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ASSESSMENT OF PELAGIC FISH ABUNDANCE ALONG THE EASTERN ADRIATIC COAST WITH SPECIAL REGARD TO SARDINE (*SARDINA PILCHARDUS* WALB.) POPULATION

PROCJENA ABUNDANCIJE PELAGIČNE RIBE NA ISTOČNOJ OBALI JADRANSKOGA MORA S POSEBNIM OSVRTOM NA POPULACIJU SRDELE (*SARDINA PILCHARDUS* WALB.)

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Taking into account statistical catch and corresponding fishing effort data for sardine (*Sardina pilchardus* Walb.) population along the eastern Adriatic coast studies of present status of sardine stock size, maximum sustainable yield and optimum fishing effort have been carried out by applying and combining Schaefer (1954) and Fox (1970) surplus yield models.

The applied method is based on Yugoslav annual catch statistics for the 1963—1978 period. In calculating the catch per unit effort, fishery statistics of one fishing organization was used. The purse-seiners fleet of this organization operates along the eastern Adriatic coast. Fishing effort unit used is one fishing day/boat with only one net shot.

Biological characteristics of exploited sardine population meet the requirements for better and more accurate application of surplus model results (Fox, 1977).

General conclusions for a management policy are mostly based on 1967—1978 series data owing to the 1963—1966 period might be considered as a period of lower sardine population availability to the fishing gears, mostly due to the lower skippers skilfulness for pelagic fish school detection of means of new devices (echo-sounders) which were more and more used by the commercial fishing fleet.

Recently reported sardine catch and fishing effort vary about optimum values of production model for this Adriatic area, but the exploitation rate (E = 0,28) of sardine population along the eastern Adriatic coast is constantly low. Catchability coefficient was found to be reduced and inversely related to stock size up to 1979. It may be assumed that only a part of population inhabiting this area was under constant exploitation.

1. INTRODUCTION

A fish stock within an ecological system is affected by a large number of different factors. Namely, if a fish stock is under exploitation by fishing, then, apart from other ecological factors of marine environment, man, as a predator directly affects fish stock size and structure. Within the complex marine ecosystem only this factor, is liable to a continuous control and eventual modifications. Therefore, proper management of living marine resources is mediated through a direct control of total or specific activities in each of the fishing areas.

Starting from this point the intention of any fishery - biological research should be to describe some fundamental principles of fishing effects on stock under exploitation as well as off the opposite effects, that is stock size effects on the profit from fishing. Thus the ways and conditions under which fishing control affects a stock might be better understood and the final aim of as objective living resources management policy as possible attained.

The puspose of fishery management is to adapt and limit fishing activities to attain as rational and optimum quantitative-qualitative changes within fish stocks and catches as possible.

From the fishery point of view, it would be optimum to keep a fish stock at such a biological production level, in relation to exploitation level, which would provide maximum sustainable yield from one year to another. Therefore, to attain the aim of proper fishing management in a defined fishing area the attention should be given to the fundamental relationships between stock size, fishing intensity and total catch which provide a basis for future planning.

Since marine environment wherefrom fish are taken is a complex ecosystem, it is frequently particularly difficult to estimate what effect the fishing has upon stock size. Namely, the majority of fish stocks are species which tend to attain natural equilibrium. Thus, within the complexity of ambiental conditions there is a rate of total biomass increase for each stock size, dependent exclusively on the size of standing stock (B a r a n o v, 1918) which could be potentially defined.

Properly regulated fishing, which is a consequence of human activity, removes that fraction of a population biomass which is in fact a natural surplus, thus that parental stock biomass is not significantly reduced. This means that, apart from biological-productive population characteristics, the variations of the fish stock abundance index are affected also by the level of fishing activity, that is fishing intensity (R u s s e l, 1939).

With reference to the already mentioned points and for the proper living marine resources management, the assessment of stock size, which is a raw material basis for the existing and potential fishing activity development, should be the starting point and principal goal of fishery-biological researches in defined fishing area. (B a r a n o v, 1918; S c h a e f e r, 1954; P e l l a and T o m l i s o n, 1969; P e r e i r o, 1975).

A literature exists of preliminary assessments of the biomass under exploitation in the Adriatic: Ž u p a n o v i ć (1955, 1964). Š t i r n (1969), P u c h e r - P e t k o v i ć & Z o r e - A r m a n d a (1973), G r u b i š i ć *et al.* (1974), K a r l o v a c *et al.* (1974), V u č e t i ć (1976), A z z a l i *et al.* (1976), P i c c i n e t t i, *et al.* (1979), K a č i ć (1978), J u k i ć & P i c c i n e t t i (1979).

Results of these authors on the size of edible marine resources, particularly of the Adriatic small pelagic fish, differ significantly, as well as the measures of potential fishing development propased on those bases.

Even though the employed methods differed the widespread and highly recommended method of fishery statistics based on total catch of defined fish stock in the Adriatic and respective fishing effort, which is an objective, qualitative-quantitative measure of potential monitoring of state and vaiations of defined population biomass in space (fishing area) and time (over a series of years) has not so far been applied. This method, however, has been applied in the present paper.

Since sardine (*Sardina pilchardus* Walb.) average about 50% of the total Yugoslav catch, the effects of fishing on the standing sardine stock in the Adriatic has been given particular attention due to its scientific-fundamental and particularly the fishery-applicative importance.

Namely, our major aim vas to establish: i) the relationship between fishing intensity and sardine stock size, ii) maximum sustainable yield and iii) sardine stock size along the eastern Adriatic coast.

Application of the already mentioned method, under the condition of continuous collection of relevant fishery-statistical data of both pelagic and trawl fishing in the Adriatic, renders possible a proper fishing regulation and optimum living marine resources management.

2. CHARACTERIZATION OF SARDINE POPULATION

One of the problems of primary concern of any marine biologist when evaluating a fish stock, under exploitation in a defined area is to know whether the fishery draw on one homogeneous population or several. A large number of previous studies relating to sardine biology and ecology have been conducted by a number of investigators. Among the other authors, Mužinić (1954, 1958), Zavodnik (1962, 1968), Škrivanić and Zavodnik (1970), Žikić and Krajnović-Ozretić (1976) studied some characteristics of the northern Adriatic sardine. General review of sardine investigations (Mužinić, 1979) enables us to make a certain biological identification of the middle Adriatic sardine.

Characterization of a population or subpopulation of sardine or any other *Clupeidae*, is based principally on the number of vertebrae. Sumarized data on the vertebral number in the Adriatic sardine are present in Table 1 for the purpose of comparison.

Table 1. A review of the investigations of the vertebral numbers in sardine (*Sardina pilchardus* Walb.) from the northern and middle Adriatic

Area	Author	Modal number	Mean
Cammachio	Fage (1920)	51—52	51.429
Kvarner	Zavodnik)1962)	51—52	51.480—51.550
Istra	Mužinić, R. (1954, 1958)	52	51.607
Istra	Krajnović-Ozretić & Žikić (1978)	52	51.448—51.760
Middle Adriatic	Mužinić, S. (1936)	52	51.653
Middle Adriatic	Mužinić, R. (1954)	52	51.635—51.728

However, it is not possible from this comparison to distinguish whether homogeneous or heterogeneous population inhabits the eastern Adriatic fishing grounds. Therefore, the characterization requires additional information.

A subpopulation study was made of the adult sardine population inhabiting the northern and middle Adriatic coastal area. Collected data refer only to the autumn — winter catch season in 1980—1981. Seven samples from the northern Adriatic comprise 828 fish and ten samples from the middle Adriatic, 1426 specimens. Morphometric measurements of total length, weight and head length were made. Branchispines in the lower edge of the first gill arch were counted. Samples were stratified by fish size classes (Fig. 1). Allometric relationships were computed for each character and total length. Analysis of variance and F-test for difference between two regression coefficient were applied.

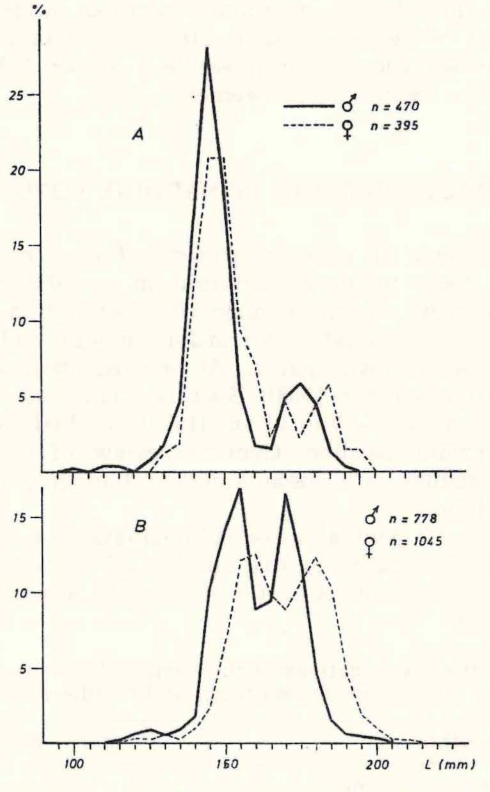

Fig. 1. Total length distribution (L) of male and female sardine from the northern (A) and central (B) Adriatic for the autumn — winter catch period in 1980—1981

The relative head length was smaller in sardine captured in the north, as shown by the head length increase index in Table 2. However, this difference is not signifficant.

The northern Adriatic sardine have 50—68 branchispines, with 60,20 mean value and mode 58. Higher values are found in sardine from the middle

Adriatic. Thus the number of branchispines was found to vary from 52 to 74, with 61,83 mean and 62 modal value. The number of branchispines increases with increase in body length. In sardine from northern. Adriatic the branchispines increase index was $b = 0.503$ and in middle Adriatic sardine $b = 0.394$ (Fig. 2). This indices are considerably higher than the values reported earlier for the Adriatic sardine ($b = 0.291$) as well as for the Mediterranean sardine ($b = 0.201 — 0.300$) by Andreu (1969). The difference between the values of branchispines increase index of sardine from the northern and central Adriatic was statistically significant at 95% level.

Table 2. Parameters of allometric relationship between total length and head length and number of branchispines in sardine from the northern and middle Adriatic in autumn—winter 1980—1981

Parameters	Fishing ground	
	Northern Adriatic	Middle Adriatic
Total length range (mm)	120—195	125—205
Head length mean (mm)	31.47	31.41
Head length increase index	0.929	0.937
Branchispines mean number	60.20	61.83
Brancispines increase index	0.503	0.394

Allometric length-weight relationship factor b, empirical condition factor $C = WL^{-b}$ and cubic condition factor $K = WL^{-b}$ have been estimated:

Northern Adriatic	$b = 2.851$	$C = 1.675 \times 10^{-5}$	$K = 0.784 \times 10^{-5}$
Middle Adriatic	$b = 2.757$	$C = 2.587 \times 10^{-5}$	$K = 0.752 \times 10^{-5}$

Even though the northern Adriatic sardine show greater tendency to isometry (Fig. 3), the difference found between these two length-weight factors is not significant.

Taking into account the stability of C factor in relation to length it may be used for an intraspecies comparison of the observed groups. It was found that the obtained C values corresponded to different statistical population ($P < 0.001$).

Cubic condition factor decreases in function of length for the period of the present observations. The correlation between fish length and condition was also examined, and results are negative and significant for samples from the middle Adriatic ($P < 0.001$). This correlation was poorer in sardine from the northern Adriatic: for the males it was significant ($P < 0.05$) while for females it was not significant. This may be indicative of some temporary mixing of stocks from different fishing grounds.

In conclusion, it may be assumed that there are some physiological differences between sardine stock from the northern and middle Adriatic.

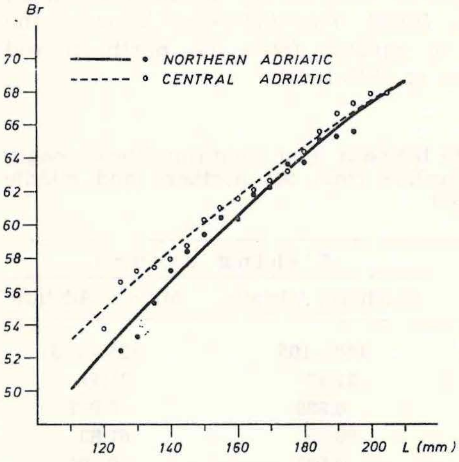

Fig. 2. Relationship between the number of branchispines (Br) and total length (L) in sardine from the northern and middle Adriatic

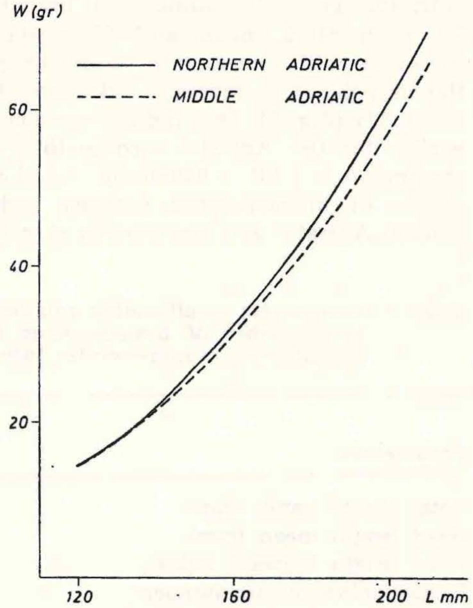

Fig. 3. Length-weight relationship of sardine from the northern and middle Adriatic. L — total length, W — weight

3. MATERIALS AND METHODS

3.1. *Fishery-biological models*

Surplus-production models are research attempts to establish direct relationship between fish stock size and stock natural increase per unit time (usually a year). Graham (1935) first applied a defined model to calculate expected catch of fish populations from the North Sea. Schaefer (1954) improved this model for fishery purposes and described a method of estimation of parameters under conditions of exploitation.

The model of Schaefer is concerned with two functions: fishery-statistical data on catch of a species and respective fishing effort exerted on a defined stock on the basis of long-term series.

The cited models which deal with a single stock unique in time and space are based on the following assumptions:

If a fish stock is exploited at a constant catch rate, it will quickly recover to the state in which its biomass changes are minimum. There is neither time lags nor different response shifts of population in relation to its own abundance, that is the population quickly recovers to the equilibrium. Natural factors of marine environment are more-or-less constant and do not seriously affect catch and adult fish behaviour, and, accordingly, stock catchability coefficient is constant. Model is best applicable in cases of simple singlespecies populations, where intra-specific relations may be ignored.

Global models at the same time show that a stock production is a function of stock size.

From this assumption it follows that the size of a virgin stock is maximum at the point at which stock biomass is no longer increased. A stock under exploitation is forced constantly to adapt to the new levels of natural equilibrium. Therefore, during adaptation period stock surplus depends on the biological character of stock increase.

A stock is frequently incapable to maintain constant optimum biological level of production in relation to the rate of constant exploitation. Thus fishery practice often witnesses the situation that annual catch of a defined fish stock is in excess of the maximum sustainable yield.

Application of surplus production model requires quite determined situation: it depends on the quality of statistical data, catch and particularly on the data of adequate fishing effort over a series of years; the longer the series the better the calculation of required values: maximum sustainable yield, stock size, maximum level of fishing intensity with an aim of proper living marine resources management. To our regret data on fishing conditions in the Mediterranean and, until recently in the Adriatic, are most frequently lacking.

Total fishing effort in relation to stock under exploitation is an essential parameter in the policy of proper edible marine resources management. Apart from the fact that data on fishing effort are not coordinated, statistics of fishing effort data faces as well other fishery-technical difficulties which should be taken into account. Namely, in the post-ward period, with the rapid development of modern fishing-technical facilities (powerful engines, hydraulic winches, efficient nets, capacities of fishing boats, application of electronics, particularly of ultrasonic detectors-echosounders, etc.), the earlier concept of fishing effort of, for example, one vessel per a fishing day, has considerably changed for the last two decades.

As distinct from the fishing effort function, data on catches of species for national and regional statistics have been more-or-less regularly collected over longer period.

Briefly, in the cases of exploitation of defined stock, rate of variations in biomass is determined by two parameters: one is positive and represents the index of natural biomass increase *(h/P/)*; other is negative and represents index of biomass reduction due to fishing *(F)*. Under the equilibrium conditions both indexes will be equal. This is expressed by:

$$h(P) = F \tag{1}$$

and the equilibrium catch (C_e) will be:

$$C_e = F\bar{P} = h(\bar{P})\,\bar{P} \tag{2}$$

where $\bar{P}$ is the mean population.

The ratios are usually changed by biomass or abundance index

$$F = qf \tag{3}$$

where q is the catchability coefficient which in fact is the correlation between catch and quantity of fish accessible by fishing gear, which inhabits defined area in defined time. Accordingly, f value will at the same time be the index of population fishing mortality.

If catch (C) of defined species in a time interval and respective fishing effort are known, an appropriate index of mean population (abundance) for each time interval, expressed as mean catch per unit effort $(\bar{U})$, may be obtained. The expression (3) may be placed in (2) and the following may be obtained:

$$C_e = qf\bar{P} \tag{4}$$

wherefrom it follows that

$$C/_f = qf = \bar{U} \tag{5}$$

As it has already been mentioned, relative ratio of surplus is reduced together with population. Schaefer (op. cit.) assumes that the correlation between stock size and its relative rate of natural increase is linear function.

The other group of authors (Ricker, 1958; Gulland, 1961; Garrod, 1968) held that correlation between relative surplus index and population biomass is not linear but exponential function, that is that virgin stock grows in time according to Gomperz function. In this connexion Fox (1970) rearranged and improved the production model to provide a more realistic reflection of production of stock under exploitation. In fact, an essential characteristics of this model is that it realizes the exponential relation between fishing effort and stock size, wherefrom an asymmetric growth curve is obtained.

3.2. *Sources of data*

The commercial fishery (»Jadran« fishing organization, Split) is the source of the data used for the representative sample of this study. Information on total Yugoslav catch were available from statistics collected for general administrative purposes by the Bureau of Statistics of the Socialist Republic of Croatia, Zagreb.

After the data of »Jadran« company, nine to thirteen purse-seiners operated in the 1963—1978 period, covered by our study, with 84 average gross tonnage per vessel along the eastern Adriatic coast, from the mouth of Neretva river, around Mid-Dalmatian island up to the Savudrija Cape on the west Istrian coast (Fig. 4).

Owing to commercial marketing reasons, fishing strategy of »Jadran« purse-seiners fleet is directed, mainly, to sardine fishing, particularly for the last decade. This selective orientation of purse-seining was provided by introduction of modern fishing facilities, from 1962 on. This refers particularly to echosounder. With time and experience fishermen learn to distinguish between fish populations from echograms.

Annual total catch of the fleet was obtained from monthly catch per vessel as well as annual total fishing effort. Annual mean catch per unit effort, was obtained from annual total catch divided by respective fishing effort.

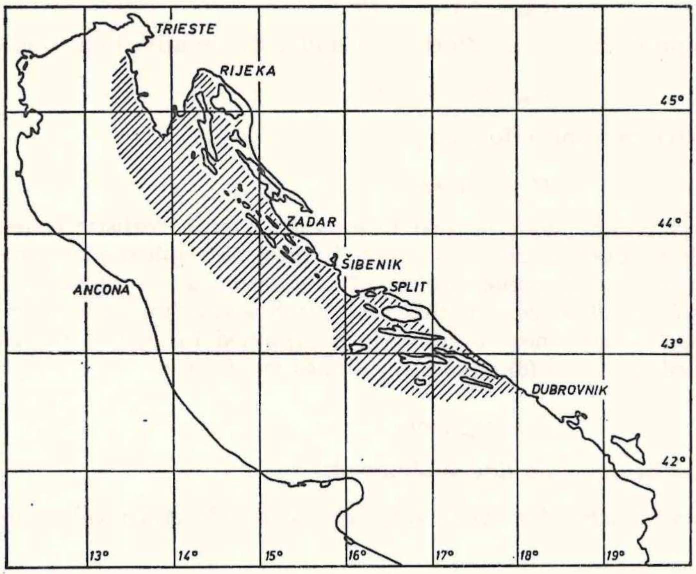

Fig. 4. Principal fishing grounds for sardine along the eastern Adriatic coast covered by statistics sample

Data of the Bureau of Statistics in Zagreb were used as an information on total small pelagic fish catch by species. We also used them to carry out the assessment of total fishing effort of Yugoslav fishing units — exerted for the catch of small pelagic fish, particularly sardine, along the eastern Adriatic coast in the 1963—1978 period.

3.3. *Model application*

After the model by Schaefer the state of equilibrium as a function of catch per unit effort and fishing effort is determined by the following expression:

$$\bar{U} = U_\infty - bf \qquad (6)$$

where U^∞ is the catch per unit effort proportional to maximum population size and b the funtional regression coefficient.

From this relation the estimated catch (C_e) for every value of fishing effort may be obtained after the expression:

$$C_e = U_\infty \, f - bf^2 \qquad (7)$$

or

$$C_e = \bar{U}f \qquad (8)$$

On the basis of equilibrium relations, maximum catch in natural stock equilibrium (C_{max}), that is maximum sustainable yield *(MSY)* may also be obtained:

$$C_{max} = U_{\infty}^2/-4b \qquad (9)$$

Since optimum fishing effort (f_{opt}) under the equilibrium conditions is:

$$f_{opt} = U_{\infty}/-2b \qquad (10)$$

optimum catch per unit effort is:

$$U_{opt} = U_{\infty}/2 \qquad (11)$$

The exponential mode is used to provide a more realistic reflection of the actual stock production characteristics. It may be applied mathematically and graphically and by the same method of calculation as in the case of the model of Schaefer. However, in this case catch logarithm value per unit effort is used. Thus a curvilinear correlation is obtained instead of the linear correlation. Accordingly, the (6) equation assumes the form:

$$\bar{U} = U_{\infty}e^{-bf} \qquad (12)$$

and the equilibrium state line is obtained.

Estimated catches for every value of fishing effort are calculated from the expression:

$$C_e = fU_{\infty}e^{-bf} \qquad (13)$$

Optimum fishing effort which does not threaten a stock of defined size by overfishing, is obtained from the relation:

$$f_{opt} = 1/b \qquad (14)$$

Optimum catch per unit effort is obtained from the relation:

$$U_{opt} = U_{\infty}/e \qquad (15)$$

Maximum sustainable yield or maximum catch in equilibrium state is calculated by the expression

$$C_{max} = U_{\infty}/be \qquad (16)$$

Whereas MSY and optimum fishing effort can be calculated directly from the correlation between equilibrium catch per unit effort and equilibrium fishing effort by the (9) and (10) and (14) and (16) equations respectively, sardine stock size may be assessed only if an estimate of catchability coefficient (q) and stock fishing mortaliy coefficient (F) are known (equation 3).

Schaefer (1957) used the term »instantaneous« index of fishing mortality (k_2) instead of catchability coefficient. This author also gave the method of calculation of k_2 value which corresponds to the q value.

Catchability coefficient and fishing mortality coefficient were also calculated by the method of Gulland (1964a). This method is based on the functional regression of annual total mortality coefficent and corresponding fishing effort:

$$Z = M + F = M + qf \qquad (17)$$

Estimation of total mortality coefficient values was made using the equation:

$$Z_t = ln\ \bar{U}_1/\bar{U}_2 \qquad (18)$$

where the time interval (t) comprises the period from autumn (October—November) of a year to the end of the next summer (August—September).

Optimum coefficient of fishing mortality corresponding to optimum fishing effort is:

$$F_{opt} = qf_{opt} \quad (19)$$

and the stock size corresponding to maximum sustainable yield:

$$P_{MSY} = C_{max}/F_{opt} = U_{opt}/q \quad (20)$$

and

$$P_{max} = U_{\infty}/q \quad (21)$$

where P_{max} is the maximum population size limited for the environmental conditions.

4. RESULTS

4.1. *Sample and catch*

Our sample data were obtained from a commercial fishery organization. The sample annual catch of small pelagic fish makes up, to the average, about 1/21 od the total Yugoslav catch along the eastern Adriatic coast per year. Fluctuations shown by the sample are similar to the total Yugoslav catch fluctuations, with an exception for the 1969—70 period in which the total Yugoslav catch reduction coincided with an increase in sample catch which make up 1/12 of the total catch. Catch fluctuations are given in Figs 5 and 6.

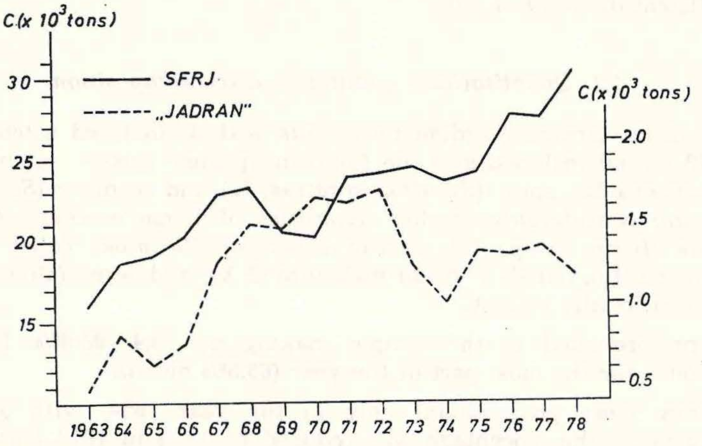

Fig. 5. Fluctuation of the small pelagic fish annual catch realized by SFRY and »Jadran« fishing organization along the eastern Adriatic coast in the 1963—1978

In the 1963—1966 period the sample ranged from 1/27—1/47 of the total Yugoslav catch. In this period modern fishing facility were introduced. Sample catch of the 1967—1978 period was considerably increased and made up 1/12—1/16 of the total cacth. Catch increase was, no doubt, due to the increasing efficiency of echosounder use, particulary in the fish search and fishing operations.

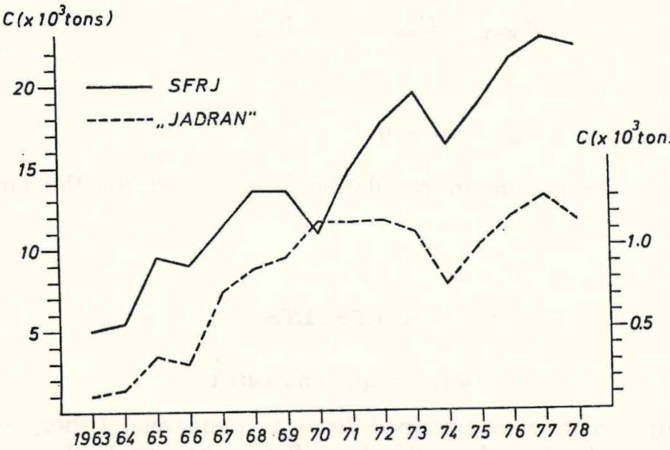

Fig. 6. Fluctuation of sardine annual catch realized by SFRY and »Jadran« fishing organization along the eastern Adriatic coast in the 1963—1978

Since »Jadran« fishing units are fishing for small pelagic fish, particularly sardine, in the wider geographical range from the island of Mljet to Kvarnerić, our representative sample covers sufficiently wide area and provides sufficient quantity of data.

4.2. *Quantitative - qualitative catch composition*

Apart from sardine (*Sardina pilchardus* Walb.), analysed catches from the 1963—1978 period included also the following pelagic species: anchovy (*Engraulis encrasicolus* L.), sprat (*Sprattus sprattus,* L.) and scomber (*Scomber scombrus* L.) and considerably smaller quantities of horse mackerel (*Tranchurus sp.*), bogue (*Boops boops* L.), pacific mackerel, (*Scomber colias* L.), picarel (*Maena maena,* L.), oblade (*Oblada melanura* C. V.) and sargo (*Diplodus saragus* L.) were occasionally caught.

Sardine prevailed in the sample making up 16.4—98.6%. In fact they exceeded 50% for the most part of the year (65.5% mean).

Anchovy were predominant only in the year 1964, with 52%. In the succeeding years this pocentage was reduced to 0.1% in 1978 (15% mean).

Sprat, which otherwise are caught during cold months (November, December) and rarely in spring, made up, on the average, 2.9%.

Table 3. Annual catch of eastern Adriatic small pelagic species for 1963—1978 period

Year	Sardine tons	%	Anchovy tons	%	Sprat tons	%	Mackerel tons	%	Other species tons	%	Total small pelagic fish/tons
1963	5 023.1	31.5	3 140.2	19.7	4 177.0	26.2	2 726.4	17.0	896.8	5.6	15 963.5
1964	5 427.7	29.1	4 863.6	26.1	5 043.5	27.0	2 617.6	14.0	680.5	3.6	18 632.9
1965	9 490.2	49.9	2 224.5	11.7	5 706.7	30.0	807.1	4.2	801.0	4.2	19 029,5
1966	9 062.1	45.0	4 844.2	24.1	3 390.7	16.8	2 311.8	11.5	514.7	2.5	20 123.5
1967	11 207.2	49.2	7 237.6	31.8	2 518.6	11.0	1 233.3	5.4	577.3	2.5	22 774.0
1968	13 518.5	58.4	4 806.6	20.8	3 230.2	14.0	1 154.1	5.0	415.8	1.8	23 125,2
1969	13 497.6	65.7	3 994.9	19.5	2 003.8	9.7	546.7	2.7	495.4	2.4	20 538.4
1970	10 871.7	53.8	2 996.5	14.8	5 536.6	27.4	316.6	1.5	469.0	2.3	20 190.4
1971	14 674.3	61.7	3 124.0	13.1	3 814.6	16.0	134.9	0.6	2 040.7	8.6	23 788.5
1972	17 604.2	73.2	2 271.7	9.5	2 794.7	11.6	99.9	0.4	1 257.5	5.2	24 028.0
1973	19 430.7	79.8	1 570.6	6.5	2 536.6	10.4	77.3	0.3	723.0	3.0	24 338.2
1974	16 201.6	68.9	2 391.3	10.2	4 250.7	18.1	67.7	0.3	701.6	3.0	23 512.9
1975	18 596.0	74.1	2 863.1	11.4	2 437.3	9.7	97.1	0.4	1 100.9	4.4	25 094.4
1976	21 559.1	78.5	2 529.3	9.2	2 363.2	8.6	21.0	0.1	1 004.2	3.6	27 476.8
1977	22 763.1	83.3	1 836.5	6.7	2 050.4	7.5	18.0	0.1	660.2	2.4	27 328.8
1978	22 247.0	74.8	2 770.0	9.3	3 809.0	12.8	9.0	0.0	887.0	2.9	29 712.0

Scomber catches ranged from 31.0—0.1% of the total catch. From 1975 on scomber pratically disappeared from the areas fished by »Jadran« fleet.

Comparison of these data with the total Yugoslav small pelagic fish catch in the Adriatic, shows that sardine are always predominant and that their proportion exceeds 50% over the series of years, except in 1963—1964, when their proportion was sligtly less than 50%. The proportion of their presence ranges from 29.1—83.7% (61.1% on the average).

Anchovy make up, on the average, 20.8% with 31.8—6.5% range, showing a decrease tendency for the last few years.

Sprat percentage proportion in the total Yugoslav catch exceeds sprat percentage in the sample with 30—7.5% (16% mean) range.

Scomber show the same trend of slight reduction from 17—0.02%.

Total Yugoslav Adriatic catch composition and fluctuations over a series of observed years, from 1963—1978, are given in Table 3.

4.3. *Seasonal catch fluctuations*

Studies of seasonal fluctuations of total catch and species provided a basis for the calculation of monthly catches over 16 years. It was observed that sardine catch fluctuated with seasons. Two peaks were marked: the first one in autumn (in October and November) and the second, slightly lower one, at the end of spring (in May), minimum sardine catch was always realized in winter (Januaru and February).

Seasonal fluctuations of sardine catch realized by »Jadran« fleet are comparable to the fluctuations of Adriatic catch realized within Yugoslav territorial waters. They broadly agree, with maxima in autumn and minima in winter (Fig. 7).

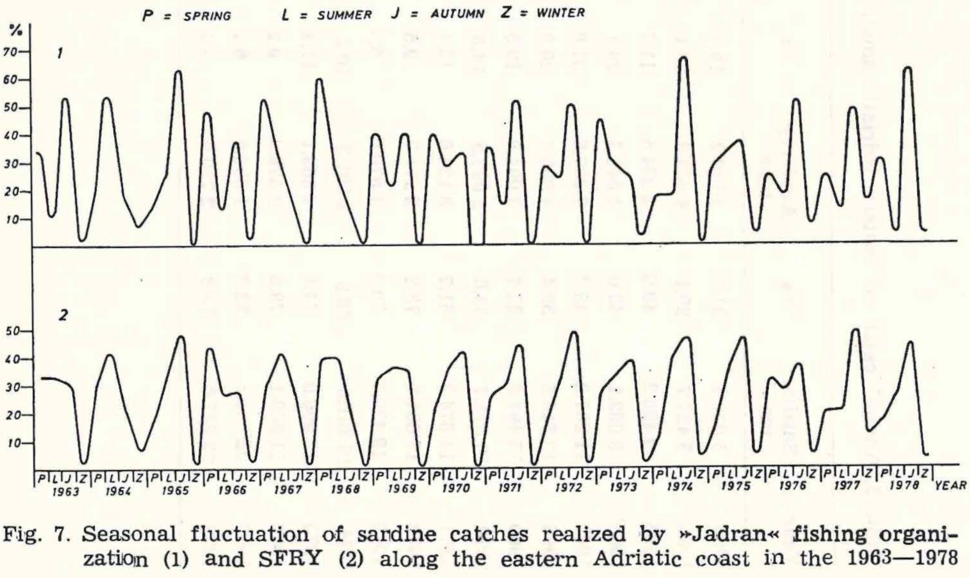

Fig. 7. Seasonal fluctuation of sardine catches realized by »Jadran« fishing organization (1) and SFRY (2) along the eastern Adriatic coast in the 1963—1978

Sardine catch per unit effort (c.p.u.e.) shows fluctuations by seasons as seen from Fig. 8.

Fishing effort which showed relative increase in the first period, 1963—1966, coincided with relatively small c.p.u.e realized. The largest catches per unit effort were mainly realized in autumn, even though maximum amount of fishing effort was exerted in summer, when small c.p.u.e. realized.

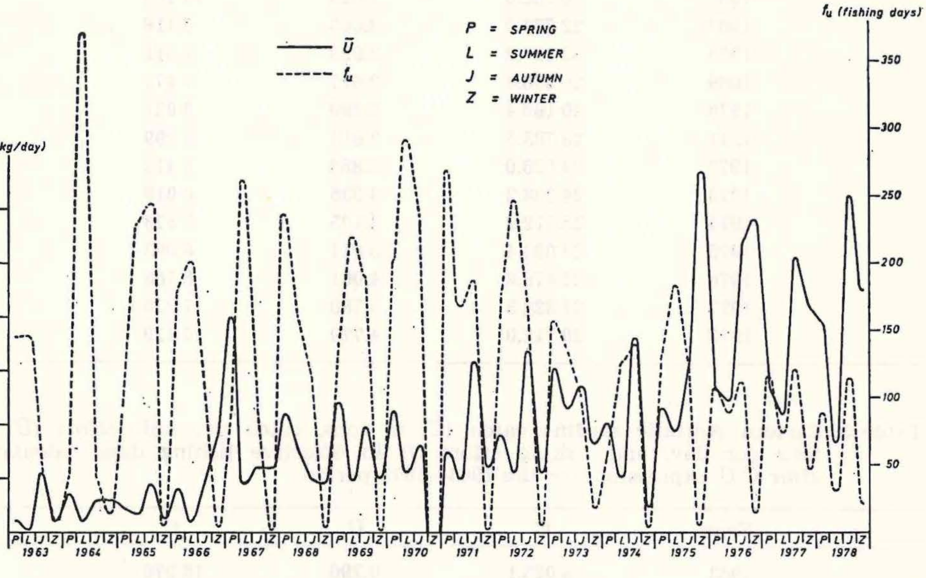

Fig. 8. Seasonal fluctuation of the sample fishing effort (fu) and catch per unit effort (U) of sardine in 1963—1978

In the second period, 1967—1972, maximum c.p.u.e. were realized in spring-autumn. However, very small c.p.u.e. were realized in summer with maximum fishing effort. Fishing effort in winter months also gave low c.p.u.e. values, however not so low as in the 1963—1966 period.

In the third period, from 1973—1978, the total number of vessels (purse -seiners) of »Jadran« fleet was reduced. However, the rest of vessels fished exclusively for pelagic fish in this period what resulted in larger catches per unit effort, particularly in winter. In this period, annual total fishing effort was reduced and catch increased. Maximum catch per unit effort was realized in winter periods (December-January) while maximum amount of fishing effort was exerted in autumn (October, November) when large catches were realized.

In these two periods sardine was the main fishing object of the whole purse-seiner fleet.

Annual small pelagic fish catch fluctuations are given in Figures 9 and 10.

Table 4. Eastern Adriatic small pelagic fish catch (*C*) in tons, catch per unit effort ($\bar{U}$) in tons per day, and fishing effort (*f*) in effective fishing days calculated after $C/\bar{U}$ expression, for the 1963—1978 period

Year	C	$\bar{U}$	f
1963	15 963.5	1.316	12 130
1964	18 623.9	1.673	11 136
1965	19 029.5	1.220	15 598
1966	20 132.5	1.529	13 160
1967	22 774.0	2.806	8 116
1968	23 125.2	2.923	7 911
1969	20 538.4	2.677	7 673
1970	20 190.4	2.289	8 821
1971	23 788.5	2.614	9 099
1972	24 028.0	2.856	8 413
1973	24 338.2	3.035	8 019
1974	23 512.9	3.105	7 573
1975	24 094.4	3.011	8 003
1976	27 476.8	4.061	6 766
1977	27 328.8	3.780	7 230
1978	29 712.0	4.779	6 319

Table 5. Eastern Adriatic sardine catch (C) in tons, catch per unit effort ($\bar{U}$) in tons per day, and fishing effort (*f*) in effective fishing days calculated after $C/\bar{U}$ expression, for the 1963—1978 period

Year	C	$\bar{U}$	f
1963	5 023.1	0.296	16 970
1964	5 427.7	0.274	19 809
1965	9 490.2	0.660	14 379
1966	9 062.1	0.591	15 334
1967	11 207.2	1.619	6 922
1968	13 518.5	1.695	7 976
1969	13 497,6	1.715	7 870
1970	10 871.7	1.595	6 816
1971	14 674.3	1.846	7 949
1972	17 604.2	1.956	9 000
1973	19 430,7	2.651	7 330
1974	16 201.6	2.290	7 075
1975	18 596.0	2.416	7 697
1976	21 559.1	3.675	5 866
1977	22 763.7	3.615	6 297
1978	22 244.0	4.711	4 722

Annual catches realized by »Jadran« fleet show slight increment from one gear to another, the value of which is given by regression coefficient $b = 41$ tons, coefficient of catch-time correlation $r = 0.516$ and determination coefficient $r^2 = 0.266$. This increase in total annual catch is more evident if the total Yugoslav catch data are analysed, where regression coefficient $b = 833$ tons, correlation coefficient $r = 0.857$ and determination coefficient $r^2 = 0.735$.

If the sardine data alone are taken, a gradual catch increase is even more evident. For the sample the increase index is expressed by regression coefficient $b = 72$ tons ($r = 0.846$, $P < 0.05$). For the total Yugoslav catch the increase is $b = 1132$ tons ($r = 0.956$, $P < 0.05$).

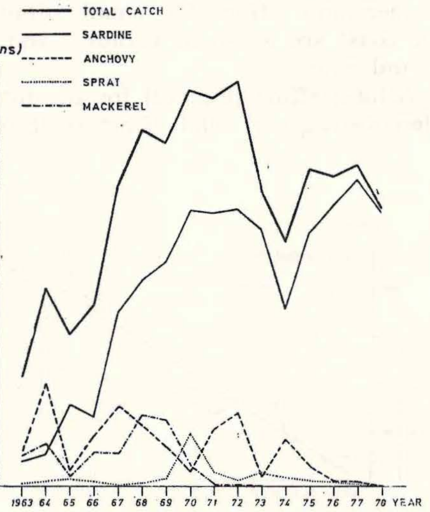

Fig. 9. Annual fluctuation of small pelagic fish catches realized by »Jadran« fishing organization in the 1963—1978 period

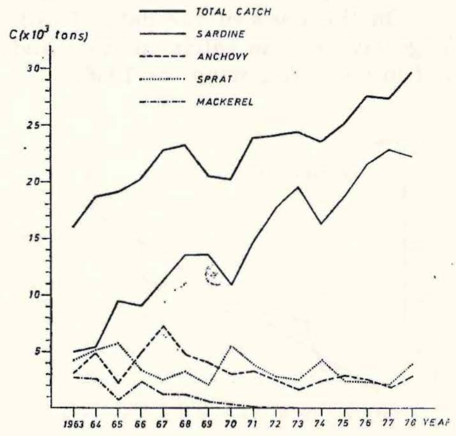

Fig. 10. Annual fluctuation of small pelagic fish total catches realized along the eastern Adriatic coast in the 1963—1978 period

Quite an opposite trend is observed in anchovy catch, both in the sample and in the total Yugoslav catch. Correlation between catch and time is negative and statistically significant ($r = -0.563$, $P < 0.05$) for the sample and ($r = -0.547$, $P < 0.05$) for the total Yugoslav catch. The same situation is with the scomber catch ($r = -0.692$, $P < 0.05$) for the sample and ($r = -0.850$, $P < 0.05$) for the total Yugoslav catch. Correlation values for sprat are negative and not statistically significant ($r = -0.033$ and $r = -0.466$ respectively).

4.4. *Functional values*

Fishing effort unit used is the fishing volume of a purse-seine shot per day (or night) during vhich time a defined fraction of small pelagic fish is removed from the population.

The analysis of the data series for the 1963—1978 period provided the information of fishing effort which varied from 244 fishing days in 1978 to the maximum of 727 fishing days in 1970. As shown by Fig. 11, fishing effort gradually increased from 1963—1970 reaching the peak in 1970. In the succeeding years fishing effort showed relatively considerable reduction to be reduced to minimum in 1978.

Catch per unit effort as an objective assessment of a defined stock abundance is obtained by dividing the catch by the respective fishing effort in the course of a year.

The calculation of total fishing effort for the entire area of the eastern Adriatic coast is based on mean annual catches per unit effort (obtained from »Jadran«) as an index of annual abundance. The equation (5) was used where C is the total Yugoslav catch and U catch per unit effort of »Jadran« sample.

Mathematically estimated total catch per unit effort for small pelagic fish and sardine along the eastern Adriatic coast are given in Tables 4 and 5 respectively with calculated fishing effort and catch.

On the basis of the data of estimated fishing effort (Fig. 12) for the total Yugoslav sardine catch, marked and sudden decrease in total effort is observed in years following the 1966.

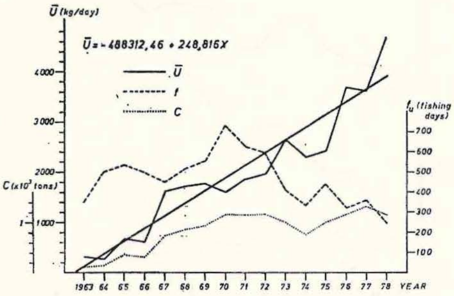

Fig. 11. Variation of annual mean abundance index (U), fishing effort (fu) and sardine catch from »Jadran« fishing organization data

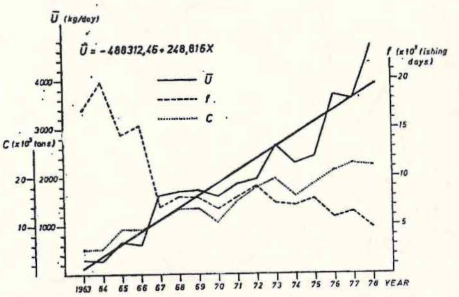

Fig. 12. Variation of annual mean abundance index (U), total catch (C) and estimated fishing effort (f) along the eastern Adriatic coast in the 1963—1978 period

It was observed in the sample that maximum fishing effort was mainly applied in August, September and October when total sardine catch was generally small (Figs. 7 and 8). Seasonal fishing effort fluctuations (Fig. 8) show higher amplitude values up to 1972 and a reduction from 1973 on.

Calculated mean annual sardine abundance as obtained from »Jadran« for the eastern Adriatic coast are given in Fig. 11. Slight increase in abundance from one year to the next is observed, with the marked increase in 1967 in relation to 1966.

Correlation between abundance index and time (years) is very significant and positive ($r = 0.945$). As seen in Fig. 11, as well, compared annual variations of fishing intensity from the »Jadran« sample show initially a tendency of increasing up to 1970 and after that a considerable reduction of fishing effort with considerably higher abundance. Similar was recorded for the total yugoslav sardine catch with the significant difference in the tendency of abundance increase in the 1963—1978 period which was accompanied by a considerable fishing effort reduction from as early as 1964. As distinct from the »sample« this reduction was recorded six years earlier (Fig. 12).

Table 6. Estimates of sardine annual equilibrium catch and respective stock size along the eastern Adriatic coast calculated on the basis of two statistics series: A for the 1963—1978 period and B for the 1967—1978 period

Year	C	f	Ū	Schaefer model A U	Schaefer model A Ce	Schaefer model A P	Schaefer model B U	Schaefer model B Ce	Schaefer model B P	Fox model B U	Fox model B Ce	Fox model B P
1963	5 023.1	16 970	296	266.351	4 519.976	7 122	—	—	—	—	—	—
1964	5 427.7	19 809	274	—383.780	—7 602.298	2 500	—	—	—	—	—	—
1965	9 490.2	14 379	660	859.690	12 361.483	23 949	—	—	—	—	—	—
1966	9 062.1	15 344	591	640.995	9 829.017	17 112	—	—	—	—	—	—
1967	11 207.2	6 922	1 619	2 567.343	17 771.148	68 646	2 632.455	18 221.854	65 976	2 443.536	16 914.159	61 242
1968	13 518.5	7 976	1 695	2 325.977	18 551.993	62 192	1 874.629	14 952.041	46 983	1 891.413	15 085.912	47 404
1969	13 497.6	7 970	1 715	2 350.251	18 496.475	62 841	1 950.843	15 353.134	48 893	1 940.765	15 273.822	48 641
1970	10 871.7	6 816	1 595	2 591.617	17 664.461	69 295	2 708.669	18 462.288	67 886	2 507.295	17 089.720	62 839
1971	14 674.3	7 949	1 846	2 332.160	18 538.340	62 035	1 894.042	15 055.740	47 470	1 905.252	15 144.849	47 751
1972	17 604.2	9 000	1 956	2 091.481	18 823.329	55 922	1 138.373	10 245.357	28 530	1 474.756	13 272.801	36 961
1973	19 530.7	7 330	2 651	2 473.911	18 133.769	66 147	2 339.103	17 145.625	58 624	2 212.897	16 220.532	55 461
1974	16 201.6	7 075	2 290	2 532.306	17 916.065	67 709	2 522.448	17 843.320	63 219	2 354.356	16 657.070	59 006
1975	18 596.0	7 697	2 416	2 389.868	18 394.814	63 900	2 072.230	15 973.045	51 936	2 024.092	15 579.438	50 729
1976	21 559.1	5 866	3 675	2 809.167	16 478.574	75 111	3 391.719	19 895.824	85 005	3 158.365	18 526.966	79 157
1977	22 763,7	6 297	3 615	2 710.468	17 067.817	72 472	3 081.830	19 406.284	77 239	2 844.312	17 910.635	71 286
1978	22 244.0	4 722	4 711	3 071.143	14 501.937	82 112	4 214.255	19 899.712	105 620	4 170.433	19 693.306	104 522

C = catch (tons)
f = fishing effort (effective fishing days)
Ū = catch per unit effort (kg)
U = estimated catch per unit effort (kg)
Ce = equilibrium catch (tons)
P = mean stock size assessed (tons)

Table 7. Estimated cath-fishing effort relationship, maximum sustanaible yield (C_{max}) in tons, optimum catch per unit effort (*U_{opt}*) in kilograms, and optimum fishing effort (*f_{opt}*) in fishing days after the surplus production models for sardine stock along the eastern Adriatic coast in the 1963—1978 (A) and 1967—1978 (B) period

Model	Series	Catch-fishing effort relationship	C_{max}	U_{opt}	f_{opt}	r	r^2
Linear	A	$U = 4.15248$ —0.000229	18 824.34	2 076.24	9 066	—0.819	0.671
	B	$U = 7.60937$ —0.000229	20 133.02	3 804.68	5 292	—0.806	0.650
Exponential	A	$U = 9.05661$ $e^{-0.000182}$	18 270.15	3 331.74	5 485	—0.962	0.925
	B	$U = 9.48325$ $e^{-0.000243}$	19 889.39	6 568.89	4 115	—0.759	0.576

Calculated correlation between the amount of fishing effort exerted and catch per unit effort for sardine catch along the eastern Adriatic coast is given in Table 7 by the entire series of statistical data divided in two series: A — for the 1963—1978 and B — for the 1967—1978. The correlations are $r_A = —0.819$ and $r_B = —0.806$ according to linear model, and $r_A = —0.962$ and $r_B = —0.759$ acording to the etponential model. They are negative and statistically very significant ($P < 0.05$). Information level which may be explained by the linear model is very high, 67.1% and 65.8% for A (1963—1978) and B (1967—1978) respectively and the exponential model 92.5% and 57.6% for and B respectively.

Resultant of correlation between small pelagic fish catch per unit effort and fishing effort is negative and statistically significant ($r_A = —0.882$, $r_B = —0.910$ after linear model and $r_A = —0.946$ and $r_B = —0.916$ after exponential model).

4.5. *Stock equilibrium state*

In Figure 14 the values *U,f* and equilibrium state lines for A (1963—1978) and B (1967—1978) data series are given. It shown that: a) in case of A, values *U,f* are below the regression line in the 1966—1974 and that in 1964, 1973 and in particularly in 1976, 1977 and 1978 show a considerable deviations and they are above the regression line; b) in case of B statistical data series, *U,f* plotted points are very close to the equilibrium state line, what is in accordance with the exponential regression line (Fig. 14). Correlation coefficient of linear model ($r_B = —0.806$) exceeds the correlation coefficient of exponential model ($r_A = —0.759$).

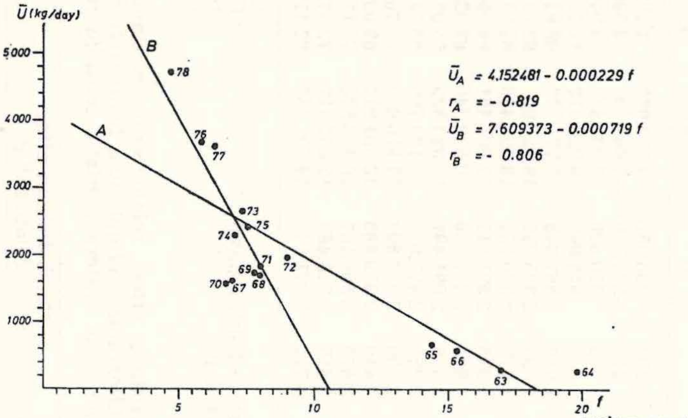

Fig. 13. Sardine population state along the eastern Adriatic coast given from the fishing effort (f) and catch per unit effort (U) relationship for the 1963—1978 (A) and 1967—1978 (B) period

Results of the adjusted model based on sardine catch data are given in Table 6. The sixth vertical column in the Table shows the estimated catches in the equilibrium for the A series in relation to applied fishing effort. The ninth vertical column shows the values of estimated catches in the equilibrium for the B series. In both cases it is apparent that sardine catches realized in 1972, 1973, 1975, 1976, 1977 and 1978 exceeded those calculated by means of the model of Schaefer. In case of the exponential model (the twelfth column) realized catches also exceeded the calculated ones in the same years.

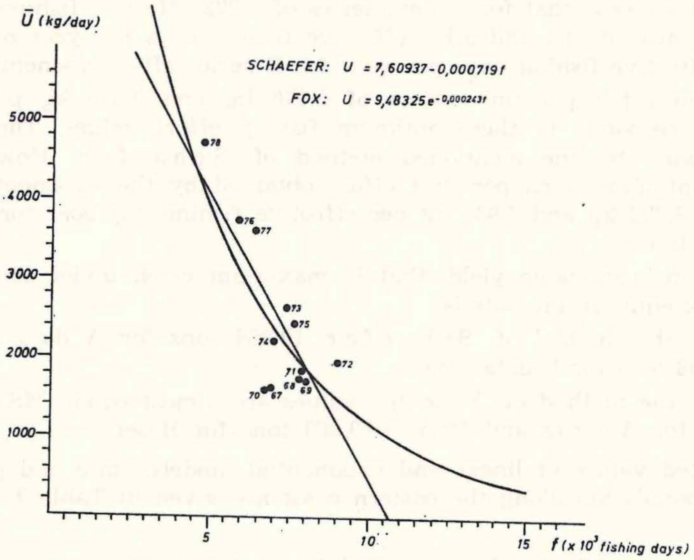

Fig. 14. Relationship between abundance index (U) and fishing intensity (f) in the eastern Adriatic sardine stock

On the basis of calculated data from Table 6, maximum sustainable yield for sardine population in equilibrium state and optimum fishing effort corresponding to that stock size (Fig. 15) for B data series, were obtained graphically. Points in the graph which represent the relation between annual catches

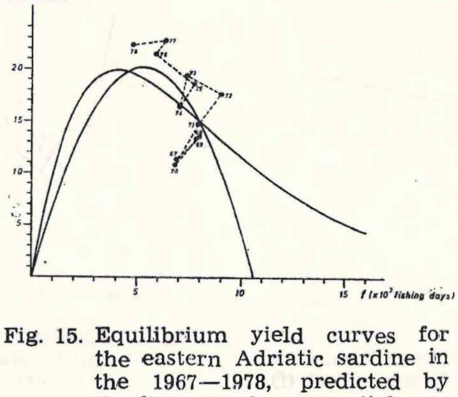

Fig. 15. Equilibrium yield curves for the eastern Adriatic sardine in the 1967—1978, predicted by the linear and exponential models

and respective fishing effort *(C,f)* are scattered along the right slope of the graphical surve, mainly close to the top of the curve and show the oscillations around *MSY* values for the last three years.

Optimum fishing effort for sardine catch along the eastern Adriatic coast estimated from the A data series is 9,067 effective fishing days per year. It considerably exceeds that for B data series of 5,292 effective fishing days per year after linear model and 5,485 effective fishing days per year or A series and 4,115 effective fishing days per year for B series after exponential model.

Optimum catch per unit effort of 2,076 kg and 3,805 kg per fishing day/boat corresponds to these optimum fishing effort values. These values were calculated by the mentioned method of Schaefer. However, the results of optimum catch per unit effort obtained by the exponential model are higher: 3,332 kg and 4,833 kg per effective fishing day/boat for A and B series respectively.

Maximum sustainable yield, that is maximum catch under the standing sardine stock equilibrium state is:

— after the method of Schaefer 18,824 tons for A data series and 20,133 tons for B data series;

— after the method of Fox the values are almost equal. MSY = 18,276 tons for A series and MSY = 19,889 tons for B series.

Calculated values of linear and exponential models, state and production of sardine population along the eastern coast are given in Table 7.

4.6. *Population catchability and mortality*

Annual coefficients of total mortality Z of the eastern Adriatic sardine stock were calculated by the Gulland (1964a) method and results are given in Table 8 and Fig. 16. Correlation between fishing effort and total mortality is statistically significant ($P < 0.05$). Accordingly, annual total mortality coefficient variations are closely connected with the fluctuations of fishing effort and, subsequently, proportional to fishing mortality (Fig. 17).

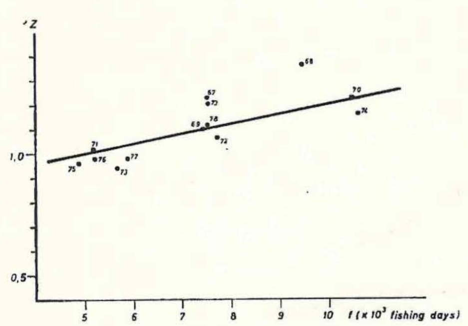

Fig. 16. Relationship between total mortality (Z) and fishing effort (f) in the eastern Adriatic sardine stock for 1967—1978 period

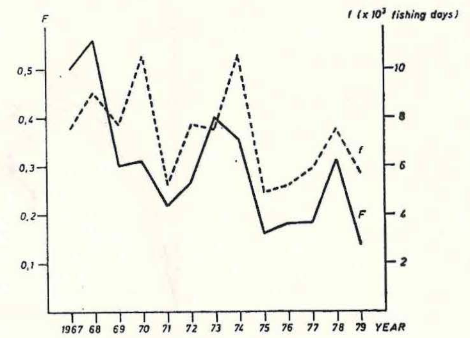

Fig. 17. Fluctuation of the fishing mortality coefficient (F) and fishing effort in the eastern Adriatic sardine stock, for 1967—1979 period

On the basis of the linear relation between estimated total mortality coefficient and related fishing effort from Table 8. natural mortality coefficient was $M = 0.802$ and catchability coefficient $q = 3.99 \times 10^{-5}$. Fishing mortality coefficient averaged F = 0.290 for the period of investigation, and its values for the given annual levels of effort are in Table 8.

Table 8. Estimated total mortality coefficient *(Z)*, fishing mortality coefficient (F) and catchability coefficient *(q)* in relation fishing effort *(f)* in fishing days, for eastern Adriatic sardine population

Year	*Z*	*f*	*F*	$q \times 10^5$
1967	1.251	7 529	0.449	5.96
1968	1.364	9 094	0.562	6.18
1969	1.103	7 473	0.301	4.03
1970	1.125	10 479	0.324	3.09
1971	1.017	5 174	0.215	4.16
1972	1.066	7 721	0.264	3.42
1973	1.202	7 534	0.400	5.31
1974	1.158	10 588	0.356	3.36
1975	0.961	4 867	0.159	3.27
1976	0.984	5 193	0.182	3.50
1977	0.986	5 890	0.184	3.11
1978	1.113	7 514	0.311	4.14
1979	0.938	5 680	0.136	2.39

From the expression (19) it was estimated that the rate of fishing at maximum sustainable yield is $F_{MSY} = 0.211$ after the linear model and $F_{MSY} = 0.164$ after the exponential model.

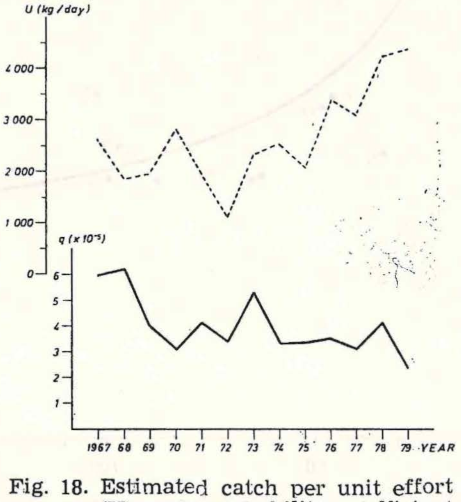

Fig. 18. Estimated catch per unit effort (U) and catchability coefficient (q) during the 1967—1978 period

In calculated catchability coefficient of Adriatic sardina stock by the method of Schaefer (1957) statistical data series was divided into two seven-year periods for which the mean coefficient $q = 3.98 \times 10^{-5}$ was obtained

Annual catchability coefficient fluctuations are given in Fig. 18. Its trend shows some persistence at a steady level in relation to catch per unit effort.

4.7. *Stock size*

With the mean catchability coefficient, the mean population size may be calculated by the $U = qP$ expression if annual mean catch per unit effort is known. If in the equation (5) the values established for U is replacted by the estimated catch per unit effort (U) for the 1967—1978 statistical data series, mean sardine stock size for the eastern Adriatic coast is obtained. Results are given in Table 6.

On the basis of optimum catch per unit effort it follows from the equation (20) that the assessed abundance of the eastern Adriatic coast sardine stock amounts to 95,335 tons after the linear model and 121,634 tons after the

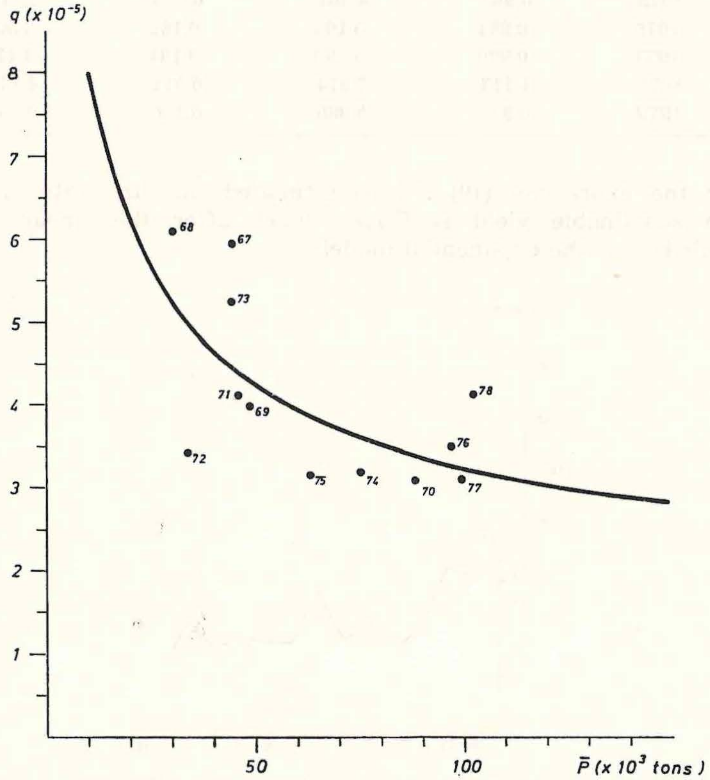

Fig. 19. Estimated average stock size (P) and catchability coeficient (q) relationship for eastern Adriatic sardine stock in the 1967—1978 period

exponential model. The maximum environmentaly limited population size may reach after the linear model 190,711 tons and after the exponential model 329,186 tons.

Linear regression of natural logarithms of catchability coefficient in relation to natural logarithms of mean annual sardine stock size is highly signihicant ($P < 0.05$) and the results shows the hollowing relationship:

$$q = a\bar{P}^{-0.393} \qquad (22)$$

The estimated relation between the q and $\bar{P}$ values and plotted $(q, \bar{P})$ points are given in Fig. 19.

5. DISCUSSION

A large number of authors dealt with the stock assessment of different edible species in the Adriatic. They, however, used different assessment methods, either those for the assessment by species or those for the assessment by principal fishing areas.

Županović (1955) assessed the Adriatic sardine stock by the method of Schnabel from sardine tagging results (Mužinić, 1950). After this author the total number of sardines amounted to 2,311,436 in 1949, what, if recalculated, would make a quantity of 77,000 tons.

Štirn (1969) calculated anchovy stock biomass to be 250,000 tons in the northern Adriatic in 1965, from mean anchovy egg number per total surface area of the area studied.

Vučetić (1976) applied the method of egg density per surface area of sardine and anchovy spawning grounds used earlier by Štirn (op. cit.) and obtained the following value: 190,000 sardine tons and 190,000 anchovy tons for the entire Adriatic.

Pucher-Petković and Zore-Armanda (1973) made an assessment of the Adriatic fish stock size from primary production and trophic steps. These authors calculated that the total amount of annual production of pelagic and demersal stocks was, on the average, 300,0000 tons in a very productive year.

From the data on primary production, trophic steps efficiency and egg and larval density of respective species, Karlovac J. *et al.* (1974) estimated that sardine and anchovy stock was 600,000 tons.

Grubišić *et al.* (1974) estimated small pelagic fish quantity in the northern Adriatic, the richest small pelagic fish fishing ground in the Adriatic, to be 37,000 tons in the area of the western Istrian coast. The basic assumption was that fish are evenly distributed in a water column.

Štirn and Kubik (1974) estimated sardine stock size in the northern Adriatic to be 100,000 tons from echosounder and trace signals. They hold that the population they studied constitutes a specific subpopulation.

Azzali *et. al.* (1976) applying ultrasonic detectors on permanent transects and surface area of 501.3 square Nm along the western Adriatic coast (Fano) assessed small pelagic fish stock to be 53,000 tons.

From echosounder and echointegrator data K a č i ć (1978) assessed Adriatic small pelagic fish stock to be 660,000 tons.

From the direct ultrasonic detection method K a č i ć (1980) estimated the total small pelagic fish stock size (anchovy, sardine) on the eastern Adriatic coast as 122,572 tons.

P i c c i n e t t i, *et. al.* (1979) assessed anchovy stock in the northern and middle Adriatic from the total number of eggs and larvae during the year (by seasons). They calculated a biomass of 927,000 tons, not taking into account egg mortality between hatching and eclosion.

In analysing catch statistics of small pelagic fish G r a n i ć *et. al.* (1980) found that MSY of small pelagic fish in the middle Adriatic was 8,830 tons at optimum fishing effort, that is 3,358 fishing days per year.

Event though these were the first attempts to quantify the long-term series of different biological data of the Adriatic edible biological resources, due to which the final assessment results considerably differ, only one of the cited papers (G r a n i ć, *et. al.*, 1980) took into account the correlation between stock size and maximum sustainable yield in relation to total fishing effort.

A l v e r s o n (1971), pointing to the shortcomings of the method which uses the primary production values for the assessment of fishing potential from fish biomass, states that the method could not resolve the crucial questions relative to fisheries: 1) which fish species are concerned and 2) what quantities of commercial fish are present in the exploited area. Namely, this author states that the method essentially differs from the tradition in fishing. While this method makes the assessment of primary and secondary production of the biomass in the widest area and unit time and obtained values refer to the thorough water mass volume of a defined aquatic area, fishing boats in practice do not operate all over an aquatic area but in the defined fishing areas which, in geographical respect are frequently far smaller.

At the same time this author holds that egg and larval distribution is of little significance for parental stock distribution over a larger part of the year. Therefore, this kind of quantitative data could not be used to design national plans of commercial fishery. This methods, however, may be useful in some specific cases for determination of production characteristics of a defined area and recruitment of defined fish stock.

The production model of S c h a e f e r was very often applied for fishery purposes, particularly for the purpose od proper management, that is exploitation and protection of marine biological resources. This model takes into account the relation between two quantitative fishery-statistics functions: catch of a species and respective fishing effort from a long term series, for either pelagic or demersal fish populations.

This production model is now fully applicable to the contemporary fishery investigations all over the world and may provide the basis for the establishment of proper national programmes for optimum exploitation of defined resources. Nevertheless, it should be pointed to some shortcomings of this model. Namely, this model ignores the biological characteristics of population recruitment rate, changes of population due to the hydrographic factor changes of marine environment, population age structure, inter- and intraspecific relations, values which are held to be constantes owing to statistical and mathematical approach. This, in some cases, affect the accuracy of obtained results and at the same time the model should be supplemented continuously.

Nevertheless, if each aquatic area (fishing ground) is observed as a complexity of interrelated and interdependent biological and hydrographic factors which are difficultly determined and quantified, no wonder that current numerical models, based on the logistic approach, use relevant numerical data, while they deal with other biological and hydrographic data only casually taking them as marginal phenomena and/or constants.

Even though a defined fish stock abundance in time and space is a direct function of species catch and respective fishing effort it should be pointed out that the majority of sources and criteria by which fishing effort is determined and on which present fishery statistics is based are defective and should be continuously supplemented and improved particularly with respect to international unification (Rotschild, 1972).

These important problems concerning monitoring of fish stock abundance all over the world, which for the most part relies on catch and respective effort statistics were discussed in detail at the ACMRR Working Party on Fishing Effort and Monitoring of Fish Stock Abundance (1976).

The papers submitted point to the fact that in a purse-seine fishery (Ulltang, 1976) and multiple-species fishery (Low, 1976) the fishing effort must be dealt with very carefully since owing to species behaviour and temporal-spatial distribution, catch per unit effort very often does not give the actual situation of population abundance.

Schaefer's model has recently been improved by adding biological functions. Thus to make the assessment of quantitative parameters more reliable Fox (1977) recommended a time series which covers at least ten years of catch and effort statistics as well as additional biological information on the stock under exploitation such as: 1) life-span of individuals of 4 to 8 years; 2) dominance in the catch of year classes of to 4; 3) age at first capture (species is recruited for the exploitation stage) of 1 to 3 years; 4) rate of fishing effort development which allows annual mean increase of catch per unit effort to range between 3 and 4% over a ten year period and 5) relatively stable environment.

With respect to the required conditions for both the linear and exponential model designs, the question is whether the available data of »Jadran« and Yugoslav statistics of sardine catch along the eastern Adriatic coast are adequate to be used in these models for sardine catch estimation in Yugoslav purse seine fishery as well as for proper management of this fishing along the Yugoslav coast.

A) Fishery-statistics meets the following requirements:

- »Jadran« statistics offers the series exceeding 10 years, from 1963—1978.
- Respective sample from the total Yugoslav catch is sufficient for the analysis of the total sardine population along the Yugoslav coast.
- Fishing effort variations give the mean increase trend of catch per unit effort in the period studied which ranges from 0.4—3.97%.

B) Biological data

Sardine of the II, III and IV age groups is predominant in the catches along the eastern Adriatic coast (Mužinić, S. 1936; Mužinić, R., 1954;

Zavodnik, 1962). R. Mužinić (1954) found that the age of sardine from the area of Vis and Biševo islands ranged from II to IX years. For the 1931 fishing season S. Mužinić (1936) reported that the age of predominant sardine groups was 0—IV years in the areas closer to the coast. More offshore, however, sardine of the III year of age was predominant. Zavodnik (1962) found sardine age groups of I—IV years in the northern Adriatic.

Judging from a defined indicators Pucher-Petković and Zore-Armanda (1973) assume that sardine are fully recruited after the third year provided that climatic and biological conditions of marine environment are favourable. However, from the data from northern Adriatic (Zavodnik, unpublished data) it may be assumed that sardine recruitment takes place in the second year.

As shown by these statistics and biological data sardine population from the eastern Adriatic coast meets the requirements of the surplus-yield model.

Some authors hold that hydrographic factor of marine environment as well as species biological characteristics significantly affect seasonal catch fluctuations. Thus, Županović (1968) accounted for the Adriatic sardine catch fluctuations by climatic and hydrographic fluctuations of marine reporting significant correlation between marine environmental factors and Adriatic sardine catch. In analysing the Adriatic sardine catch over 100 years as affected by solar activity Regner and Gačić (1974) found marked oscillations with eleven year periods what indicates that solar activity and sardine catch and, consequently, sardine stock size are interdependent.

Trend of annual small pelagic fish catches along the eastern Adriatic coast shows continuous increase with index b = 833 tons and b = 1132 tons for sardine. Mužinić (1967), however, reported quite different sardine catch trend in the 1947—1964 period. Namely, this author found a trend of sardine catch decline in this period (b = —0.17 thousand tons), accompanied with the increase of total annual catch of the other small pelagic fish (sprat, anchovy, mackerel and spanish mackerel): b = 0.47 thousand tons.

Three different seasonal trends of catch per unit offort may be distinguished from the observed sardine catch data series: in the 1963—1966 period maximum values were recorded in autmun, in the 1967—1972 they prevailed in spring and in the 1973—1978 higher catches per unit effort were recorded in autmun and winter (December). The lowest abundance indexes were found for summer months. This different seasonal values of abundance indexes are not indicative of an actual increase and decrease of sardine population size, but rather of the degree of aggregations due to biological requirements and migrations.

The analysis of catch per unit effort during small pelagic fish fishing season renders possible the observations of seasonal fluctuations of abundance of a defined population. Namely, it is often the case that the degree to which the population is within the reach of fishing gear which are determined by the population distribution in space and time (Gulland, 1968). The success of comercial fishing depends, to a greater or lesser extent, on seasonal changes of marine environmental factors (hydrographic, biological) assuming that the fishing efficiency of the gear used is practically constant. If the degree to which population is available is proportional to the total population which inhabits a defined geographical fishing area (Ahlstrom, 1960), species availability should be observed as a change in the rate of distribution and aggregation of the population of an ecosystem (Margaleff, 1960). Thus in case of migratory species proportion of population which inhabits a defined fishing area is constantly changed with the changes of seasons.

Based on tagging experiment data Mužinić (1950, 1954, 1973) established the central Adriatic sardine onshore migrations at the beginning of spring where they stay to the beginning of autumn when they undertake the seaward migrations. These observations were supported by the analysis of sardine catch data (Županović, 1955).

The northern Adriatic sardine was found to inhabit the eastern part of the northern Adriatic during summer. At the beginning of autumn, when they begin to spawn, the population moves towards the middle Adriatic. Thus, in December sardine are concentrated in the vicinity of Susak island and south from it. After spawning, in Jaruary and February, sardine migrate again towards the shallow northern Adriatic (Zavodnik 1968; Škrivanić and Zavodnik, 1973; Štirn and Kubik, 1974).

The observations of Mužinić (1974) show wide horizontal sardine distribution in the Adriatic. Škrivanić and Zavodnik (1973) also found wide sardine distribution in the Adriatic. In addition, they established that at the beginning of summer hydrographic properties of the intermediate sea water layers, which sardine mainly inhabit, are favourable for an extensive migration all over the area of sardine distribution, however of the limited extent.

The analysis of seasonal fluctuations of sardine population abundance index along the eastern Adriatic coast shows heterogeneous population distribution (Alegría Hernández and Jukić, 1981). Winter fishing showed the greatest sardine population abundance index and summer fishing showed the lowest abundance index.

From the sardine catch statistics for the area of Castellon in Spain for the 1957—1958 period, Larrañeta (1967) reported heterogeneous sardine distribution in space. This author found the greatest aggregations in October 1957 and April 1958 and the lowest ones in June 1957. Mužinić, (1954) holds that the autumn aggregation period of sardine is in fact the stage of prematuration and first spawning. The same vas reported by Gamulin (1954) and Karlovac (1964).

The analysis of the properties of total small pelagic fish catch along the eastern Adriatic coast shows that the sardine »sample« is sufficiently representative statistics and that the bias is minimised in estimation of total fishing effort exerted to sardine catch.

Gulland (1968), realizing the importance of at least a part of information on fishing effort, gave the expression by which the total fishing effort may be calculated provided that two values are known: total species catch and catch per unit effort of the same species of the sufficiently representative sample (group of vessels). We used this expression for the total fishing effort estimation:

$$\text{Total fishing effort} = \frac{\text{total catch (of a species)}}{\text{catch per unit effort (of a group of vessels)}} = \frac{C}{U}$$

In collecting fishery statistics Brander (1975) pointed out that in many cases data on fishing effort were not uniform and included significant statistical errors. It may be said that a good piece of information often refers to only one vessel type within a defined fishing area and defined time. If defined species catch is known, this author holds that the total fishing effort exerted to the respective species catch realized from a defined area in defined time may be estimated by dividing it by the catch per unit effort of the group of vessels, the data of which are available and reliable.

Fishing effort has frequently been defined in terms of the activity of fishermen to extract fish or in terms of energy applied or money spent. This means that simply a fraction of population is removed per each fishing effort unit and at the same time fishing effort is the function of population fishing mortality and catchability coefficient or $F = qf$ (Garrod, 1976).

Data on fishing effort per, for example, fishing day have quite different meanings and values in different types of fishing such as in purse-seining or trawling. Namely, in trawling (towing o bottom trawls) the variables such as ship engine power, vessel size and trawl net size, are directly related to the stock under exploitation. Since demersal populations are most frequently evenly distributed in close vicinity to the bottom, relative and absolute abundance of defined fish population are relatively easily estimated in this kind of flishing.

On the contrary, in the case of encircling gears: purse-seining and tuna fishing, by which pelagic fish are caught predominantly by night (sardine, anchovy, sprat) and big pelagic fish (tuna) by daylight, fishing effort per day depends on several essential factors:

a) those of subjective nature (fishermen and crew experience)

b) biological characteristics of population (behaviour, population distribution in time and space) and

c) technical and technological characteristics of a fishing unit (nets, vessel being well or poorly equiped with navigational and electronic devices). Therefore, for the standardization of criteria on fishing effort in this kind of fishing, the following values are recommended to be used in addition to fishing effort per unit time (hour, day-night): total number of shots of purse seine (Beverton and Parrish, 1956), fuel consumption per vessel (Levi, 1976) and total number of hours spent in searching for fish what is often the case in tuna fishing (Schaefer, 1957).

In any case, catch per unit effort per unit time, used in pelagic fish abundance index estimation is a value liable to considerable variations since it is affected by the following factors: species distribution, population aggregation characteristics, density and distribution in space and consequently species vulnerability. Therefore, in case of pelagic fish populations production models are not always applicable.

In case of sardine fishing the unit fishing effort should be calculated as the effective fishing effort of a purse-seiner day or night. That is, a single shot of a purse-seine of vessels of the same category operating in the same fishing area (eastern Adriatic coast) and the technical characteristics and construction (length, net depth. engine power, vessel's dimensions, ultrasonic detectors) of which are very similar, corresponds to a fishing day.

Technical characteristics as well as fishery strategy characteristics of our »sample« helped us to minimize the errors in the sardine abundance index estimation for the eastern Adriatic coast. The same fishing effort unit is recommended by Larrañeta (1967). For fishing effort calculation in purse seine herring fishing in Norway waters, Østvedt (1964) suggests the use of the data on effective boat days (with catch).

Since fishing effort of »Jadran« purse-seiners was in the 1963—1978 period mainly applied for fishing for sardine, as a major commercial species, it is useless in the calculation of other pelagic fish (anchovy, sprat) abundance.

Due to the complexity of interpretation and presentation of the original data as well as due to the dependence between hydrographic, biological and fishery-technical factors in estimation of the state and maximum sustainable yield of pelagic resources in particular, we were forced to control continuously the reliability of available original data.

Namely, the abundance trend of sardine catch realized by »Jadran« (Fig. 11) and as shown by the data on the total Yugoslav catch (Fig. 12) it appears that in the 1963—1978 period two periods of different sardine abundance indexes may be clearly distinguished: the former up to 1967 with lower abundance index and the latter from 1967 on with considerably higher values.

Even though general trend of abundance was an increasing one over the sixteen year period (1963—1978) referred to as A data series in analysis, our basic conclusion on sardine stock size maximum sustainable yield and maximum fishing effort required are based on the B data series for the 1967—1978 period owing to the following reasons:

— since in the period up to 1967 technological changes and consequently the strategy of purse-seiners (seine construction, instalations, learning period and use of ultrasonic detectors) were objectively poorer and therefore affected fishing activity by limiting it in space, fishery statistics for that period was not reliable and probably, lead to an understimation of abundance, which means that catch per unit effort would not represent actual natural population biomass of sardine along the Yugoslav coast.

— prior to echosounder introduction »Jadran« purse-seiners operating range was limited and they mainly fished in the known fishing localities.

Catch per unit effort as an index of abundance i.e. stock size, and fishing effort as an index of fishing mortality are mathematically related to the rate of catchability coefficient variations according to the expressions (3) and (5).

The values of catchability coefficient for the Adriatic sardine population calculated by the Schaefer (1957) interative method ($q = 3.98 \times 10^{-5}$) and Gulland (1964) method ($q = 3.99 \times 10^{-5}$) are very similar.

In his criticism of the Schaefer's method for species catchability coefficient calculation Ricker (1975) states that this approach includes a considerable number of potential errors, particularly in using two equations with three unknowns and that the author arbitrarily divided a long-term series in two parts, the first series with one kind of values and the second series with, most frequently, values different from those of the first series. This means that the data may be divided into two equal parts or 1/3 in relation to 2/3 what may give quite different q values.

Županović (1955) calculated fishing mortality of sardine population from the central Adriatic ($F = 0.17$) from tagging data for 1949 (Mužinić, 1950). This author holds that F is lower than actual owing to some technical errors in tagging experiment. Since the data refer to the state of stock of the immediate post-war period when stock vulnerability to fishing gear was reduced, this value from the expression (3) for our 1963—1978 data series was not used for the calculated of q and stock size.

Ulltang (1976) considers that if the exponent in the relationship between q and stock size is $0 < b < 1$, it will mean that there is an increase in catch per unit effort with increasing stock size. The exponent of the function (22), as well which is lower than 1, showed that catch per unit effort was a good index of abundance and accordingly was increased with the stock size increase.

It was earlier reported (Palloheimo and Dickie, 1964; Pope and Garrod, 1975; Ulltang, 1976; Sissenwine, 1978) that catchability coefficient might be inversely related to stock size (Fig. 19). This means that only a part of the population which inhabits a defined area was under continuous exploitation.

Annual sardine catchability coefficient variations as related to the abundance index variations are indicative of the fact that the trend of catchability coefficient reduction over the analysed period was probably not due to the natural changes in the total stock size in the exploited area, but to the stock aggregation changes in space and fishing strategy. This means that the geopraphic distribution area of sardine population is not reduced but is liable to changes in space and time (seasonally) dependently on its biological requirements (feeding, spawning) due to which population vulnerability is changed, as well. The analysis of seasonal catchability cofficient variations of sardine population along the eastern Adriatic coast showed maximum in autumn and spring and minimum in summer (Alegría Hernández and Jukić, 1981).

From the data on the biology of sardine population from the eastern Adriatic coast and using the expression for the calculation of natural mortality coefficient of fish populations (Rikhter and Effanov, 1976, after Larrañeta, 1979):

$$M = \frac{1.521}{x^{0.72}} - 0.155 \qquad (23)$$

where x is the dominant age at first maturity, we found that natural mortality coefficient of the Adriatic sardine which attain first sexual maturity at 1.5 to 2 years of age was somewhere between $M = 0.708$ and $M = 0.980$.

Namely, the calculated value of $M = 0.802$ may be held to be relatively real value of the Adriatic sardine population natural mortality. This value is almost equal to $M = 0.768$ found for sardine along the Atlantic coast of Spain (López-Veiga, 1979) and sardine of the western Mediterranean coast $M = 0.920$ and $M = 1.160$ (Larrañeta, 1979). The same author holds that natural mortality values of $M = 0.36$ and $M = 0.49$) obtained by Taylor (1950) and Beverton (1963) respectively, were too small with respect to the biological and ecological properties of sardine population. Murphy (1966) obtained $M = 0.38$ for sardine *(Sardinops caerula)* population from the Pacific ocean (California), but with the information derived from the assessment of the population from egg survey, the estimate was $M = 0.8$. This author also holds that natural mortality coefficients of $M = 0.2$ to $M = 0.4$ are too small, particularly in case of short-living fish species.

Annual coefficient of fishing mortality was calculated from the $Z = F+M$ expression. Results show marked decrease of F, and accordingly the exploitation rate decreases from $E = 0.41$ in 1968 to $E = 0.15$ in 1978. This is probably due to the relationship between sardine stock size which is constantly increasing and fishing effort, which shows a trend of decrease even though within narrow ranges.

The analysis of results of surplus- production model for sardine population along the eastern Adriatic coast and taking into account that linear correlation coefficients ($r = -0.806$) and exponential correlation coefficients ($r = -0.759$) are practically statisfactory, showed that the number of fishing days which should be realized during the year ($f_{opt} = 5{,}292$ and 4,115 respectively) was lower than mean number of fishing days realized so far ($\bar{f} = 7{,}127$). However, marked reduction in total Yugoslav fishing effort from 6,922 fishing days in 1967 to 4,722 fishing days in 1978 is observed. Effective fishing effort has recently varied about the value of calculated optimum fishing effort.

Calculated annual mean sardine abundance index, that is catch per unit effort, indicates gradual increase from one year to the next, from 1.619 tons per boat day in 1967 to 4.711 tons per boat day in 1978. The 1978 value is in agreement with the optimum catch per unit effort $U_{opt} = 3{,}805$ tons per boat day and $U_{opt} = 6{,}569$ tons per boat day after linear and exponential models respectively.

Scattering of points (U, f) in Fig. 14 shows that the catch per unit effort and respective fishing effort data are better fitted by linear curve what has already been shown by the correlation coefficient. This means that linear model satisfactorily describes stock equilibrium situation.

Since catch per unit effort is an abundance index and at the same time the index of stock size, constant population growth with the reduction of applied fishing effort is evident. The population of 65,000 tons in 1967 amounted to 105,000 tons in 1978. All the points (C, f) from Fig. 15 are scattered close to the calculated curves what is indicative of the satisfactory population increase.

The linear model postulates that the maximum sustainable yield is obtained when the stock size is half the maximum population size. On the basis of the analysis of catch and effort statistics sardine stock size at *MSY* value was 95.335 tons and the estimated maximum population size value was 191 thousand tons. In contrast, the exponential model predicts that the maximum sustainable yield would be obtained at about 37% of the maximum (Fox, 1970). For sardine from eastern Adriatic coast, population size at *MSY* was 121,634 tons and estimated *Pmax* value was 329 thousand tons. Calculated quantities are very close to Vučetić (1976) and Kačić (1980) estimates.

Estimated index of sardine population natural increment in the 1967—1978 period is, on the average, $h(P) = 0.367$. This value exceeds calculated fishing mortality coefficient mean ($F = 0.290$). It follows from the equation (1) that the fraction removed from the population by fishing is slightly lower than maximum sustainable yield. This means that sardine catch along the eastern Adriatic coast may be very little increased since any greater increase would significantly affect the equilibrium of the population under exploitation.

6. CONCLUSIONS

The production models of Schaefer (1954) and Fox (1970) were applied for the eastern Adriatic coast small pelagic fish stock state and abundance assessment. Particular attention was given to sardine, *Sardina pilchardus* Walb. The following was established:

1. Trend of annual small pelagic fish catch, and particularly sardine catch, with the correlation coefficients in relation to time $r = 0.857$ and $r = 0.956$ respectively, showed positive value, that is continuous increase along the eastern Adriatic coast in the 1963—1978 period. Catch increase trend $b = 833$ tons per year. Small pelagic fish catch amounted from 15,963 tons in 1963 to 29,712 tons in 1978.

2. Sardine make, on the average, 61,1% of the Yugoslav total annual small pelagic fish catch with the 29.1—83.7% range. Annual sardine catch amounted from 5,023 tons in 1963 to 22,244 tons in 1978. Sardine catch increase index was $b = 1,132$ tons/year in the analyses period. This increase was probably due to the natural increment of the whole Adriatic population as well as to the improvement of fishing strategy and techniques.

3. After the catch statistics it appears that sardine catch is of seasonal character as well as other small pelagic fish catch. Thus, bigger total catches are mainly realized in autmun (October, November) and spring (May) periods when population abundance values are higher. The highest fishing effort is applied to summer catches however with very small population abundance values. The highest sardine population abundance values were recorded in winter months.

4. Two values of total fishing effort, that is number of effective fishing days may be distinguished: the first significantly higher in the 1963—1966 period and the second lower one in the 1967—1978 period.

5. Reduction of fishing effort with the increased catch per unit effort from 1967 on was due to the increased fishing efficiency of purse-seiners by the introduction of echodetectors.

6. Sardine population abundance showed two markedly distinct values for the period of investigations: considerably lower one in the 1963—1966 period and the higher one in the 1967—1978 period.

7. Two time series were analysed on the basis of sixteen year catch statistics available and taking into account technical and technological changes in commercial purse-seiners: (A) time series for 1963—1978 and (B) time series for 1967—1978.

8. Sardine population mortality coefficients were calculated from sardine monthly catches and respective fishing effort statistics for the 1967—1978 period:

— total popuhation morality ranges from $Z = 0.938$ to $Z = 1.364$;

— sardine population natural mortality coefficient is $M = 0.802$. It seems to be in agreement with biological and ecological characteristics of this species and with the values obtained for other areas (Mediterranean, Pacific);

— fishing mortality coefficient is, on the average, $F = 0.290$. Calculated value is probably low for this fish species. At the same time fishing mortality coefficient tred is reduced with fishing effort reduction.

— rate of fishing at maximum sustainable yield was $F_{opt} = 0.2$.

9. Calculated catchability coefficient of the eastern Adriatic coast sardine population is $q = 3.99 \times 10^{-5}$.

10. Catchability coefficient was found to be reduced and inversely related to population size. It may be assumed that only a part of the eastern Adriatic sardine population has been exploited.

11. Linear and exponential correlation between catch per unit effort and respective fishing effort are statistically negatively significant ($r = -0.806$ and $r = -0.759$ respectively). They are indicative of a marked dependence between these two parameters. Their functional dependence renders possible the application of surplus production model to sardine catch along the eastern Adriatic coast.

12. Biological characteristics of the population under exploitation meet the following requirements for better and more correct use of global model results:

— that the observed period of statistics covers the 16 years data on catch and respective fishing effort;

— that sardine of the II, III and IV age groups are predominant in the catches;

— that sardine are recruited (enter the stage of exploitation) in the II and III year of age.

13. It was calculated by Schaefer's and Fox's production models that optimum sardine stock size along the eastern Adriatic coast was 95,355 tons and 121,634 tons respectively in the 1967—1978 period. Stock size was 66,000 tons in 1967 and increased to 106,000 tons in 1978.

14. The estimates of maximum population size limited by environmental conditions of the eastern Adriatic would be 195 thousand tons after linear model and 329 thousand tons after exponential model.

15. Sardine stock size along Yugoslav coast allows the following optimum fishing biological exploitation levels:

— optimum catch per unit effort of 3,805 to 6,565 kg per boat during a effective fishing day (purse-seining);

— optimum fishing effort in sardine catch should range between 4,115 and 5.292 effective fishing days during the year;

— maximum sardine sustainable yield per year should not exceed 20,133 tons.

16. According to the estimated maximum sustainable yield values the exploitation rate of sardine population in analysed fishing period averaged $\bar{E} = 0.26$.

17. Existing exploited resources of sardine along the eastern Adriatic coast and Yugoslav total annual sardine catch, has, particularly for the several last years, varied about optimum values of sardine population biological production. Therefore, not any significant increase of annual sardine catch may be expected in the period to come, provided that increased catch would not significantly affect the existing stock size.

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PROCJENA ABUNDANCIJE PELAGIČNE RIBE NA ISTOČNOJ OBALI JADRANSKOGA MORA S POSEBNIM OSVRTOM NA POPULACIJU SRDELE *SARDINA PILCHARDUS* WALB.

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KRATAK SADRŽAJ

Srdele (*Sardina pilchardus* Walb.) je najvažnija pelagična vrsta istočne obale Jadranskog mora. U ukupnoj lovini Jugoslavije čini u prosjeku 47% ukupne lovine SFRJ. Smatra se da na istočnoj obali Jadrana obitava jedin-

stveni eksploatacioni stock, iako na temelju ispitivanja odnosa između dužine ribe i dužine glave, broja branchispina i težine, može se pretpostaviti da postoji određena fiziološka razlika između populacije srdele sjevernog i srednjeg Jadrana, uz mogućnost postojanja mješanja na mrijestilištima.

Kako između intenziteta ribolova i veličine populacije postoji funkcionalna ovisnost koja se direktno odražava na visinu ribolovne smrtnosti i time na sveukupni rast populacije, to smo u radu nastojali utvrditi ovu povezanost i dati odgovor na pitanja: kolika je sirovinska baza srdele u Jadranu, koliki je maksimalni nivo dozvoljenog iskorištavanja eksploatirane populacije i koliki je nivo potrebnog intenziteta ribolova za dozvoljeni optimum lovine srdele.

Studija obuhvaća statističke podatke ukupne lovine srdele i odgovarajućeg ribolovnog napora za vremensko razdoblje 1963—1978., u kojoj su upotrebljeni produkcioni modeli: linearni (S c h a e f e r, 1954) i eksponecijalni (F o x, 1970).

U ukupnoj godišnjoj lovini male plave ribe SFRJ, srdela u prosjeku čini 61,1% s rasponom od 29,1% do 83,7%. Godišnja lovina srdele od 5.023 tona u 1963. godini povećana je do 22.244 tona u 1978. godini. Indeks rasta lovine srdele u analiziranom razdoblju bio je 1.132 tona/godinu. Lovina srdele kao ostale male plave ribe sezonskog je karaktera i veće ukupne lovine se općenito ostvaruju u jesenskom i proljetnom razdoblju, kad su vrijednosti izračunatog indeksa abundancije populacije više. Ljetne lovine odgovaraju najvišim vrijednostima utrošenog efektivnog ribolovnog napora i veoma niskim indeksima abundancije populacije.

Izračunato je, da pri stalnom trendu smanjenja ribolovnog napora, lovina po jedinici napora, tj. indeks abundancije pokazuje tendenciju rasta ($b = 248{,}82$ kg/danu). Ova relacija je uvjetovana, vjerojatno, povećanjem ribolovne efikasnosti brodova plivaričara uvođenjem ultrazvučnih detektora, uz povećanje veličine populacije.

Linearna i eksponencijalna korelacija između lovine po jedinici napora i odgovarajućeg ribolovnog napora su negativno signifikantne ($r = 0{,}806$, $P < 0{,}05$ odnosno $r = -0{,}759$, $P < 0.05$). Njihova funkcionalna ovisnost dozvoljava metodološki pristup globalnog produkcionog modela. Biološke karakteristike eksploatirane populacije srdele zadovoljavaju također uvjete za bolje i točnije korištenje modela.

Produkcionim modelima izračunato je da se veličina populacije srdele uzduž istočne obale Jadrana, za period 1967—1978. godine, kreće od 95.355 tona prema S c h a e f e r o v o m modelu do 121.634 tona prema F o x o v o m modelu. Veličina populacije bila je 66.000 tona u 1967. godini i 106.000 tona u 1978. godini. Maksimalna veličina populacija ograničena ambijentalnim prilikama sredine bila bi 195.000 tona prema linearnom modelu i 329.000 tona prema eksponencijalnom modelu. Navedena veličina populacije omogućava slijedeće optimalne nivoe iskorištavanja:

— optimalna lovina po jedinici napora od 3.805 do 6.565 kg po brodu tokom jednog efektivnog ribolovnog dana;

— optimalni ribolovni napor u lovu srdele trebao bi se kretati u rasponu između 4.115 i 5.292 efektivnih ribolovnih dana tokom jedne godine;

— maksimalna godišnja lovina srdele koja odgovara maksimalnom dozvoljenom nivou iskorištavanja ne bi smjela biti veća od 20.133 tona.

Koristeći statističke podatke mjesečnih lovina srdele i odgovarajućeg ribolovnog napora za razdoblje 1967—1979. godine, izračunati su koeficijenti smrtnosti populacije. Koeficijent ukupne smrtnosti nalazi se u rasponu od $Z = 0,938$ do $Z = 1,364$. Koeficijent prirodne smrtnosti srdele iznosi $M = 0,802$, što je u skladu s biološkim i ekološkim karakteristikama vrsta i s vrijednostima izračunatim za druga područja (Mediteran). Koeficijent ribolovne smrtnosti u prosjeku iznosi $F = 0,290$.

Vrijednost izračunatog koeficijenta lovnosti populacije srdele iznosi $q = 3,99 \times 10^{-5}$. Godišnje vrijednosti q pokazuju slabi trend smanjenja u odnosu na lovine po jedinici napora. Iz analiza godišnjih promjena koeficijenta lovnosti može se pretpostaviti da se areal koji populacija srdele obitava prostorno i vremenski mijenja zbog bioloških potreba. Nađeno je da je koeficijent lovnosti obrnuto proporcionalan veličini populacije, što znači da je samo dio ukupne populacije bio stalno eksploatiran.