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THE ASSESSMENT OF THE STATE AND MAXIMUM BIOECONOMIC SUSTAINABLE YIELD OF PELAGIC AND DEMERSAL RESOURCES IN THE CENTRAL ADRIATIC

PROCJENA STANJA I MAKSIMALNOG BIOEKONOMSKOG NIVOA ISKORIŠTAVANJA PELAGIČKIH I DEMERZALNIH RESURSA SREDNJEG JADRANA

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Taking into account the methodology of production model (Fox, 1970) and available fisheries statistic data: annual catches of pelagic and demersal, (bottom trawl and coastal fisheries) fish, crustaceans and cephalopods populations, of cooperative and private fishing sectors in the central Adriatic, as well as estimated fishing effort for the period 1961/1975 year it has been tried to estimate the following bioeconomic factors, for management purposes of:
— sustainable yield of existing pelagic and demersal resources of the central Adriatic;
— to assess the possibilities for a higher catch production (yield), as well as to optimize fishing effort.
In this study statistic data of total yearly pelagic and demersal species catch have been considered from Republic Statistics Departament, while more precise statistical data od one cooperative, »Jadran« — Split, taken as »representative statistics samples« have been used in calculating, estimation of total fishing effort for purse-seining and trawling fishing operations for fifteen years period.

INTRODUCTION

Fisheries biological investigations of quantitative and qualitative pelagic and demersal resources characteristics, in the central Adriatic, began before the 2nd World War (Zei and Sabioncello, 1940) and were intensified immediately after the War treating ichthiologic problems of this area in connection to the ecologic and hydrographic conditions of the analised area.

Studies of demersal resources along the eastern Adriatic coast, especially central Adriatic (Karlovac, O., 1959; Županović, 1953, 1961 and 1963; Jukić, 1972, 1975), are of significant importance.

Ichthiological and ecological studies of pelagic resources mainly »small pelagic fish« in the central Adriatic have started more recently. Because of greater economic importance of small pelagic fish populations, especially sardines and anchovies, the importance of fisheries studies on resources quantity aspects and the space and time distribution of pelagic populations becomes evidently important in the last decade (Županović, 1955; Mužinić, 1967, 1974; Grubišić, 1968; Regner and Gačić, 1974; Kačić, 1973). During the last several years direct methods for stock size assessment of small pelagic fish populations have been used, such as acoustic estimation (Kačić, *et. al.*, 1976) and method for evaluation of parental stock size by means of eggs and larve quantity (Piccinetti *et. al.*, 1979).

Preliminary assessments of demersal resources and exploatation level of more prominent fishing resources in the central and northern Adriatic (Jukić, 1975; Jukić and Piccinetti, 1979; Levi, 1976) have been carried out in recent time, using fisheries statistic data od annual catch and, mainly, estimated fishing effort.

The usage of the production model technique (Schaefer, 1954; Fox, 1970) is of the most recent origen in fisheries biological studies in Adriatic sea (Alegria-Hernández and Jukić, 1980 — in press) whose methodology have been also used in this study for management purposes.

MATERIAL AND METHODS

With assumptions that hydrographical sea water properties do not influence very much on size of studied pelagic and demersal populations, i.e. its has been taken that environmemtal factors are constant except »predation« by man, that is amount of fishing. Relationships between the fishing effort (f) and catch per unit effort ($\bar{U}$) that is abundance, fishing effort (f) and equilibrium yield (Y_E), then population size (P) and equilibrium yield (Y_E), are treated by production model (Fox, 1970). With regard to achieved results, i.e. coefficient correlation (r) between catch per unit effort ($\bar{U}$) and estimated effort (f) in the case of exponential relationship is more significant (r = —0,75) than in linear relationship, and because population growth is based upon Gompertz exponential growth function (Rittenburg, 1960), Fox's exponential model has been undertaken in this study, where the following relationships are used:

1. Population size (P) and equilibrium yield (Y_E)

$$Y_E = Pk\,(\ln P_\infty - \ln P) \qquad (1)$$

where k is the constant of the population increase rate.

2. Fishing effort (f) and catch per unit effort ($\bar{U}$)

$$\bar{U} = U_\infty\, e^{-bf} \qquad (2)$$

3. Fishing effort (f) and equilibrium yield (Y_E)

$$Y_E = fU_\infty\, e^{-bf} \qquad (3)$$

This the so called exponential model and has the following characteristics:

– The optimum fishing effort (f_{OPT}) which produces equilibrium yield is obtained by equaling the derivation of function (3) with zero, so it is

$$f_{OPT} = b^{-1} \quad (4)$$

— The optimum catch per unit effort (UOPT) will be

$$U_{OPT} = U_{\infty} e^{-1} \quad (5)$$

— The maximum equilibrium yield (YEMAX) will be

$$Y_{EMAX} = U_{\infty} b^{-1} e^{-1} \quad (6)$$

— The constant of the rate of population increase (k)

$$k = qb^{-1} \quad (7)$$

Two explicit assumptions are contained in this production model: the dependance of the average population size to the fishing effort level, and the dependence of the equilibrium yield on the average population size and the fishing effort. These assumptions are propably not always perfectly fulfilled because the changes in the sea environmental conditions resulting in the fluctations of the fish population size and, accordingly, in the size increase on each level of fishing effort. It is, nevertheless, possible to treat these fluctuations as the edge deviations of the average conditions predicted by the model.

Statistical data considered in this study of the central Adriatic resources were gathered from the review »Sea Fisheries« Zagreb, as well as from the Republic Bureau of Statistics of Croatia.

To define the function of equilibrium state, i.e. $U = f \cdot (f)$ it is necessary to calculate the average catch per unit effort (abundance) by relation:

$$\bar{U} = \frac{C}{f} \quad (8)$$

for pelagic and demersal catches.

RESULTS

The used data in the model are summarized, for cooperative and private fishing sector. Although they did not include the 1976, 1977 and 1978 year time, period is long enough to enable us for assessment of the optimum sustainable fishing effort, the optimum catch per unit effort and the maximum equilibrium yield.

Obtained data from the tables 1 and 2 found, third (f) and fourth (U) columns, have been automatically processed in order to get the shape funtion (2). In fact it has been carried out the aproximation of the empiric points (f_i, U_i) where i = 1961, 1962, ..., 1975, with the curve which is the basic result in this study of optimum fishing effort, optimum catch per unit effort, maximum equilibrium yield for pelagic and demersal population.

Table 1. Annual catch o purse-seining fishing operation (C) in the central Adriatic with corresponding calculated fishing effort (f) and catch per unit effort ($\bar{U}$) for 1961—1976 year.

Year	C (tons)	f (fishing days/year)	$\bar{U}$ (kg/day/seiner)
1961	7.301	5.540	1.316
1962	4.658	3.540	1.316
1963	5.680	4.316	1.316
1964	7.480	4.471	1.673
1965	7.026	5.759	1.220
1966	8.906	5.825	1.529
1967	10.157	3.620	2.806
1968	11.370	3.890	2.923
1969	10.042	3.751	2.677
1970	8.252	3.605	2.289
1971	10.321	3.948	2.614
1972	9.750	3.413	2.856
1973	10.739	3.533	3.035
1974	8.420	2.712	3.105
1975	10.260	3.406	3.011

Table 2. Annual catch of bottom trawl and small scale coastal operations (C) in the central Adriatic with corresponding calculated fishing effort (f) and catch per unit effort ($\bar{U}$) for 1961—1975

Year	C (tons)	f (fishing day/year)	$\bar{U}$ (kg/day/trawler)
1961	4.025	10.280	391
1962	2.996	11.332	264
196ß	2.793	10.508	266
1964	4.453	12.247	364
1965	4.664	16.250	287
1966	4.312	17.051	253
1967	4.617	16.310	283
1968	4.615	13.148	351
1969	4.165	11.466	363
1970	4.218	11.946	353
1971	4.251	12.063	352
1972	4.058	13.402	303
1973	3.703	11.123	333
1974	4.462	12.014	371
1975	4.177	10.253	407

The results obtained for pelagic resources in the central Adriatic are:

1. The shape function (2), which illustrates the dependence of the catch per unit effort to the fishing effort

$$U = 7148{,}637e^{-0{,}0002978f} \qquad (9)$$

2. The average number of the fishing days

$$\bar{f} = 4.089 \qquad (10)$$

3. The average of catch per unit effort (in kg/day)

$$\bar{U} = 2.114 \qquad (11)$$

4. Correlation coefficient

$$r = -0,750 \qquad (12)$$

5. The optimum number of fishing days, by formula (4)

$$f_{OPT} = 3.358 \qquad (13)$$

6. The optimum catch (in kg/day) by the formula (5)

$$U_{OPT} = 2.630 \qquad (14)$$

7. The maximum equilibrium yield (in tons) by the formula (6)

$$Y_{EMAX} = 8.831 \qquad (15)$$

The function graph (9) is set out in the figures 1 and 2 which enable to see that the catch per unit effort oscilates around the equilibrium state.

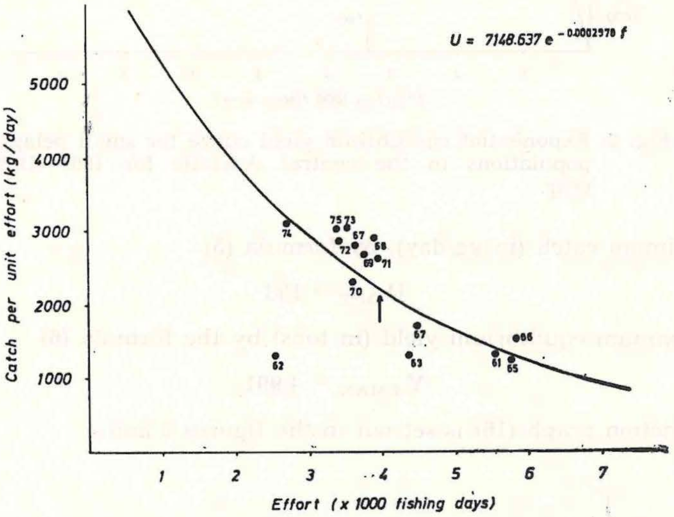

Fig. 1. Relationship among fishing effort in pelagic fisheries (purse-seining) and catch per unit effort in the central Adriatic for the period 1961—1975 year.

The values obtained for demersal and coastal resources are:

1. The shape function (2) which exprese the dependence of the catch per unit effort to the fishing effort

$$U = 537,256e^{-0,0000396f} \qquad (16)$$

2. The average number of the fishing days

$$\bar{f} = 12.675 \qquad (17)$$

3. The average of the catch per unit effort (in kg/day)

$$\bar{U} = 326 \qquad (18)$$

4. Correlation coefficient

$$r = -0,572 \qquad (19)$$

5. The optimum number of fishing days, by the formula (4)

$$f_{OPT} = 25.253 \qquad (20)$$

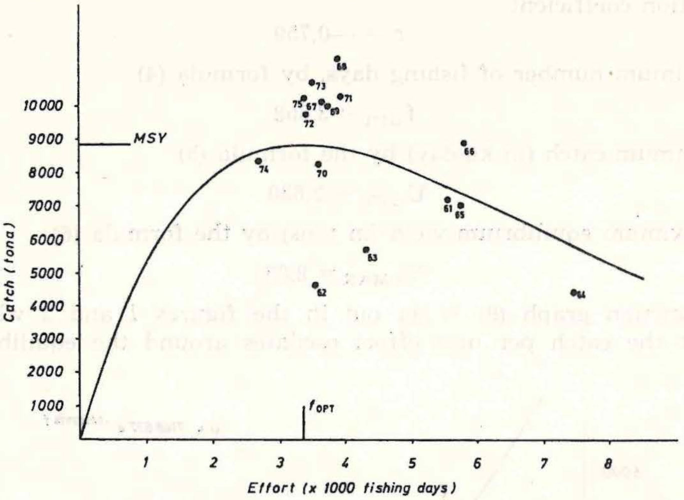

Fig. 2. Exponential equilibrium yield curve for small pelagic populations in the central Adriatic for 1961—1975 year.

6. The optimum catch (in kg/day), by formula (5)

$$U_{OPT} = 198 \quad (21)$$

7. The maximum equilibrium yield (in tons) by the formula (6)

$$Y_{EMAX} = 4.991 \quad (22)$$

The function graph (16) is set out in the figures 3 and 4.

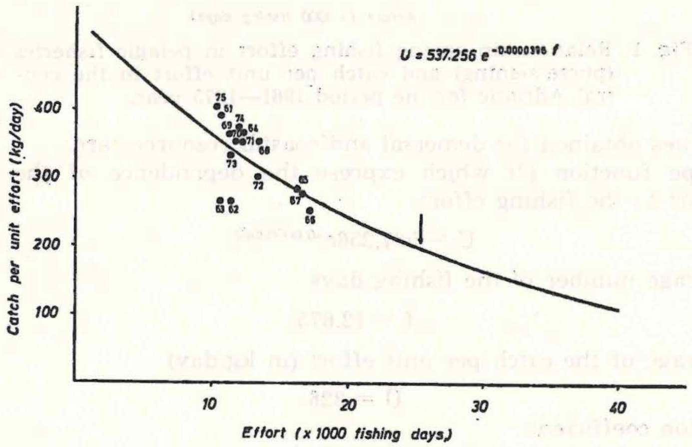

Fig. 3. Relationship among fishing effort in demersal fisheries (bottom trawl, small-scale coastal fisheries) and catch per unit effort in the central Adriatic for the period 1961—1975 year.

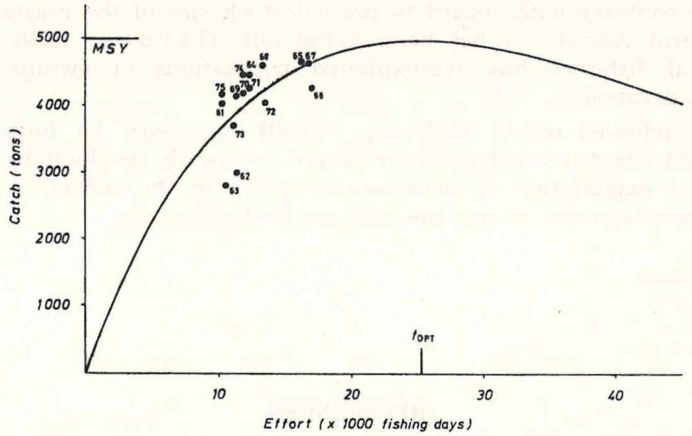

Fig. 4. Exponential equilibrium yield curve for demersal populations (trawl grounds, coastal resources) in the central Adriatic for 1961—1975 year.

DISCUSSION AND CONCLUSION

Analysing the results of the exponential production model for pelagic resources in the central Adriatic, taking into consideration that the correlation coefficient value (r = —0,750) satisfied one criterion of the model it has been stated:

— the number of the optimum fishing days (f_{OPT} = 3.358) in a year is less than the average number of the until now realized fishing days (f = 4.089),

— it is posible to increase the catch per day from actual ($\bar{U}$ = 2.114 kg/day) to (U_{OPT} = 2.630 kg/day) what might be done by fishing technique improvement,

— maximum sustainable yield of small pelagic populations, mostly sardines and anchovies equals (Y_{EMAX} = 8.831 tons/year) what means that average yearly catch in the central Adriatic might be doubled.

Results reffering to demersal and coastal resources in the central Adriatic are more difficult to explain because of low significant value of correltion (r = —0572) owing to the fact that statistical data informations of private fishermen and especially of sports fishing activities are not fully controled what probably results the fact that the basic supposition on »mean population size« has not been realized in the exponential production model.

As far as trawl fishing grounds is concerned in the eastern central Adriatic, following statments found (Jukić, 1975; Jukić and Piccinetti, 1979) of the catch trend per unit effort and standing stock size, it seems that annual yield might be increase with increment of fishing effort, especially, trawl fishing technique.

On the contrary with regard to present stock size of the coastal resources in the central Adriatic it has been found out (Jardas, 1979) that small scale coastal fisheries has overexploited populations of »white fish« and crustaceans decapods.

So, by achieced result of ($Y_{EMAX} = 4.991$ tons/year) for both resources, demersal and coastal, which is lower of present yearly productions, statement and level of exploitation of demersal resources in the central Adriatic, for management purpouses, in this case can not be forecasted.

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KRATAK SADRŽAJ

Koristeći metodologiju eksponencijalnog produkcionog modela (Fox, 1970), a na osnovu raspoloživih statističkih podataka o: ukupnim godišnjim lovinama pelagičkih vrsta riba (»mala plava riba«) i demersalnih populacija (kočarska naselja, priobalne vrste), društvenog i privatnog sektora ribolova u srednjem Jadranu, za vremensko razdoblje 1961—1975. godina, nastojali smo ocijeniti, za potrebe pravilnog gospodarenja, slijedeće bio-ekonomske faktore ribolova:

— razinu iskorištenosti postojećih pelagičnih i demersalnih jestivih naselja u srednjem Jadranu;

— ocijeniti mogućnost povećanja godišnje produkcije (lovina) u plivaričarskom, kočarskom i priobalnom ribolovu.

Za svrhu ove studije korišteni su ribarstveno-statistički podaci Republičkog zavoda za statistiku SR Hrvatske, kao i podaci ribolovnog poduzeća »Jadran« — Split, koji su nam poslužili u računanju i praćenju abundancije (gustoće) ispitivanih naselja riba, rakova i glavonožaca, kao i za potrebe procjene ukupnog ribolovnog napora.

Računskim i grafičkim (slika 1 i 2) načinima utvrđeno je, u slučaju lovina male plave ribe (srdela, inćun), da optimalni godišnji nivo iskorištavanja (Y_{EMAX} = 8.831 tona/godina), s optimalnim ribolovnim naporom (f_{OPT} = 3.358 ribolovnih dana/godina), podaci koji ukazuju da je godišnju produkciju (lovina) male plave ribe u području srednjeg Jadrana moguće udvostručiti (tabela 1).

U slučaju demersalnih naselja (kočarska naselja i priobalna naselja), zbog niske signifikantnosti koeficijenta korelacije ($r = —0{,}57$), koji je najvjerojatnije uzrokom niske vrijednosti ribarstveno-statističkih podataka, ukupnih lovina i ribolovnog napora, izračunate vrijednosti eksponencijalnim modelom (slika 3 i 4), s vrijednostima optimalnog biološkog nivoa iskorištavanja (Y_{EMAX} = 4.991 tona/godina) i optimalnim ribolovnim naporom (f_{OPT} = 25.253 ribolovna dana/godina), ne pružaju vjerodostojnu sliku postojećeg stanja i razine iskorištenosti priobalnih naselja u srednjem Jadranu. Zbog dva razloga: prvo, nedostatka statističkih podataka privatnog sektora ribolova nije zadovoljena temeljna pretpostavka eksponencijalnog produkcionog modela o »srednjoj veličini populacije«. Naime, realni iznosi godišnjih lovina priobalnih vrsta u privatnom i sportsko-rekreativnom ribolovu statističkom službom se ne evidentiraju, pa je realno za pretpostaviti da su godišnji iznosi ovih lovina znatno viši od postojećih (tabela 2) te izračunatih vrijednosti putem produkcionog modela. Drugo, izračunate vrijednosti optimalnog biološkog nivoa iskorištavanja, za potrebe pravilnog gospodarenja, demersalnih resursa u srednjem Jadranu u suprotnosti su s nalazima (Jardas, 1979; Jukić, 1975), kako za priobalna naselja, tako i za kočarska naselja srednjeg Jadrana.