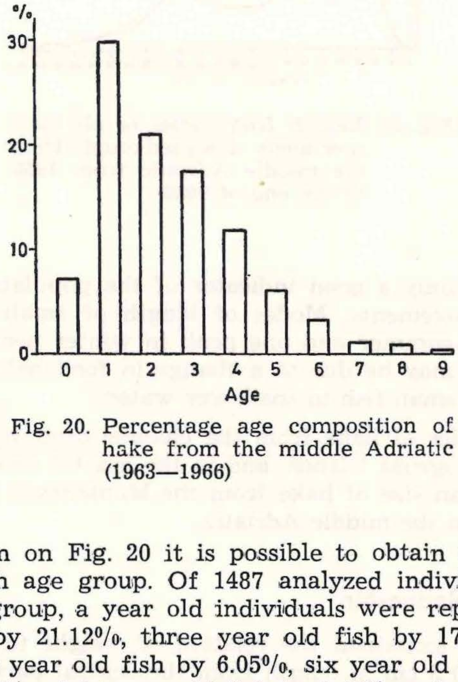


Fig. 20. Percentage age composition of hake from the middle Adriatic (1963—1966)

From hystogram on Fig. 20 it is possible to obtain the number of hake individuals per each age group. Of 1487 analyzed individuals 7.26% of fish belonged to 0 age group, a year old individuals were represented by 29.46%, two year old fish by 21.12%, three year old fish by 17.55%, four year old fish by 13.85%, five year old fish by 6.05%, six year old fish by 3.23%, seven year old fish by 1.01%, eight year old fish by 0.40% and nine year old fish by 0.07%.

Total length frequency distribution of all the analyzed hake individuals is given in Fig. 21. Polymodal curve is indicative of the fact that different age groups were differently represented in the population. Juvenile hake dominated in catches.

Length frequency distributions

Length frequencies of hake from the Jabuka Pit were analyzed by months and years at depths of 150—200 m (Fig. 6). Shift of modal lengths in different

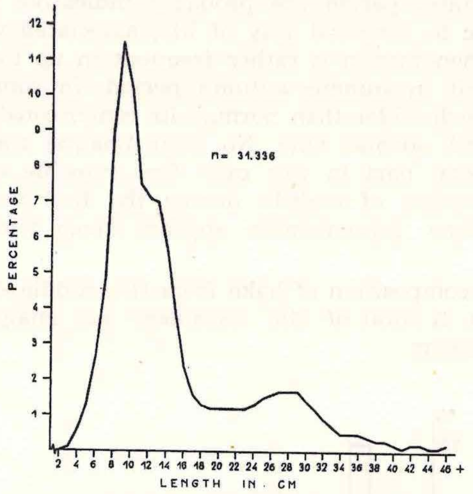


Fig. 21. Length frequencies of all hake specimens analyzed caught from the middle Adriatic from 1956 to the end of 1966

months may be not only a good indicator of the population growth but also of juvenile hake movements. Modes of length of small hake show mainly two peaks in spring-summer and one peak in winter period. This absence of second winter mode may be due to a change in food habits of small hake or reflect movement of small fish to shallower waters.

Length frequencies of hake from the channel area, open middle Adriatic, between Vis and Palagruža islands, and in the coastal area of Montenegro are given in Fig. 22. Mean size of hake from the Montenegro coastal area exceeds that of the hake from the middle Adriatic.

Weight-length relationship

Jardas (1976) examined the relation of weight to length in 295 hake specimens of 15 to 51.5 cm in length from the central part of the open Adriatic. Author obtained three distinct growth phases in both sexes. These phases last slightly different in males and females. The first (juvenile) phase lasts in males until they reach 18 cm, the second (adolescent) phase extends from 18 to 26.5 cm and third (adult) beyond the limits of adolescent phase.

In females the second phase extends up to the mean length of 30.5 cm and third in fish exceeding this length.

Negative allometry was obtained in juvenile males ($n = 2.625$) and positive allometry for other two phaces ($n = 3.235$ and $n = 3.161$). In adolescent females the relation of weight to length is almost ideal ($n = 3.033$) while negative allometry was obtained in adult females ($n = 2.862$).

Matta (1956b) obtained a constant relationship for both female and male hake exceeding 16 cm in length ($n = 3.01$ for females and $n = 2.80$ for males). The inflexion point was at about 32 cm for females and about 29 cm for males. The inflexion point in the Adriatic hake is after Jardas (1976) at slightly smaller lengths.

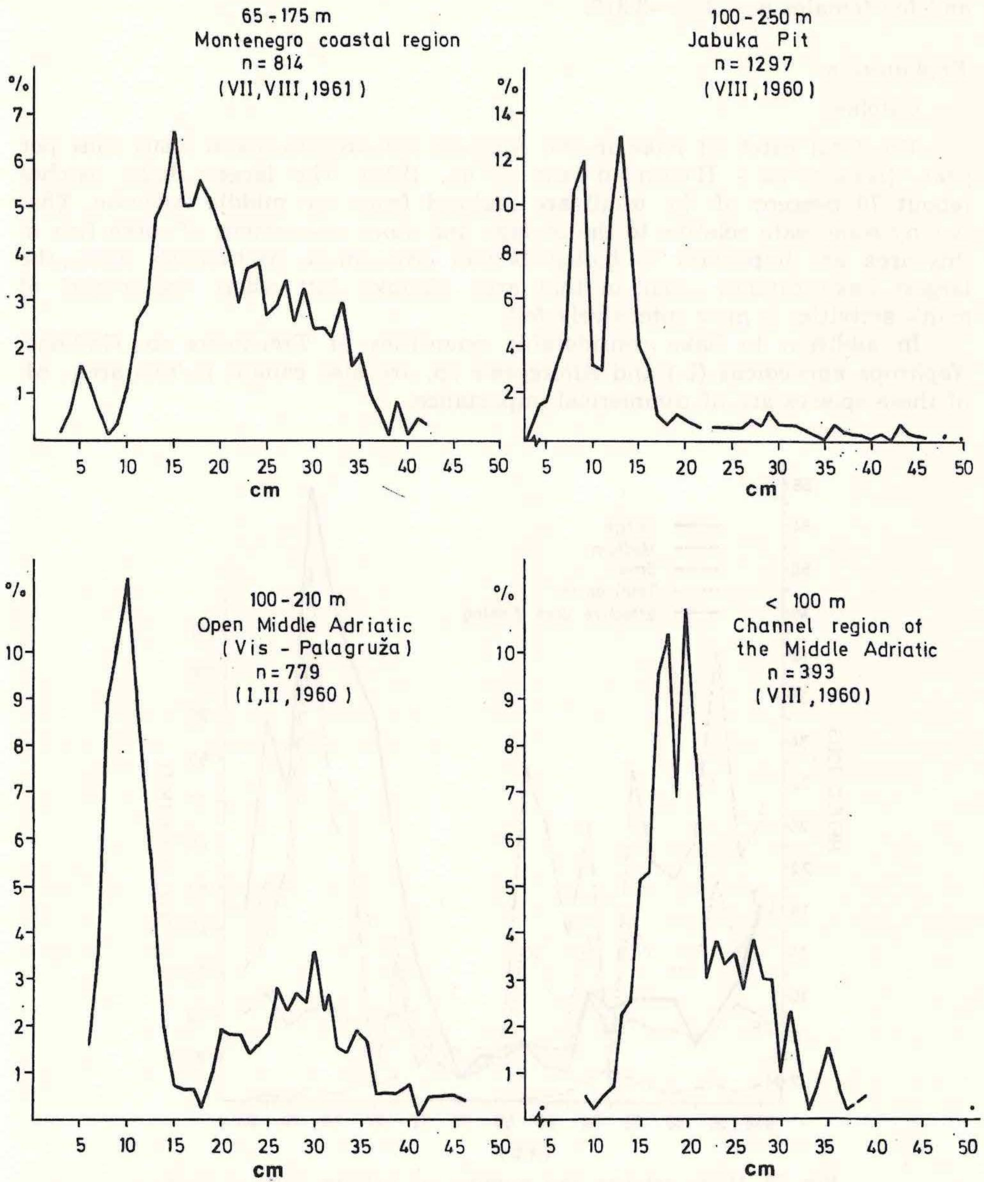


Fig. 22. Length frequencies of hake from the Jabuka Pit, channel area of the middle Adriatic, open middle Adriatic and Montenegro coastal area in 1960 and 1961

Yaunopoulos (1976) reported a constant relationship ($n = 3.153$, $r = 0.89$) for hake from Greek waters, on the basis of measurements of 504 individuals of 10 to 53 cm in length.

Flamigni (1983) obtained for male hake from the northern and middle Adriatic from May and November 1982 the following values: $n = 3.16—3.35$, and for females $n = 3.26—3.317$.

Exploitation

Catches

The total catch of hake in the Adriatic amounts to about 2,600 tons per year (Alegría - Hernández *et al.*, 1982). The largest hake catches (about 70 percent of the total) are realized from the middle Adriatic. That is why some data relative to the biology and stock assessment of these fish in this area are important to biologists and economists, particularly since the largest hake catches occur in that area (Jabuka Pit) where the impact of man's activities is most intensively felt.

In addition to hake considerable quantities of *Trachurus* sp. Gadidae, *Nephrops norvegicus* (L.) and *Alloteuthis* sp. are also caught in this area. All of these species are of commercial importance.

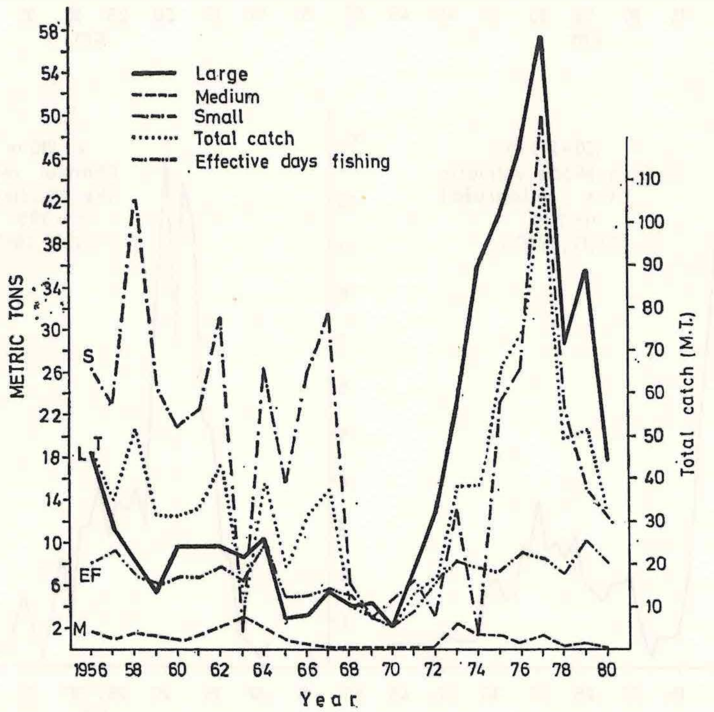


Fig. 23. Hake catches and number of fishing days of commerial trawlers in the Blitvenica trawling area from 1956 to 1980

Hake catch by Yugoslav trawlers in the area of Blitvenica (in the Jabuka Pit) in the 1956—1980 period is given in Fig. 23. Data on the number of effective fishing days by individual years are also given in Fig. 23.

An analysis of hake catch variations in the area of Blitvenica in the 1956—1980 period shows the total catch as well as the catch of medium and large fish to decrease up to 1970 with a sudden catch increase thereafter up to 1977. As distinct from medium and large hake small hake behaved quite differently in the same area. A considerably increased catch of small hake in 1958 and 1977 is presumably the consequence of ingression of more saline and richer Mediterranean water into the Adriatic, which also affects temperature increase. These fluctuations of small hake in the area of Blitvenica are not a regular phenomenon repeating from one year to another, they are subject to the fluctuations of »weather regime« (Županović, 1968).

Variations in hake catch in the Blitvenica fishing ground are similar to those for the entire Adriatic (Alegría-Hernández *et al.*, 1982).

Levi and Gianetti (1972) established, on the basis of an analysis of the relationship between the total hake catch and catch per unit effort for the 1958—1969 period, that hake stock was overexploited in the areas where Italian fishermen operated and that reglementation of fishing effort was necessary. Similar trend was reported for the Blitvenica area for the same period (Alegría-Hernández *et al.*, 1982).

Fishing intensity and fish stock

On the basis of cohort analysis Županović (1968) estimated coefficient of total mortality of hake from the middle Adriatic for the 1963—1966 period to be Z = 0.79.

This was proved by later analyses. Index of variations of hake abundance in the 1970—1979 period showed total mortality coefficient to be the same (Z = 0.79). Similar values were obtained by the experiments of the codend selectivity in bottom trawls (Z = 0.77). On the basis of obtained values Alegría-Hernández *et al.* (1982) came to the conclusion that the level of hake exploitation in the middle Adriatic had remained more or less the same for the last 20 years.

The mentioned studies deal with the relationship between fishing intensity in the Adriatic bottom trawl fishing and hake stock size. From such relationship an attempt was made to assess the maximum sustainable yield (MSY) of the population with corresponding optimum fishing effort (f. opt.).

On the basis of obtained parameters of hake exploitation in the Adriatic, Alegría-Hernández *et al.* (1982) calculated maximum sustainable yield to vary between 2,819 tons/year (exponential model) and 3,373 tons/year (linear model) with optimum fishing effort between 54,349 (exponential model) and 62,638 (linear model) fishing days per year.

The first standing stock assessments of the hake in the Adriatic with respect to the exploitation intensity were given by Jukić and Piccinetti (1979). Applying »trawt-survey methodology« after Alverson and Pereyra (1969) they assessed that hake standing stock in the Adriatic ranges between 3,657 and 7,383 tons (after Alegría-Hernández *et al.*, 1982).

The technique used to determine the standing stock for demersal fish and the limitations of such estimates have been discussed by Alverson *et al.* (1964). The method is based on the assumption that catch per unit effort is a function of stock density within the area being surveyed and that changes in catch per unit effort are directly proportional to the changes in density (Ricker, 1940; Gulland, 1964; Alverson, 1971).

In these calculations of the standing stock of commercial catch the coefficient of vulnerability (q) is equal to 1.0 (Alverson, 1971).

It is unlikely that the coefficent of vulnerability ever reaches this value ($q = 1.0$) since authors believe (Kreuzer, 1964) that a trawl captures and retains different percentage of the fish in its path, varying from the species to species. Although there was a marked increase in efficiency with speed (Schärfe, 1961) and a considerable difference between day and night it was determined that a minimum efficiency of trawl varied from 19 to 35 percent (Jones, 1962; Dickson, 1975; Robertson, 1977).

Therefore, an estimate of the effective pathwidth of a trawl — using hake data from the Blitvenica area — should indicate a degree of efficiency based on »catchability« figures from which an assessment of the trawl efficiency could be deduced.

An estimate of the effective pathwidth of a trawl from the Blitvenica area — using hake data.

The method used follows that devised by Jones (1962) relating the fishing mortality F (in the equation $Z = M + F$) to the percentage of each square mile that is effectively swept in one year. Details of the method are given as an appendix to a review of bottom trawl efficiency (Dickson, 1974, 1975).

The method is more easily understood if turned around so that the efficiency of the trawl in taking a certain percentage of the fish within its measured otter board spread is known and the percentage of each sqare mile (on the average) that is swept each year is known, then fishing mortality (F) can be calculated. On the contrary an independent estimate of (M) should make possible an estimate of trawl gear efficiency.

Using hake data from the Blitvenica area (Table 5) a regression analysis of this table gives:

intercept a = 0.408 = estimate of natural mortality M
slope b = $6.5 \times 10^{-4} = F/AH$,
where F = fishing mortality at a given rate of exploitation
A = area of statistical squares (Blitvenica) in which hake abound say between 150 and 210 m depth or 55 square nautical miles
H = hours fishing per square mile per year

Since the data refer to no more than few years the 95% confidence limits for the slope are wide and the following estimates are no more than indicative

$$b = 6.5 \times 10^{-4} \pm 4.6 \times 10^{-6}$$

Table 5. Estimated values of the total mortality coefficient (Z), fishing effort (f) and fishing mortality coefficient (M) of the hake population in the open middle Adriatic (Blitvenica) for period 1970—1979 (after Alegría — Hernández *et al.*, 1982)

Year	f	Z	F
70/71	251	0,597	0,163
71/72	356	0,777	0,231
72/73	653	0,765	0,424
73/74	594	0,954	0,386
74/75	518	0,412	0,337
75/76	705	1,137	0,458
76/77	641	0,566	0,417
77/78	866	0,943	0,563
78/79	706	0,956	0,459
Average	588	0,790	0,382
	q = 0,0006498		M = 0,408

Proportion of each square mile that is effectively swept in each year, following Jones (1962), $= \frac{H\,W\,V}{1852}$

where W = effective width of gear, i. e. that pathwidth that would capture 100% of fish occurring within it

V = trawling speed in knots

1852 = No. of m. in one Nm

also proportion of each square mile that is effectively swept clean in a short interval of time $\delta t = \frac{H\,W\,V}{1852}\,\frac{\delta t}{T}$

where T = one year

Furthermore by the usual definition of F the proportion of each square mile that is effectively swepth clean in a short interval of time $\delta t = F\,\frac{\delta t}{T}$

$$\text{therefore } F\,\frac{\delta t}{T} = \frac{H\,W\,V}{1852}\,\frac{\delta t}{T}$$

$$\text{or } bAH = \frac{H\,W\,V}{1852}$$

$$W = \frac{bA \times 1852}{V}$$

in this case where the trawling speed of »Jadran« trawlers may be taken 3.5 knots, the effective pathwidth of trawl

$$W = \frac{6.5 \times 10^{-4} \times 55 \times 1852}{3.5} = 18.9 \text{ m}$$

To find the efficiency of a trawl its actual patwidth ($2y_b$) between the otter boards has to be known. Then trawl gear efficiency

$$f = \frac{W}{2y_b} \text{ (Fig. 24).}$$

Yugoslav and Italian bottom trawl gears are known to be similar in this area (Jabuka Pit) and the following typical operating dimensions for a Yugoslav bottom trawl on the Blitvenica ground was taken from Schärfe (1961).

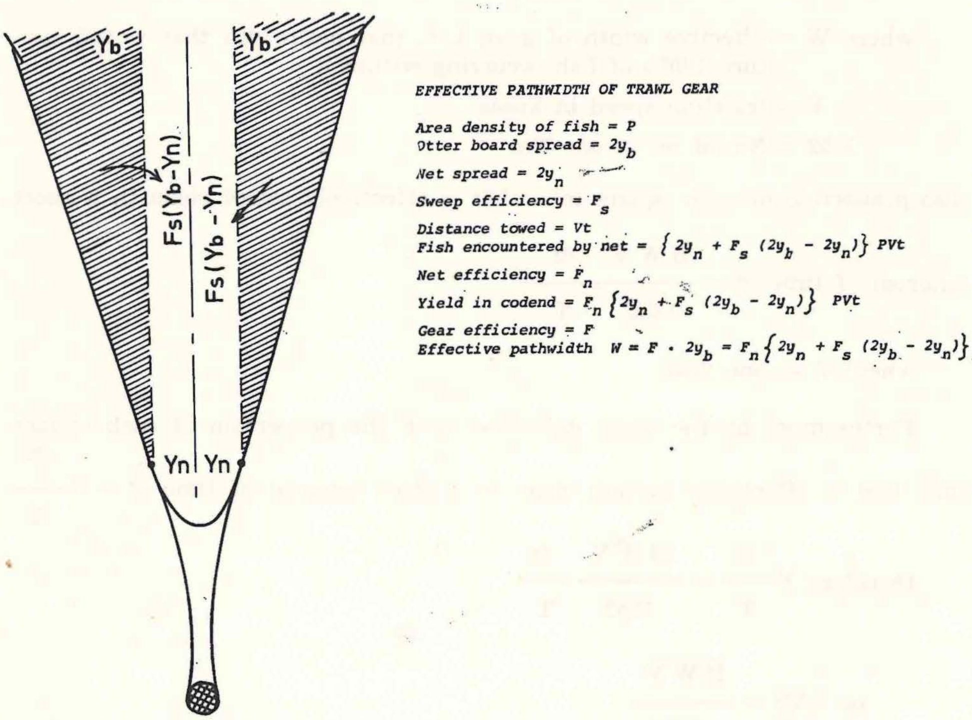


Fig. 24. Effective pathwidth of trawl gear

The length of »sweeplines« means here all the wire between otter boards and wing tips. The spread between the otter boards was calculated from divergence and length of the warps. The net spread is $2y_n$ here taken as the mean of headline and groundrope spread. The distance between the wing tips was derived from this spread and the lenght of the sweeplines.

	$2y_b$	$2y_n$	$(2y_b - 2y_n)$ (Fig. 24)
sweeps etc.			
120	56 m	14 m	42 m

$$\text{Thus gear efficiency } f = \frac{18.9}{56.0} = 0.34$$

An overall gear efficiency of 34% could mean, either that if all fish are below headline height, 34% of those between the otter boards will be captured.

In bottom trawling for hake the vertical density profile may be expected to be most dense close to the bottom, but nevertheless bottom trawling is often conducted where and when hake are passing over the headline (Dickson, 1975).

The figure 34% efficiency means that on the average 34% of hake between the otter boards and in the entire water column are captured. This does not mean that fishing at random, 34% of hake in the water on the Blitvenica ground will be caught. The figure is based on commercial fishing data and bottom trawling is or should be concentrated on situations where and when the vertical density profile of hake is closely associated with bottom.

The obtained results indicate a degree of gear efficiency based on »catchability« figures from which an assessment of the trawl efficiency could be deduced. Therefore, if an overall gear efficiency of 34% could be taken for the hake catch in the Adriatic than the estimates of Jukić and Piccinetti (1978) were higher than the true values.

CONCLUSIONS

A study of biology and population dynamics of hake, *Merluccius merluccius* (L.), in the Adriatic has shown the following:

1. Hake are distributed almost throughout the Adriatic Sea inhabiting mainly the areas between 10 and 800, predominantly from 100 to 200 (or slightly more) metres, with marked preference to muddy bottoms even though were captured also from other bottom types.

2. Morphometric and meristic properties proved the existence of a single hake population.

3. Male hake mature at length of 20 to 28 cm and female hake at lenght between 23 and 33 cm.

4. Hake spawn in summer and winter. The earliest spawning begins in deeper waters in winter and as spawning season progresses hake spawn in more and more shallow waters (spring-summer period).

5. The occurrence of juvenile hake (7—15 cm) in the Jabuka Pit in spring and autumn is probably associated with the long spawning season.

6. Adolescent hake from the middle Adriatic mainly reside in more shallow channel waters until maturation.

7. Adult individuals showed a periods of onshore movements and vice versa. These local movements of adults the authors attempted to associate with spawning and feeding.

8. Hake food habits change with age. Juvenile hake up to 16 cm mainly feed on Crustacea (Euphausiacea) while adolescent and adult hake prey mainly on fish *(Sardina pilchardus, Sprattus sprattus sprattus* and *Engraulis encrasicolus).*

9. Hake growth in the Adriatic is analogous to the hake growth in the northern Mediterranean and Tunisian waters. Authors tried to account for this similarity by the occurrence of divergence.

10. Diurnal variations in hake catches showed better catches in early morning hours and a tendency of decrease with the increase of daylight. The exception are the summer catches when biggest catches of mature individuals were realized in the same area.

11. Ratio of females to males in the channel area of the middle Adriatic, showed the prevalence of males at smaller lengths and that of females at greater lenghts.

12. Studying of age composition of hake from the Jabuka Pit, using otoliths, showed highest presence of age groups 1 and 2.

13. The analysis of length frequencies in the middle and southern Adriatic showed two peaks in spring-summer and one peak in winter in the hake from the middle Adriatic. The authors tried to account for the second winter mode absence by the metamorphosis in feeding of juvenile hake and their movements from the Jabuka Pit to the shallower channel waters. Mean lengths of hake from the Montenegro coastal area exceeded those of hake from the middle Adriatic.

14. Weight-length relationship is indicative of three distinct growth phases of hake from the Jabuka Pit. The inflexion point occurs at about 32 cm in females and about 29 cm in males (J a r d a s, 1976).

15. Hake catch has increased for the last decade (1970—1980). For a better assessment of hake stock in the Adriatic and potential exploitation the authors tried to calculate the coefficient of efficiency of bottom trawl in the Blivenica fishing ground. Obtained fishing coefficient (q) is 34%. Authors hold that the assessed standing stock of hake in the Adriatic is considerably in excess of its actual value. Obtained results are still preliminary.

REFERENCES

Alegría Hernández, V., B. Granić and S. Jukić. 1982. The protection of the hake (*Merluccius merluccius L.*) in the Adriatic sea by regulation of the level of exploitation. Acta Adriat., 23 (1/2): 431—440.

Allain, Ch. 1960. Topographie dynamique et courante généraux dans le bassin occidental de la Méditerranée (Golfe du Lion, Mer catalane, Mer d'Alboran, secteur à l'Est de la Corse). Rev. Trav. Inst. Pêches marit., 24 (1): 121—145.

Allain, Ch., M. L. Furnestin et C. Maurin. 1965. Schema pour l'étude d'un element océanographie important dans le sud Méditerranean »le courant atlantique«. UNESCO/AVS. 9/23 A. 56 pp. (mimeo).

Alverson, D. L. 1971 (ed.). Manual of methods for fisheries resource survey. FAO Fish. Tech. Pap., 102: 80 pp.

Alverson, D. L., T. Pruter and L. L. Ronholt. 1964. A study of demersal fishes and fisheries of the northeastern Pacific Ocean. Vancouver, 190 pp.

Alverson D. L. and W. Pereyra. 1969. Demersal fish explorations in the northeastern Pacific Ocean, an evaluation of exploratory fishing methods and analytical approaches to stock size and yield forecasts. J. Fish. Res. Board Can., 26: 1985—2001.

Anon., 1960. Dubinski ribolov. (prir. B. Stulli). Prinosi proučavanju ekonomike ribarstva i ribarskog prava, 3. JAZU. Zagreb, 152 pp.

Bagenal, T. B. 1954. The growth rate of the hake, *Merluccius merluccius* (L.), in the Clyde and other Scottish Sea areas. J. Mar. Biol. Ass. U. K., 33 (1): 69—95.

Bas, C. 1964. Aspectos del crecimiento relativo en peces del Mediterráneo occidental. Inv. Pesq., 27: 13—119.

Bello, G., G. Marano, E. Rizzi, S. Jukić and C. Piccnetti. 1986. Preliminary survey on the Adriatic hake, *Merluccius merluccius* (L.), within the Demersal Resources Assessment Programme, Spring 1985 survey. FAO Fish. Rep., (345): 200—204.

Belloc, G. 1929. Etude monographique du Merlu (*Merluccius merluccius* L.). Trav. Off. Pêches Marit., 2: 153—231.

Belloc, G. 1935. Poissons de chalut. III. Etude monographique du merlu (*Merluccius merluccius* L.) Rev. Trav. Off. Pêches Marit., 8 (2): 145—202.

Belloc, G. 1937. Note sur la présence du merlu dans les eaux de la presqu'ile du Cap Vert. Rev. Trav. Off. Pêches Marit, 10 (3): 341—346.

Blaxter, J. H. S., B. B. Parrish and W. Dickson. 1964. The importance of vision in the reaction of fish to driftnets and trawls. In: Modern fishing gear of the world, 2, Fishing News (Books), pp., 529—536.

Bouhlal, M. et M. H. Ktari. 1975. Croissance du merlu de la région du Golfe de Tunis. Bull. Inst. Natl. Sci. Tech. Oceanogr. Pêche, 4 (1): 5—47.

Buljan, M. 1953. Fluctuations of salinity in the Adriatic. Izv. Rep. Rib.-biol. Eksp. »Hvar«, 2 (1): 1—64.

Buljan, M. 1957. Fluctuations of temperature in the waters of the open Adriatic. Acta Adriat., 8 (7): 1—26.

Buljan, M. 1974. Osnovne karakteristike Jadrana kao produkcionog bazena. Acta Adriat., 16 (2): 31—62.

Castro, J. de 1955. La merluza, el bacalao y especies afines. Pub. Inst. Esp. Ocean. Ser. Inf.: 1—45.

Crnković, D. 1959. Contribution to the study of economically valuable benthonic species of the channels of the northeastern Adriatic. Proc. gen. Fish. Coun. Medit., 5: 355—363.

Crnković, D. 1970. Prilog biološkoj i ekonomskoj problematici koćarenja u kanalskom području sjeveroistočnog Jadrana. Thalassia Jugosl., 6: 1—90.

D'Ancona, U. 1926. Dell'influenza della stasi pechereccia del periodo 1914—18 sul patrimonio ittico dell'Alto Adriatico. Memoria 126: 95 pp.

D'Ancona, U. 1949—50. Rilievi statistici sulla pesca nell'Alto Adriatico. Atti Inst. Ven. Sci. Lett. Arti, 108: 41—53.

Dickson, W. 1974. A review of the efficiency of bottom trawls. Fiskeriteknologisk Forsknjinungsinstitut 5011. Bergen Nordness.

Dickson, W. 1975. Estimate of the effective Pathwith of a Trawl-using hake data from the ICSEAF Area: 4 pp. (MS).

Domanovsky, L. et Patokina. 1981. Nutrition de *Merluccius merluccius* sur le plateau continental atlantique des ressources halieutiques dans la région du COPACE. COPACE/TECH (81), 31: 5—11.

Dupont, E. 1972. La valeur de la méthode otolithometrique pour la détermination de l'age du merlu (*Merluccius merluccius*, Pisces, Gadidae) en Méditerranée. Bull. Inst. r. Sci. nat. Belg., 48 (1): 1—15 p.

Figueras, A. 1955. Datos sobre la edad y crecimiento de la pescadilla (*Merluccius merluccius* L.) de Levante (sector Castellón) determinados por medio de los otolitos. Inv. Pesq., 1: 73—86.

Figueras, A. 1964. Edad y crecimiento de la merluza (*Merluccius merluccius* L.) del noroeste del Mediterráneo español. Inv. Pesq., 28: 81—96.

Figueras, A. 1965. Age et croissance du Merlu (*Merluccius merluccius* L.) de la Méditerrannée occidentale (Costa Brava, North-Est de l'Espagne). Proc. gen. Fish. Coun. Medit., 8: 161—171.

Flamigni, C. 1983. Preliminary utilization of trawl survey data for hake (*Merluccius merluccius* L.) population dynamics in the Adriatic Sea. FAO Fisheries Report, 290: 109—115.

Froglia, C. 1973. Osservazioni sull'alimentazione del merluzzo (*Merluccius merluccius* L.) del medio Adriatico. Atti V Cong. Naz. Soc. It. Biol. Mar.,: 327—341.

Froglia, C. and M. E. Gramitto. 1986. Diurnal changes in fishery resources by bottom trawl in the Adriatic Sea. FAO Fish. Rep., (345): 111—118.

Furnestin, J. 1960. Hydrologie de la Méditerranée occidentale (Golfe du Lion, Mer catalane, Mer d'Alboran, Corse orientale, 14 Juin — 20 Juillet 1957. Rev. Trav. Inst. Marit., 24 (1): 5—119.

Furnestin, J. et Ch. Allain. 1962. L'hydrologie algérienne en hiver (campagne du »Président-Théodore. Tissier«, Février 1960). Rev. Trav. Inst. Pêches marit., 26 (3): 277—308.

Gast, R. 1918. Weniges über die Motorenfischerei bei Fiume. Wien, Son. Oest. Fish. Zeit., 15: 5—10.

Gast, R. 1925. Über Fischerei-Probleme in der Adria. Glasnik Hrvatskog Prirodoslovnog društva. God. 36, 1—2: 87—98.

Ghirardelli, E. 1959. Contribution à la connaissance de la biologie du merlu (*Merluccius merluccius* L.) en moyenne Adriatique. Proc. gen. Fish. Coun. Medit., 3: 489—494.

Giovanardi, O., M. Rizzoli and S. Jukić, 1985. Preliminary considerations on the fishery management of the hake (*Merluccius merluccius* L.) stock in the Adriatic Sea. FAO Fish. Rep., (345): 71—77.

Graham, M. (ed.) 1956. Sea Fisheries, their investigation in the United Kingdom. Ed. Arnold (Publ.) Ltd. London, 487 pp.

Granić, B., P. V. Alegrí a-Heranández and S. Jukić. 1980. The assessment of the state and maximum bioeconomic sustainable yield of pelagic and demersal resources in the central Adriatic. Acta Adriat., 21 (2): 227—236.

Granić, B. and S. Jukić. 1982. Protection of demersal resources of the Adriatic Sea, with references to hake (*Merluccius merluccius* L.) population, by means of cod-end mesh size regulation. Ichthyologia, 14 (1): 1—11.

Grinols, R. B. and M. F. Tillman, 1970. Importance of the worldwide hake, *Merluccius*, resource. Circ. Fish. Wild., Ser. Wsh., 332: 1—21.

Gulland, J. A. 1964. Catch per unit effort as a measure of abundance. Rapp. Proc. — v. Réun. Cons. perm. int. Explor. Mer, 155: 8—14.

Hart, T. J. 1948. The distribution and biology of hake. Biol. Rev. Cambridge Phil. Soc., 23 (1): 62—80.

Hickling, C. F. 1927. The natural history of the hake. Part I. Periodic changes in the fishery, and II. Food an feeding habits of the hake. U. K. Min. Fish. Agr. Food Fish. Inv., Ser. 2, 10 (2): 100 pp.

Hickling, C. F. 1933. The natural history of the hake. Part IV. Age-determination and the growth-rate. U. K. Min. Fish. Agr. Food Fish. Inv. Ser., 2, 13 (2): 120 pp.

Hickling, C. F. 1935. The hake and the hake fishery. Buckland Lect. for 1934. Ed. Arnold, London, 142 pp.

Hickling, C. F. 1946. The recovery of a deep sea fishery. Fish. Invest. Lond. (2), 17 (1): 59 pp.

Inada, T. 1981. Studies on the Merluciid Fishes. Bull. Far. Seas Fish. Res. Lab., 18: 1—172.

Jardas, I. 1976. Contribution to the knowledge of the biology of hake in the Adriatic Sea. Rev. Trav. Inst. Pêches marit., 40 (3 et 4): 615—618.

Jones, R. 1962. An estimate of the effective pathwith of a trawl. (In Dickson, 1974, 1975).

Jukić, S. 1972. Ishrana oslića (*Merluccius merluccius*), bukve (*Boops boops*), trlje (*Mullus barbatus*) i arbuna (*Pagellus erythrinus*) u Kaštelanskom zaljevu. Acta Adriat., 14 (4): 40 pp.

Jukić, S. 1975. Koćarska područja u srednjem Jadranu. Acta Adriat., 17 (1) 86 pp.

Jukić, S i D. Crnković. 1974. Stanje naselja pridnenih jestivih vrsta u Jadranu. Acta Adriat., 16 (8): 137—156.

Jukić, S. and C. Piccinetti. 1979. Standing stock estimation and yield per exploitable biomass (YEB) forecast of the Adriatic demersal resources. Inv. Pesq., 43: 273—282.

Jukić, S. and C. Piccinetti. 1981. Quantitative and qualitative characteristics of demersal resources in the Adriatic Sea with some population dynamicis estimates. FAO Fish. Rep., (253): 73—91.

Jukić, S. and C. Piccinetti. 1985. Biological and economic aspects on management of the multispecies demersal resources by regulation of cod-end mesh size (mimeo).

Jukić, S. and E. Arneri 1983. Distribution of Hake (*Merluccius merluccius* L.), Striped Mullet (*Mullus barbatus* L.) and Pandora (*Pagellus erythrinus* L.) in the Adriatic. FAO Fisheries Report, 290: 85—91.

Karlovac, J. 1965. Contribution à la connaissance de l'écologie du merlu *Merluccius merluccius* L. dans le stade planctonique de sa vie en Adriatique. Rapp. P. V. Comm. Int. Explor. Sci. Mer Médit., 18 (2): 461—464.

Karlovac, O. 1957. Extensive investigations of captures by ottertrawl in the Adriatic off shore waters. Proc. gen. Fish. Coun. Medit., 4: 243—250.

Karlovac, O. 1959 a. Istraživanja naselja riba i jestivih beskralježnika vučom u otvorenom Jadranu. Izv. Rep. Rib.-biol. Eksp. »Hvar«, 1948—1949, 5 (1) 203 pp.

Karlovac, O. 1959 b. La nouriture du merlu (*Merluccius merluccius* L.) de la mer Adriatique. Proc. gen. Fish. Coun. Medit., 5: 333—339.

Karlovac, O. 1961. Contribution aux connaissances de la répartition de la sardine , *Sardina pilchardus* Walb., en Adriatique. Rapp. Comm int. Mer Medit., 16 (2): 325—332.

Kirinčić, J. et V. Lepetić. 1955. Recherches sur l'ichthyobenthos dans les profondeurs de l'Adriatique méridionale et possibilité d'exploitation au moyen des palangres. Acta Adriat., 7 (1): 113 pp.

Kotthaus, A. 1938. Die Entwicklung und heutige Lage der jugoslawischen Grundschleppnetzfischerei. Der Fishmarket, Heft 9.

Kotthaus, A. i M. Zei. 1938. Izvještaj o pokusnom ribarenju »koćom« u Hrvatskom Primorju. God. Oceanogr. inst., 1: 125—140.

Kreuzer, C. O. 1964. Utilisation of fish reactions to electricity in sea fishing. In: Modern Fishing gear of the World, 2, Fishing News (Books), London, pp., 545—550.

Kutaygil, N. 1965. Analyse préliminaire de l'âge de *Mullus barbatus* L. et *Merluccius merluccius* L. dans la mer de Marmara et de quelques poissons pélagiques de Turquie. Proc. gen. Fish. Coun. Medit., 8: 361—383.

Larrañeta, M. G. 1970. Sobre la alimentación, da madurez sexual y la talla de primera captura de *Merluccius merluccius* (L). Inv. Pesq., 34 (2): 267—280.

Le Danois, E. 1922. Nouvelles recherches sur le Régime des eaux Atlantique et sur la biologie des poissons comestible. Notes et Mémoires, 17: 1—16.

Le Danois, E. 1938. L'Atlantique-Histoire et Vie d'un Océan. Paris, 288 pp.

Lepetić, V. 1965. Sastav i sezonska dinamika ihtiobentosa i jestivih avertebrata u Bokakotorskom zalivu i mogućnosti njihove eksploatacije. Studia marina, 1: 1—127.

Letaconnoux, R. 1955. Rapport sur le merlu. Cons. Int. Explor. Mer Comité Atlantique: 5 pp. (mimeo).

Levi, D., C. Froglia e R. Scorcelletti. 1971. Selettività di una rete di tipo relingato (chalut à grande ouverture verticale) Quad. Lab. Tecnol. Pesca, 1 (2): 23—35.

Levi, D. and G. Giannetti. 1972. Analisi sullo stato di sfruttamento di una popolazione ittica mediante un modello matematico di cattura e sforza. Quand. Lab., Tecnol. Pesca, 1 (4): 101—114.

Marr, J. C. 1953. Marine fishery biology. FAO. Santiago de Chile, 143 pp.

Matta, F. 1953. Qualche considerazione sulla Biologia del Merluzzo (*Merluccius merluccius* L.) dei mari italiani. Nota I. Boll. Pesca Pisc. Idrobiol, 8 (1): 82—102.

Matta, F. 1954. Il merluzzo del Mediterraneo. Nota II. Boll. Pesca Piscicolt. Idrobiol., 9 (1): 5—29.

Matta, F. 1956 a. L'accrescimento ponderale del merluzzo mediterraneo (*Merluccius merluccius* L.) Boll. Pesca Piscicolt. Idrobiol., 11 (1): 31—36.

Matta, F. 1956 b. L'accrescimento ponderale del merluzzo mediterraneo (*Merluccius merluccius* L.). Boll. Pesca Piscicolt. Idrobiol., 11 (2): 283—290.

Maurin, C. 1954. Les merlus du Maroc et leur pêche. Bull. Inst. Pêches Marit., Maroc, (2): 4—65.

Maurin, C. 1968 a. Les merlus des côtes nord et nord ouest d'Afrique (Atlantique et Méditerranée). Theses l'Univ. Nancy, 43 pp. (mimeo).

Maurin, C. 1968b. Ecologie ichthyologique des fonds chalutables Atlantiques (de la Baie Ibéro-Marocaine à la Mauritanie) et de la Méditerranée Occidentale. Rev. Trav. Inst. Pêches Marit., 32 (1): 1—136.

Maurin, C. 1972. Les merlus des mers européennes et nord-ouest africaines. Importance de la moyenne certébrale dans la determination des sous-espèces et groupements raciaux. Rapp. Com. int. Explor. Sci. Medit., 18 (2): 215—220.

Merker, K. i T. Ninčić. 1973. Sastav i gustina betonskih ihtionaselja u Južnom Jadranu. Studia marina, 6: 75—117.

Moller, G. 1775. Sopra la pescagione della Dalmazia. Letta in una Riunione della Società Economica da Spalato tenutassi nell'anno 1775. (MS).

Mužinić, R. and O. Karlovac. 1975. On food preferences of the Adriatic hake, *Merluccius merluccius* (L.). Acta Adriat., 17 (7): 48 pp.

Piccinetti, C. e G. Piccinetti-Manfrin. 1971. Osservazioni sull'alimentazione del merluzzo (*Merluccius merluccius* L.) in alto e medio Adriatico. Note Lab. Biol. Mar. Pesca, Frano, 4 (3): 41—64.

Ricker, W. E. 1940. Relation of »Catch per unit effort« to abundance and rate of exploatation. J. Fish. Res. Bd. Can., 5: 43—70.

Rijavec, L. 1975. Biologija i dinamika populacije *Pagellus erythrinus* (L.) u Bokakotorskom zalivu i otvorenom području južnog Jadrana. Studia marina, 8: 3—109.

Robertson, I. J. B. 1977. Eastern Central Atlantic Fisheries. Summary of report: Fiolent 1976 Eastern Central Atlantic coastal fishery resource survey, southern sector. CECAF/TECH. REP./72/2, Dakar; 115 pp. (mimeo).

Scaccini, A. e C. Piccinetti. 1968. Il fondo del mare da Cattolica a Falconara. C. N. R., Ser. E, 98 pp.

Scaccini, A. e C. Piccinetti, 1969. Il fondo del mare da Falconara a Tortoreto. C. N. R., Ser. E, 146 pp.

Schärfe, J. 1961. Mediterranean trawling. Stud. Rec. gen. Fish. Coun. Medit., (14): 1—21.

Svetovidov, A. N. 1948. Fauna of the U. S. S. R., Fishes 9 (4). Gadiformes. Zool. Akad. Nauk., 221 pp. (english translation).

Wheeler, A. 1969. The fishes of the British Isles and northwest Europe, 613 pp

Woodhead, P. M. J. 1964. Diurnal changes in trawl catches of fishes. Rapp. P. — v. Réun. Cons. perm. int. Explor. Mer, 155 (7): 35—44.

Yannopoulos, C. 1976. The feeding niche of *Merluccius merluccius* L. and its influence on the length-weight relationship. XXV^{e} Congrès-Assemblée pleniére, CIESMM: 3 p. (mimeo).

Zei, M. 1940. Pregled rezultata dosadašnjeg ribarstveno-biološkog istraživanja Oceanografskog instituta u kanalima Hrvatskog primorja. God. Oceanogr. inst., 2: 139—147.

Zei, M. 1949. Raziskovanie s travlom na ribolovnem področju vzhodnega Jadrana. Rasprave Slovenske Akademije znanosti in umetnosti v Ljubljani, 4: 89—119.

Zei, M. i I. Sabioncello. 1940. Prilog poznavanju naselja bentoskih riba u kanalima srednje Dalmacije. God. Oceanogr. inst., 2: 103—115.

Zore, M. 1956. On gradient currents in the Adriatic Sea. Acta Adriat., 8 (6): 38 pp.

Zore-Armanda, M. 1963. Les masses d'eau de la mer Adriatique. Acta Adriat., 10 (3): 93 pp.

Zore-Armanda, M. 1968. The system of currents in the Adriatic Sea. Stud. Rev. gen. Fish. Coun. Medit., 34: 1—48.

Zore-Armanda, M. 1969. Temperature relations in the Adriatic. Acta Adriat., 13 (5): 51 pp.

Zore-Armanda, M. 1984. Hydrographic and productivity conditions of the Palagruža region in the middle Adriatic. Acta Adriat., 25 (1/2): 119—138.

Županović, Š. 1953. Statistical analysis of catches by trawling in the fishing regions of the eastern Adriatic in 1951. Acta Adriat., 5 (8): 55 pp.

Županović, Š. 1956 a. Prilog analizi lovina tartanama na sjevernodalmatinskom području 1951—1953. Acta Adriat., 8 (1): 16 pp.

Županović, Š. 1956 b. Productivity and intensity of exploitation of the Adriatic. In: Intern. Tech. Conf. Cons. Liv. Resources Sea, UN New York, pp. 326—337.

Županović, Š. 1959. Influence de l'intensité d'exploitation sur la composition du stock de poissons. Proc. gen. Fish. Coun. Medit., 5: 285—291.

Županović, Š. 1961 a. Influence des facteurs physiques sur les deplacements des poissons. Proc. gen. Fish. Coun. Medit., 6: 137—143.

Županović, Š. 1961 b. Contribution à la connaissance de la biologie de *Merluccius merluccius* L. dans l'Adriatique moyenne. Proc. gen. Fish. Coun. Medit., 6: 145—150.

Županović, Š. 1961c. Kvantitativno-kvalitativna analiza ribljih naselja kanala srednjeg Jadrana, Acta Adriat., 9 (3): 152 pp.

Županović, Š. 1963a. Experiments on the fishing effectiveness of trawls using wire cable bridle and wire cable bridle with manila. ICNAF Spec. Publ., 5: 222—225.

Županović, Š. 1963b. Utjecaj intenziteta ribolova na riblji fond u Jadranu. Pomorski zbornik, 1: 693—716.

Županović, Š. 1964. Exploitation of the fish stock of the Adriatic. Journal for Sci. Agric. Res., 17 (55): 28—45.

Županović, Š. 1968. Study of hake (*Merluccius merluccius* L.) biology and population dynamics in the central Adriatic. Stud. Rev., 32: 1—24.

Županović ,Š. 1969a. Prilog izučavanju bentoske faune Jabučke kotline. Thalassia Jugosl., 5: 477—493.

Županović, Š. 1969b. Behaviour of hake (*Merluccius merluccius* L.) in relation to trawls wire cable Bridles. Fisheries Report (FAO), 62 (2): 409—416.

Županović, Š. 1971. Ribarstvo Jadrana. Matica Hrvatska; (8): 84 pp.

Županović, Š. 1974. Riblji fond i ribarstvo Jadrana. Acta Adriat., 16 (27): 441—447,

Županović, Š. 1985. Biological effects of the hydroclimatic changes in the middle Adriatic. Acta Adriat., 26 (2): 165—189.

Županović, Š. i F. Grubišić, 1958. Ribolovna efektivnost u eksperimentima sa strugarima. Acta Adriat., 8 (12): 27 pp.

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PRILOG IZUČAVANJU BIOLOGIJE I DINAMIKE POPULACIJE JADRANSKOG OSLIĆA, *MERLUCCIUS MERLUCCIUS* (L.)

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KRATKI SADRŽAJ

Na osnovu izučavanja biologije, dinamike populacije, eksploatacije i procjene stock-a oslića, *Merluccius merluccius* (L.), u Jadranu autori ovog rada došli su do slijedećih zaključaka:

Oslić je u Jadranu rasprostranjen skoro na čitavoj površini (Fig. 2). U odnosu na dubinu oslić u Jadranu naseljava područje od cca 10 do 800 m, abundantnije između cca 100 i 200 (ili nešto više) m, a s obzirom na teksturu taloga dna preferira finija (muljevita) dna, međutim dobro je zastupljen i na ostalim dnima.

Najgušća populacija oslića zapažena je u srednjem otvorenom Jadranu, tj. u Jabučkoj kotlini, koja je poznata kao »nursery ground« za ovu vrstu. Abundantna populacija zapažena je i južnije od Jabučke kotline.

Na osnovu izučavanja njegovih morfometrijskih i merističkih karaktera radi se o jednoj populaciji u Jadranu. Mužjaci oslića postizavaju prvu spolnu zrelost između 20 i 28 cm, a ženke pri dužini od 23 do 33 cm.

Mriještenje oslića u Jadranu se vrši u ljetnjem i zimskom periodu. Najranije mriještenje se vrši u dubljim vodama u zimskim mjesecima i kako sezona napreduje, mriještenje se prebacuje u pliće vode u proljetno-ljetnjem periodu (Fig. 3).

Pojava juvinilnih oslića (7—15 cm) u Jabučkoj kotlini u proljetno-jesenskom periodu, po mišljenju autora, vjerojatno je povezano sa dugim periodom mriještenja.

Adolescentni oslići u srednjem Jadranu se uglavnom zadržavaju u plićim kanalskim vodama do prve spolne zrelosti.

Adultni individui takođe ukazuju na periode pomicanja obalnim, plićim vodama, i vice versa. Autori. pokušavaju povezati ta lokalna pomicanja adultnog oslića prema plićim vodama sa periodom mriještenja, odnosno ishrane.

Ishrana oslića varira sa uzrastom. Juvenilni oslići do 16 cm se uglavnom hrane racima (Euphausiacea), a adolescentni i adultni uglavnom ribama *(Sardina pilchardus, Sprattus sprattus sprattus* i *Engraulis encrasicolus).*

Rastenje oslića u Jadranu je analogno rastenju u sjevernom Mediteranu i u vodama Tunisa. Autori su navedenu sličnost pokušali povezati sa pojavom divergencije.

Dnevne promjene u lovinama oslića su pokazale da su najbolji ulovi postignuti u zoru i sa povećanjem dnevne svijetlosti ulov pokazuje tendenciju opadanja. Jedina iznimka u ulovu je registrirana u ljetnjem periodu kad je na istom području ulovljen najveći broj zrelih individua (Fig. 14).

Odnos spolova oslića u srednjem Jadranu ukazuje da su mužjaci predominantni u kanalskom području kod manjih, a ženke kod većih dužina.

Izučavanja starosti oslića u srednjem Jadranu pomoću otolita je pokazalo da su u ulovu bile najbrojnije zastupane prva i druga starosna grupa u periodu 1963—1966.

Analiza frekvencije dužina oslića u srednjem Jadranu u odnosu na južni Jadran, je ukazala da su oslići u srednjem Jadranu pokazivali dva maksimuma u proljetno-ljetnjem periodu i samo jedan u zimskom. Autori su nestajanje drugog modusa u zimskom periodu pokušali objasniti metamorfozom ishrane kod juvenilnih oslića i njihovim pomicanjem iz Jabučke kotline, prema plićim kanalskim vodama.

I frekvencije dužine oslića u Crnogorskom primorju u ljetnjem periodu pokazuju dva maksimuma. Prosječne dužine oslića u kolovozu 1961. g. na ovom području su bile veće od dužina izmjerenih u srednjem Jadranu (Fig. 22).

Odnos između dužine i težine oslića u Jabučkoj kotlini (prema J a r d a s-u, 1976) ukazuje na tri faze rastenja. Infleksiona točka se susreće kod cca 32 cm za ženke i oko 29 cm za mužjake.

Ulov oslića u Jadranu u posljednjem desetljeću ukazuje na izvjestan porast. Analiza indeksa promjena abundancije oslića u Jadranu, u periodu 1976—1969. je pokazala, da je stopa eksploatacije oslića u Jadranu ostala, više ili manje, konstantna (A l e g r í a - H e r n á n d e z *et al.*, 1982).

Radi bolje procjene biomase oslića i mogućnosti eksploatacije iste, autori su pokušali na osnovu izračunavanja prirodnog mortaliteta i dobivenog koeficijenta regresije (A l e g r í a - H e r n á n d e z *et al.*, 1982), izračunati lovni koeficijent (q) dubinske povlačne mreže (koće) brodova »Jadran« poduzeća — Split na ribolovnom području Blitvenice. Prema dobivenim rezultatima, lovni koeficijent (q) mreže iznosio je 0,34. Po mišljenju autora, a na osnovu dobivenog lovnog koeficijenta mreže od 34%, proizlazi, da je procjena biomase oslića u Jadranu veća od njegove prave vrijednosti.