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Reproductive cycle and changes in condition of the horse mackerel (*Trachurus trachurus* L.) from the Adriatic Sea

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*Annual cyclical changes in gonad weight, gonosomatic index and condition factor in male and female horse mackerel (*Trachurus trachurus *L.) from the Adriatic Sea were studied. This species is a late winter through early spring spawner. Maturation lasts from December to May and spawning occurs during March to early June, the peak in May. Testes initially increase in weight faster and earlier than the ovaries and they maintain a greater weight for a longer period. However, at the most advanced gonadal development ovarian weight exceeds testicular weight. Changes in condition were closely linked to the reproductive cycle, condition factor being high and constant for both males and females during the prespawning periods. It was lowest after spawning and highest at the end of the recovering period.*

INTRODUCTION

The horse mackerel (*Trachurus trachurus* L.) is one of three species of *Trachurus* genus present in the Adriatic waters. This species makes up a significant part of commercial trawl catches, particularly in the middle Adriatic. Even though horse mackerel is widely distributed throughout the Adriatic, the available literature concerning the biology of this species is very scarce (KARLOVAC and KARLOVAC, 1971; ALEGRIA, 1984, 1985; ARNERI, 1984; MUŽINIĆ, 1986; KRPO, 1988) especially that referring to the reproduction of this species. The reproductive cycle causes considerable gonadal changes manifested as variations in gonad size. These changes are expressed by the gonosomatic index, that is the ratio of gonadal weight to body weight. The increase in gonosomatic index during gonadal maturation is mainly affected by deposition of reserve material (proteins, lipids) in gametes, particularly in oocytes. The condition factor based on the weight-length relationship is an indicator of the changes in food reserves and therefore an indicator of the general fish condition. Changes in condition reflect seasonal changes in the maturation pattern of fish. The present study reports the results of observations of some aspects of the reproductive cycle as related to the general condition of the horse mackerel.

MATERIAL AND METHODS

Monthly samples of horse mackerel were collected from commercial trawl catches in the middle Adriatic in 1986 through 1988 (Fig. 1). Each specimen was measured to the nearest 0.1 cm total length. The gonads and the gut were removed and the fish was weighed to the nearest

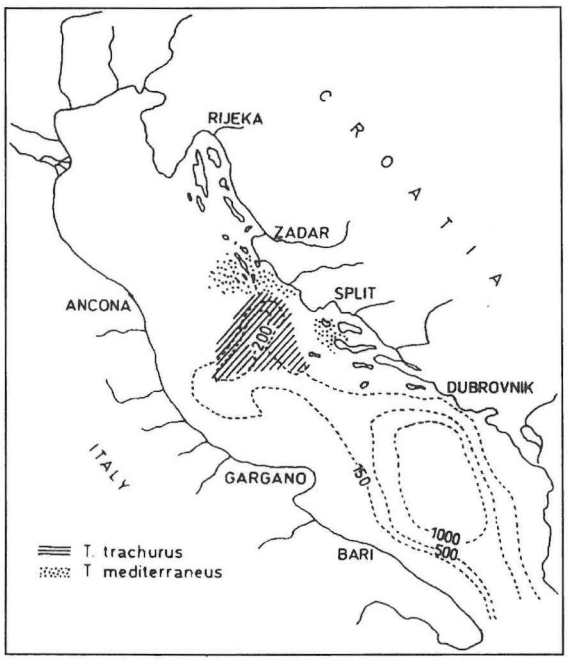

Fig. 1. Horse mackerel sampling area

0.1 g. Removed gonads were weighed to the nearest 0.01 g. Maturity stages were determined by macroscopic examination of gonads applying the Macer scale of specific maturation (MACER, 1974). In order to analyse the gonad weight variation the gonosomatic index (GSI) was calculated by the relation:

$$GSI = (\text{Gonad weight/fish weight}) \times 100$$

Otoliths were removed for age determination. Whole otoliths were observed in a clearing agent under reflected light and on a black background. Age was estimated by counting the complete hyaline zones.

Changes in condition were measured by indices based on length-weight data. The length-weight relationship was calculated by the equation $W = aL^b$, where W is the weight and L total length. Mean length and mean weight values of 0.5 cm interval groups were used. Condition factor was estimated according to the Fulton equation:

$$K = (W/L^3) \times 100.$$

RESULTS

The horse mackerel maturation process starts at the end of autumn and extends to spring, the spawning beginning at the end of winter, and being most intensive at the end of March and April. Females with hyaline oocytes (stage V) first appear at the end of January. The first partly spent fish were recorded in March. By June almost the whole samples consisted of partly spent and spent fish. This indicates that the reproductive season is nearing its end. However, partly spent gonads were also found in September, when the spawning had been completed. It is probable that the rest of the ripe oocytes are reabsorbed.

Horse mackerel with gonads at developmental stage VI, which corresponds to the running stage, were not recorded, with the exception of a female of 16.6 cm in length. Presumably, maturation is rather rapid which affects the possibility of occurrence of the specimens at this stage in the catches. Samples from the North Sea and English Channel showed also very rare specimens at stage VI (MACER, 1974).

Differences in development of ovaries and testes during the maturation cycle are shown by the seasonal variation in gonad weight. The changes are presented in Fig. 2, in

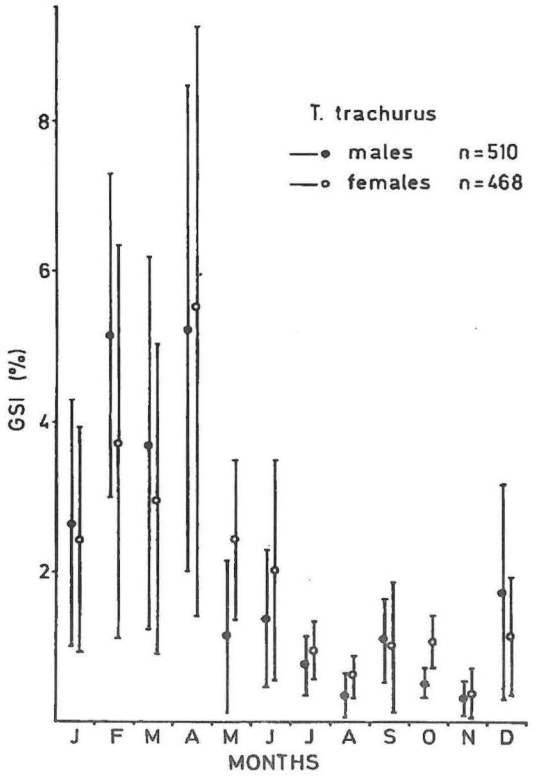

Fig. 2. Seasonal variation of gonad weight (GSI), as a percentage of body weight, the guts and gonads removed in horse mackerel from the middle Adriatic. Only adults were considered

which the gonad weight is expressed as a percentage of ungutted weight of the fish. Testes rapidly grow at the beginning of the maturation season and retain greater weight for a longer period. Maximum testes weight (on average 9.2 % of the gutted body weight) was reached by February through April. Thereafter they suddenly lose weight and the recovery phase starts. Weight of ovaries gradually increases reaching maximum in April, when it constitues, on the average, 10.7 % of the gutted body weight. During the following month it considerably decreases. This indicates that egg release lasts for a very short period.

On the basis of larval numbers in the open Adriatic waters, which were highest in April and May, KARLOVAC and KARLOVAC (1971) concluded that horse mackerel spawned most intensively in this area during these two months. However, based on the gonad maturity of horse mackerel from the inshore waters of the middle Adriatic, it was assumed that this species spawned in winter (JARDAS *et al.*, 1981).

Maturation of horse mackerel from the western Mediterranean begins in November and extends to March, with the maximum in February, when the highest values of gonosomatic index were obtained (PLANAS and VIVES, 1951). A similar result obtained by BEN SALEM and KTARI (1980) for the horse mackerel from Tunisian inshore waters.

Horse mackerel maturation in the north Atlantic waters takes place later than in the Adriatic. Gonad maturation begins in November but the spawning is most intensive from May to August (LETOCONNOUX, 1951; MACER, 1974). ARRUDA (1984) found that in horse mackerel from Portuguese inshore waters gonadal activity began in November, the gonads reaching maximum weight in April-May. So the most intensive egg release is from February to April.

Changes in gonad weight during the maturation cycle are shown in Fig. 3. The variation in gonosomatic index follows a defined similar pattern of changes in both sexes. Testes rapidly

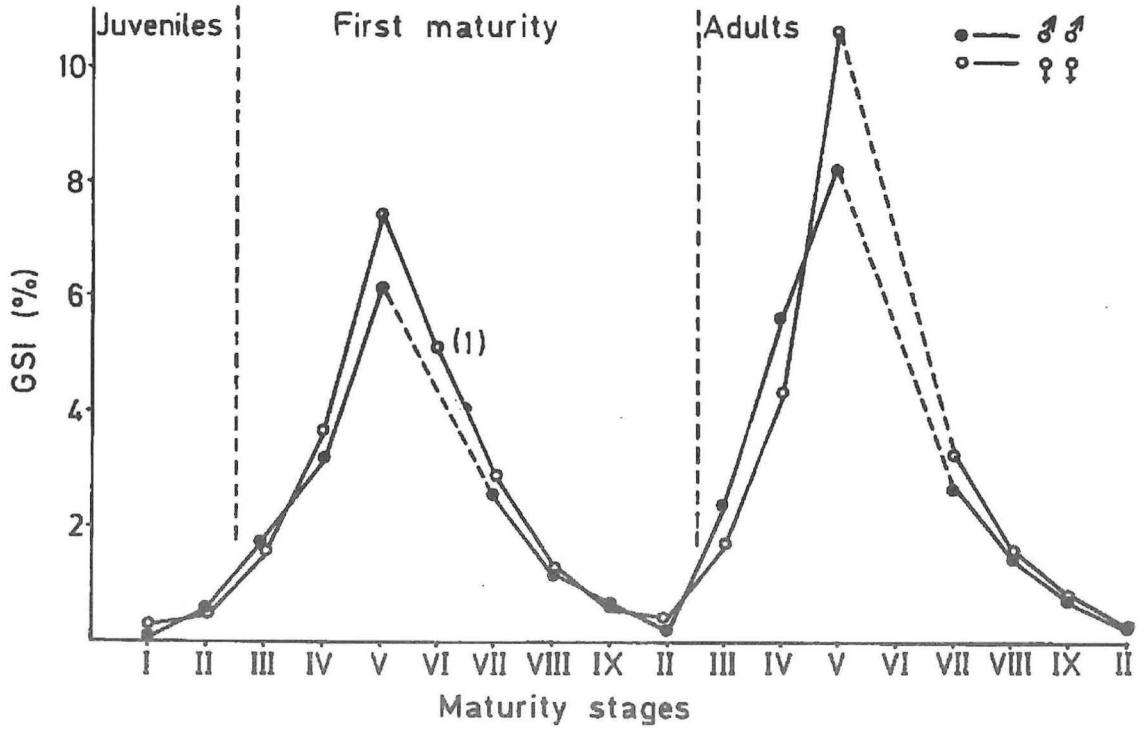

Fig. 3. The relationship between gonosomatic index and gonad maturity stage in male and female horse mackerel from the middle Adriatic, during three life cycle stages

grow at the beginning of the maturation season and retain greater weight for a longer period. Thereafter, they suddenly lose weight and the recovery phase starts . The weight of ovaries gradually increases, reaching a maximum in April. In females there is a gradual increase of the GSI values during the prespawning phase, a marked increase in the spawning period, a decrease in the postspawning phase and a relatively unchanging GSI in the resting phase.

Regression analysis for gonad weight on body weight in horse mackerel is presented in Table 1. The analysis shows that the relationship changes with the gonadal development. A significant positive correlation between gonad weight and body weight was noted in all stages of gonad development. The significance of this correlation increases with the progress of the maturation process reaching a maximum at the maximum gonadal development and decreasing after spawning. Gonad weight was either not correlated or it was slightly correlated with body weight during the resting phase.

Gonad weight shows good correlation with fish length and therefore with the age (Table 2). During maturation the absolute gonad weight in older individuals considerably exceeds that in younger individuals at the same developmental stage, whereas GSI values increase only slightly. However, at peak devel-

Table 1. Relationship between gonad weight at different stages of development and body weight of *Trachurus trachurus* from the Adriatic Sea. N is number of individuals and r is the correlation coefficient

Developmental stages	Males				Females			
	N	b	a	r	N	b	a	r
I Virgin	56	0.001	0.012	0.181	38	0.001	0.029	0.253
II Virgin	36	0.001	0.095	0.302	53	0.003	0.045	0.430
III Early development	63	0.021	-0.363	0.799	52	0.019	-0.183	0.752
IV Later development	125	0.049	-0.890	0.911	118	0.045	-0.302	0.904
V Ripe	38	0.093	-1.823	0.920	27	0.131	-2.761	0.918
VI Running	-	-	-	-	1	-	-	-
VII Partly spent	42	0.025	-0.017	0.912	28	0.032	-0.128	0.866
VIII Spent	36	0.013	-0.004	0.901	30	0.016	-0.262	0.938
IX Recovering	54	0.005	0.147	0.706	51	0.007	0.027	0.883
II Resting	42	0.001	0.141	0.273	27	0.001	0.129	0.367

Table 2. Evolution of mean gonad weight ($\overline{Wg}$,g) during the advanced developmental stages (IV-V) as related to the size ($\overline{L}$,cm) and age. The coefficient r relates to the correlation between *Trachurus trachurus* length and gonad weight within every age group, $s_{y.x}$ is the variation of gonad weight in relation to the length and N the number of individuals

Age	Males					Females				
	N	$\overline{L}$	$\overline{Wg}$	r	$s_{y.x}$	N	$\overline{L}$	$\overline{Wg}$	r	$s_{y.x}$
2	39	19.25	1.15	0.338	0.594	48	19.31	1.47	0.480	0.619
3	28	22.42	2.62	0.705	1.266	26	22.20	2.63	0.438	1.201
4	20	24.22	3.30	0.546	1.286	15	24.40	3.24	0.174	2.259
5	14	25.59	5.23	0.791	1.552	14	25.71	4.49	0.158	2.340
6	8	26.49	6.22	0.236	1.369	5	27.03	4.71	0.527	3.266
7	3	28.43	6.59	-0.571	3.415	6	27.98	7.50	0.625	2.479
8	4	29.43	9.12	0.683	3.666	5	29.46	8.63	-0.330	3.272
9	3	30.96	13.30	-	-	2	31.03	9.87	-	-

opment increase in gonadal weight causes sudden increase in GSI values which are considerably higher with age especially in females. Maximum GSI values were determined in female specimens of six-seven years of age, and males of seven years of age (Fig. 4). After reaching the peaks GSI values decrease.

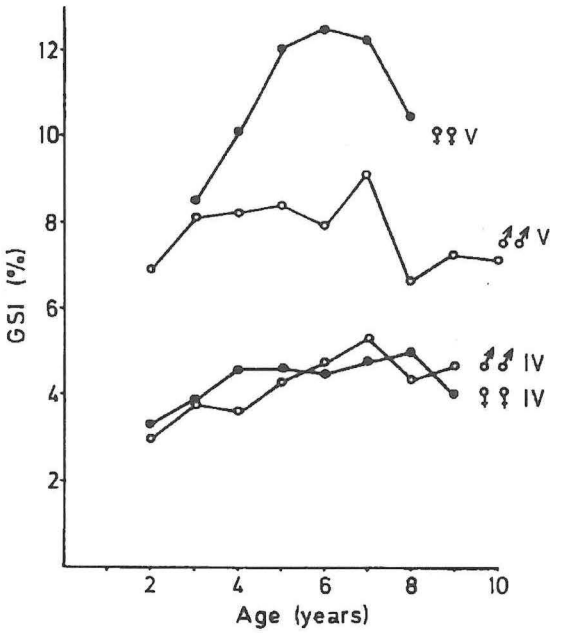

Fig. 4. Changes in gonad weight during the advanced developmental stages in relation to age of horse mackerel from the middle Adriatic

The calculated length-weight relationship in male and female horse mackerel at different life cycle phases is given in Table 3. Statistical tests confirmed that the rate of relative growth (b) of this species in adult stage did not differ significantly from the third power. However, the index of relative growth of younger individuals differs significantly from 3. Based on these results the value 3 was used as exponent for all adult and preadult specimens for condition factor calculations, even though the condition factor was understimated in younger individuals.

Taking into account only the adults at all stages of gonadal cycle, mean condition factor was calculated for every month. Seasonal variation in horse mackerel condition was obtained (Fig. 5). It is closely related to month-

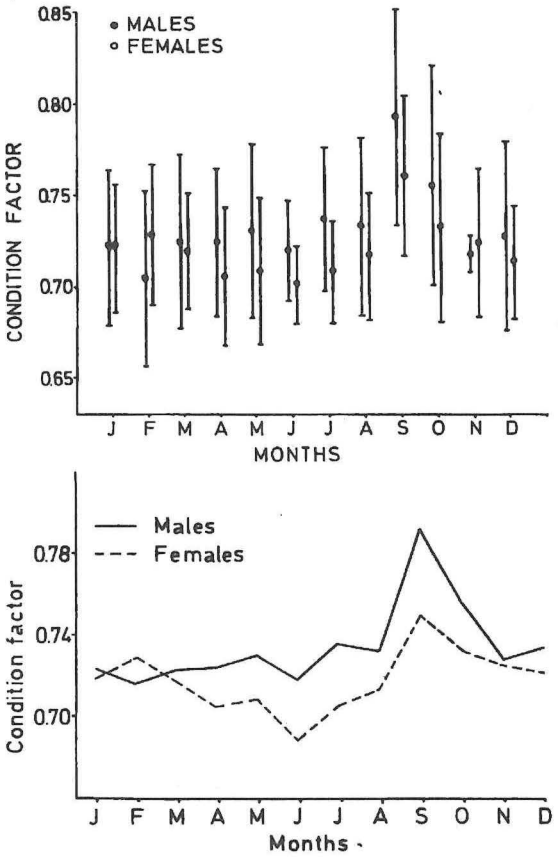

Fig. 5. Seasonal variation of condition factor in male and female horse mackerel from the middle Adriatic

Table 3. Length-weight relationship in *Trachurus trachurus* from Adriatic Sea in 1986-1988. N is the number of individuals and r is the correlation coefficient

Sex	Period	Relation	N	r
Males	Juvenile	$W = 0.01551\ L^{2.719}$	105	0.991
	Prespawning	$W = 0.00614\ L^{3.052}$	266	0.993
	Postspawning	$W = 0.00767\ L^{2.989}$	109	0.991
Females	Juvenile	$W = 0.01309\ L^{2.782}$	97	0.990
	Prespawning	$W = 0.00611\ L^{3.047}$	222	0.992
	Postspawning	$W = 0.01013\ L^{3.012}$	100	0.987

ly changes of the gonads. The correlation between both maturation cycle and condition of the fish was inverse (Figs. 1 and 5). Specimens of both sexes were in best condition in September when they were at either the recovery or resting phase. Their condition was lowest in June immediately after spawning. It was established that males remained in a relatively high and constantly better condition than females. Mean values of condition factor ranged from minimum 0.704 to 0.793 in males and from 0.689 to 0.760 in females, the greater variation corresponding to higher values.

Variation of condition factor in relation to the gonadal changes is shown in Fig. 6. The analysis of horse mackerel condition by each gonadal development stage showed that fish were in poor condition during first maturation as compared to the succeeding reproduction seasons, when during the prespawning period fish condition was at similar levels in both sexes. However, male condition was greatly improved when males were in the most advanced stages of gonad development.

Condition related to the age showed different levels at every stage of gonad maturity (Table 4). Higher condition factor values were obtained for fish at all considered ages in recovering-resting stage. The lowest values corresponded to the postspawning stage.

DISCUSSION

Horse mackerel is serial spawner species with a relatively long reproductive season characterized by one peak. However, the present study suggests that the spawning season of an individual fish is relatively short. The annual curve in gonosomatic index shows a pro-

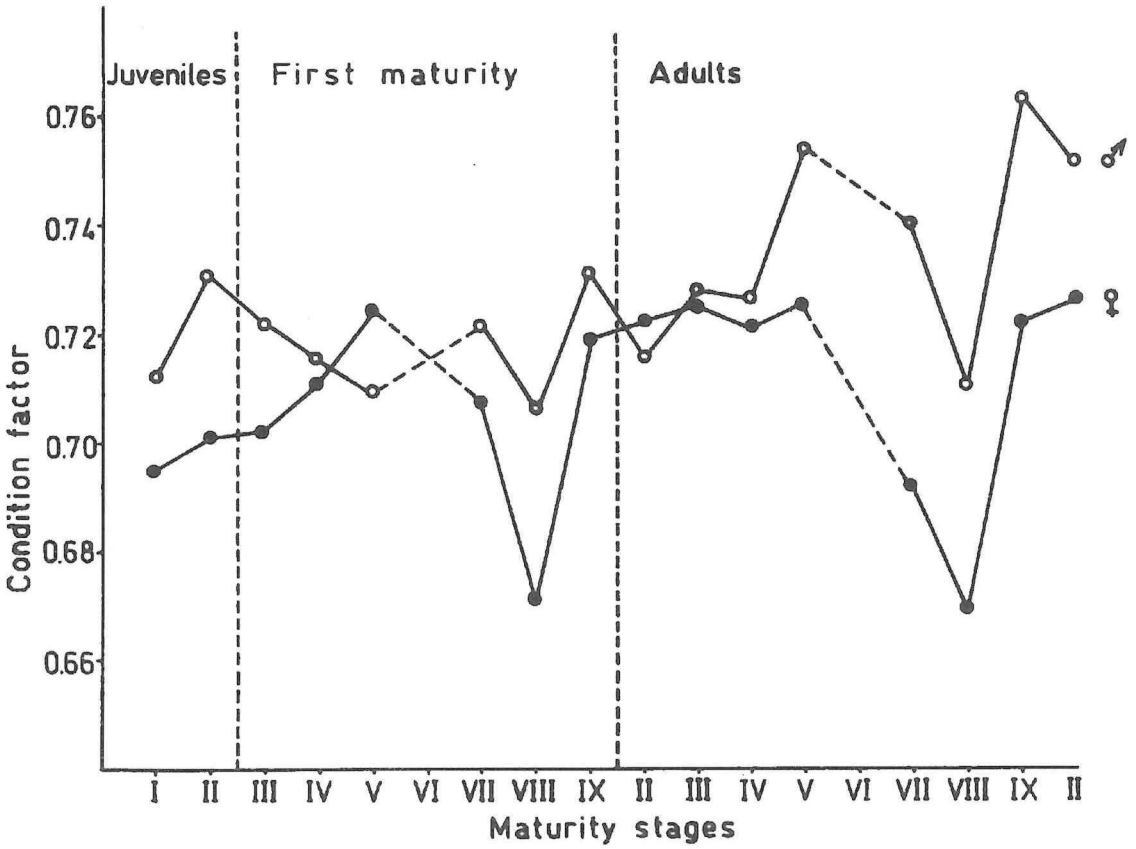

Fig. 6. Condition factor variations in relation to maturation cycle of horse mackerel from the middle Adriatic

Table 4. Age-condition relationship with respect to gonad development of *Trachurus trachurus* from the Adriatic Sea. The figures in brackets represent the number of individuals

Age	Juvenile	Prespawning	Spawning	Postspawning	Resting
			Males		
1	0.724 (19)	-	-	-	-
2	0.713 (35)	0.721 (38)	0.727 (3)	0.685 (8)	-
3	0.697 (4)	0.724 (30)	0.732 (12)	0.693 (7)	0.780 (6)
4	-	0.725 (22)	0.757 (13)	0.706 (4)	0.760 (7)
5	-	0.721 (13)	0.765 (5)	0.697 (10)	0.792 (5)
6	-	0.712 (8)	0.748 (5)	0.720 (2)	0.774 (4)
7	-	0.703 (5)	0.743 (3)	0.692 (3)	0.732 (4)
8	-	0.694 (3)	0.733 (4)	-	-
9	-	0.725 (3)	0.729 (2)	-	0.730 (1)
>10+	-	-	0.701 (2)	0.678 (2)	-
			Females		
1	0.710 (23)	-	-	-	-
2	0.708 (45)	0.702 (55)	-	0.700 (2)	-
3	0.679 (3)	0.705 (29)	0.700 (8)	0.692 (9)	0.747 (3)
4	0.753 (2)	0.698 (20)	0.706 (5)	0.674 (6)	0.739 (7)
5	-	0.713 (12)	0.740 (6)	0.676 (2)	0.762 (7)
6	-	0.729 (8)	0.753 (3)	0.702 (3)	0.739 (3)
7	-	0.739 (6)	0.726 (2)	0.706 (4)	0.802 (1)
8	-	0.724 (5)	0.714 (2)	0.664 (3)	0.732 (2)
9	-	0.721 (2)	-	0.628 (1)	0.741 (1)
>10+	-	-	-	0.676 (1)	0.755 (1)

nounced peak in the spawning season, and keeps the high value for very short period.

Early observation on the reproduction process of horse mackerel revealed a serial spawning strategy, with a larger proportion of oocytes released at first batch (MACER, 1974; ARRUDA, 1983).

Seasonal variation in gonad weight expressed as gonosomatic index shows differences in development of ovaries and tests. The former gradually increases reaching a maximum in April. Testes rapidly grow at the beginning of the maturation season and retain greater weight from February through April. Athough the testis initially increases in weight faster than the ovary, at most advanced gonadal developmental stage (V) ovarian weight exceeds testicular weight. Presumably this is due to an increase in fluid quantity in ripe oocytes prior to spawning. After HTUN-HAN (1978) there is rapid fluid absorption just before ovulation.

Changes in gonad weight are also related to the age of the horse mackerel. Maximum gonosomatic values were determined in females of six years and males of seven years of age. Afterward GSI values decrease, which presumably means that gonad size decreases in older individuals, that is, their reproductive potential is reduced. However, the number of older specimens was small not providing the basis for any definite conclusion.

The seasonal cycle in horse mackerel condition is closely related to gonad changes. Males remain in a higher and constantly better condition than females. Specimens of both sexes were in best condition in September when they were at the recovery phase. The lowest values of condition factor correspond to the fish in postspawning stage. However, the differences in condition between males and females, especially in the postspawning phase, suggest that cost of reproduction in females, particularly the

older ones, is bigger, which is evident by a greater drop in condition after spawning. Therefore, they are more liable to predation and diseases than males. The overall sex ratio for horse mackerel (1.122) confirmed this assumption.

The age-condition relationship in horse mackerel shows condition to be improved at age of 6 to 7 years, whereas it gets lower with ageing of individuals. This suggests that the reproductive process is getting weaker after three or four maturation cycles, since the first maturation of this species occurs during the second half of the third year of life (ALEGRIA, 1990).

The results point to the fact that oocyte maturation is not entirely governed by accumulated reserves, since it was observed that the condition factor was relatively stable during maturation, particularly in adults of both sexes. The specimens at the recovering stage showed the best condition, which decreased thereafter. This would mean that accumulated energy is spent for somatic growth of individuals. It was confirmed that the horse mackerel from the middle Adriatic attain 50 % of their maximum length at the third year of age, prior to the first maturation (ALEGRIA, 1990). This way of energy distribution allows horse mackerel to attain most of their total length prior to the first maturation, maximizing gonad capacity growth and therefore reproductive potential of the species.

In conclusion, during gonad maturation to the advanced stage, the condition factor is relatively stable. This points to the possibility of simultaneous energy expenditure for reproduction process and somatic growth.

This distribution of energy expenditure allows maximization of gonad capacity and therefore of reproductive potential of the species.

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Ciklus razmnožavanja i promjene u kondiciji šnjura (*Trachurus trachurus* L.) iz Jadranskog mora

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KRATKI SADRŽAJ

Izučavane su godišnje cikličke promjene težine gonada, gonosomatskog indeksa i faktora kondicije kod ženki i mužjaka šnjura (*Trachurus trachurus* L.) iz Jadranskog mora. Ova se vrsta mrijesti kasno zimi i kroz rano proljeće. Sazrijevanje traje od prosinca do svibnja te mrijest otpočinje tijekom ožujka i traje do početka lipnja sa vrhuncem u svibnju. Testisi u početku dobivaju na težini ranije i brže nego ovariji te ostaju teži kroz duže vrijeme. Međutim, kada gonade dosegnu najnapredniji stadij razvitka, ovariji postaju teži od testisa. Promjene kondicije ribe usko su vezane za ciklus razmnožavanja. Faktor kondicije je visok i postojan i kod mužjaka i kod ženki tijekom razdoblja prije mrijesta, najniži nakon mrijesta i najviši na kraju razdoblja oporavka.