Total and natural mortality of *Mugil cephalus* and *M. curema* (Pisces: Mugilidae), in Tamiahua Lagoon, Veracruz. I. Selectivity.

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ABSTRACT

Total and natural mortality were determinated. Total mortality (Z) was estimated through the catch curves and natural mortality (M) through Taylor method. An study on the selectivity of the most used gill gear was made. The obtained values were the following: Z=0.27, S= 0.73, M=0.106 for *M. cephalus,* and Z=0.85, S=0.15, M=0.160 for *Mugil curema.* Natural mortality rates for sexes were the following: *Mugil cephalus:* females=0.114; males=0.113; *Mugil curema:* females=0.156; males=0.213. Selectivity for *M. cephalus* was l_c = 323 mm (mesh size gill 35 mm) and l_c =257 mm for *M. curema* (mesh size gill 30 mm).

Key words: Total mortality, natural mortality, selectivity, *Mugil cephalus*, *Mugil curema*.

RESUMEN

Se determinaron la mortalidad total y natural. La mortalidad total (Z) fue estimada por medio de las curvas de captura y la mortalidad natural (M) por el método de Taylor. Se realiza un estudio de la selectividad de la red agallera de mayor uso en la captura de estas especies en la zona. Los valores obtenidos fueron los siguientes: Z= 0.27, S= 0.73, M= 0.106 para *M. cephalus,* y Z= 0.85, S= 0.15, M= 0.160 para *Mugil curema.* Las tasas de mortalidad natural (M) para cada sexo son las siguientes: *Mugil cephalus:* hembras= 0.114; machos= 0.113; *Mugil curema:* hembras= 0.156; machos= 0.213. Se obtiene una talla media de selección de l_c = 323 mm con una red agallera de 35 mm para *M. cephalus* y una l_c = 257 mm con una red agallera de 30 mm para *M. curema.*

Palabras clave: Mortalidad total, mortalidad por pesca, selectividad, *Mugil cephalus*, *Mugil curema*.

INTRODUCTION

In fish biology the most practical way to express the decrease in number of an age group is throughout the use of instantaneous mortality rates (Pauly, 1983), because they can be summed or rested when total mortality (Z) is considered as the number of individuals that die in a population in a given time. The components of Z are: instantaneous mortality rates (M) and instantaneous mortality rates due to fishing (F), therefore $Z = M + F$.

Fish natural mortality is correlated to longevity and growth rates (*k*, catabolic index), as well as to size, because older and bigger individuals have less predators than small individuals.

In addition natural mortality in fishes is correlated to temperature (Pauly, 1983).

Studies of fishing selectivity are oriented to estimate the correct mesh size in order to catch fishes of certain lengths. Assuming that the biomass they catch has the best yields, if we consider that a portion of the population non-catched will have the potential to regenerate the removed biomass (Gallardo, 1984).

In this study we present information on total mortality (Z), natural mortality (M) and selectivity of the used fishing gear (gill gear) for *Mugil cephalus* (Linneo, 1758) and *M. curema* (Valenciemes, 1836) in Tamiahua lagoon, Veracruz., México. This two species of mullets contribute to one of the most important fisheries in México with catches of up to 10,000 annual tons (Polanco *et al.* 1987)

MATERIALS AND METHODS

Organisms were collected monthly from April to March of 1992, from the commercial catches that landed near Tamiahua Lagoon.

The total length of 2, 628 individuals of *M. cephalus* and 3, 354 of *M. curema* were registered. The examination of 232 and 292 otoliths (right sagitta) belonging to 200 to 400 mm individuals of *M. cephalus* and 180 to 330 mm individuals of *M. curema* was carried out. The results of the otolith examination allowed us to defined 5 age groups for *M. cephalus* and 6 for *M. curema* (Ibañez, 1995).

The constants for the von Bertalanffy equation (1938) were obtained for *M. cephalus* by using Fishparm's program (1987) and the Beverton method (1954), and for *M. curema* by using the Fishparm program (1987). Parameters of the von Bertalanffy growth model were compared with those reported in the literature, using the growth performance index (Φ') (Pauly and Munro, 1984). We also compared the Φ' of the different areas for *M. cephalus* but not for *M. curema* because of the scarcity of the data for this species.

Longevity was obtained by using Taylor methods (1958, 1959, 1960 and 1962). Growth and longevity parameters were obtained for each species and sexes (Ibañez, 1995).

Catch curves were used to estimate total mortality in both species and with the surviving rate (S) and total mortality coefficient (Z) we plot age groups versus the natural logarithm of the relative abundance of each age group.

Natural mortality (M) was estimated by using Taylor's method (1960), which is based on the von Bertalanffy growth parameters (1938). The method considers that fishes with low longevity have in average high natural mortality rates and natural mortality is proportional to the number of individuals in time *t* (Bererton and Holt, 1957), therefore M is a growth rate function (*k*), where age limit or longevity ($A_{0.95}$) is the time required to get the 95% of L_∞.

The most used gear in commercial catches of *M. cephalus* and *M. curema* is that with a mesh size of 35 and 30 mm respectively. We made a selection curve by plotting length classes (in mm), and the total frequency of the number of individuals catched. And estimated theoretical curves to notice the fitting and catch probabilities.

RESULTS AND DISCUSSION

Pauly's and Munro's Φ' Method (1984).

The results of this study are shown at the left of the frequency distribution (Figure and Table 1). A ponderation using the mean lengths of each age group of *M. cephalus* (Table 2) was made in order to prove their consistency, using the following criteria: 1) number of individuals, 2) standard deviation and 3) coefficient of variation. Afterwards we proceeded to estimate growth parameters with two variants: a) using the age groups obtained through the readings of otoliths (age groups from 2 to 6), and b) using the average lengths 0 and 1 obtained with the back calculation method (age groups 0 to 6). The results of this study shown the solidity and consistency of this information even when using different treatments. The Φ' values show differences of 10^{-3} which considers the data as solid and valid.

Considering the wide geographic distribution of *M. cephalus*, we had grouped the Φ' values in relation to different zones (Table3). The results show that in average the low values falls in the Golf of México, following by those of the Black Sea, the Mediterranean Sea, Australia and the Indo-Pacific. In the same way the variance increases from

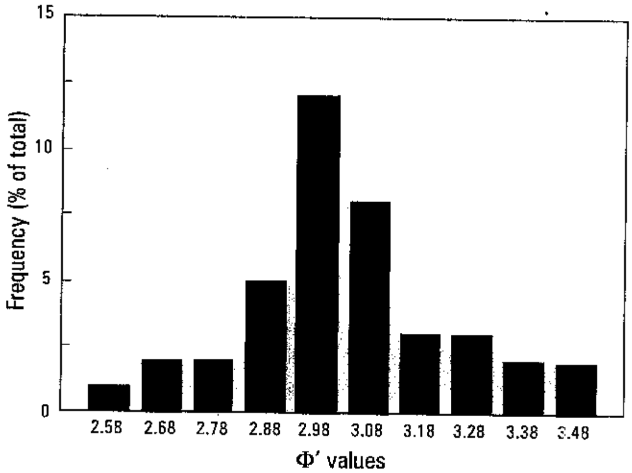

Fig. 1.- Frequency distribution of Φ' values for *M. cephalus*.

Table 1.- Growth rate and Φ' values in different areas for *Mugil cephalus*.

Authority	Year	Area	Method	Sex	L_∞ (cm)	*k*	#	Φ'
Devasundaram	1952	India	Scl.	Species	143.9	0.133	4	3.439973
Heldt	1948	Tunis	Scl.	Species	62.04	0.65	4	3.398257
Zaky-Rafail	1968	Egypt	Scl.	Species	74	0.39	3	3.329528
Alexandrova	1957	Black Sea	Scl.	Species	85.9	0.27	5	3.299350
Heldt	1948	Kelbia	Scl.	Species	82.9	0.28	4	3.284267
Kesteven	1942	Australia	Scl.	Species	172.9	0.06	6	3.253741
Serbetis	1939	Italy	Scl.	Species	56.3	0.561	5	3.249980
Alessio	1976	Italy	Scl.	Species	61.5	0.4	6	3.179810
Grant and Spain	1975	Australia	Scl.	Species	60.46	0.344	8	3.099495
Thomson	1951	West Australia	Scl.	Species	82.8	0.18	7	3.091333
Thomson	1963	Australia	Scl.	Species	72.7	0.229	7	3.082904
Broadhead	1958	N and NO Florida	Scl.+Tag	Females	36.2	0.91	3	3.076459
Thomson	1951	West Australia	Scl.	Females	59.15	0.34	5	3.075388
Thomson	1951	West Australia	Scl.	Males	60.9	0.3	5	3.046356
Thomson	1951	West Australia	L fr.	Species	50.5	0.399	5	3.007556
Thakur	1967	India	Scl.	Males	103.4	0.094	3	3.002169
Erman	1959	Marmara Sea	Oth.	Species	79	0.16	5	2.999374
Farrugio	1975	Tunis	Scl.	Males	51.9	0.36	5	2.986637
Broadhead	1958	N and NO Florida	Scl.+Tag	Males	37.9	0.652	3	2.971526
Hora and Pillary	1962	Indo-pacific	L fr.	Species	63.6	0.23	4	2.968642
Farrugio	1975	Tunis	Scl.	Females	69.3	0.19	6	2.960220
Marquez	1974	Mexico	Scl.	Species	51	0.34	6	2.946619
Morovic	1964	Yugoslavia (p)	Scl.	Species	74.2	0.152	6	2.922651
Ezzat	1964	France	Oth.	Species	41.77	0.47	4	2.913827
Morovic	1957	Italy	Scl.	Species	61.9	0.214	6	2.913795
Morovic	1957	Yugoslavia (e)	Scl.	Species	59	0.234	6	2.910920
Morovic	1964	Yugoslavia	Scl.	Species	68.3	0.173	6	2.906888
Morovic	1957	Yugoslavia (p)	Scl.	Species	59.9	0.22	6	2.897276
Morovic	1954	Italy	Scl.	Species	61.1	0.21	6	2.894302
Morovic	1957	Yugoslavia	Scl.	Species	56.6	0.244	6	2.893023
Thakur	1967	India	Scl.	Females	57	0.23	3	2.873478
Díaz and Hernandez	1980	Mexico	Scl.	Species	58.8	0.1943	6	2.827227
Provatov and Terechensko	1954	Caspian Sea	?	Species	60	0.18	7	2.811575
Illin	1949	Black Sea	Scl.	Species	108.9	0.052	10	2.790059
Provatov and Terechensko	1954	Mar Negro	?	Species	51.6	0.23	5	2.787027
Cech and Wohlschlag	1975	USA, Texas	Scl.	Females	40.7	0.32	5	2.724339
Cech and Wohlschlag	1975	USA, Texas	Scl.	Species	45	0.24	4	2.686636
Ibáñez	1995	Mexico	Oth.	Females	62.29	0.1074	7	2.619679
Ibáñez	1995	Mexico	Oth.	Species	64.24	0.0993	7	2.612560
Ibáñez	1995	Mexico	Oth.	Males	60.39	0.1054	7	2.584606

Abbreviations= #= number of age groups used to obtain the parameters of von Bertalanffy; Scl.= scales; Oth.= otholits; Tag= tagging; L fr.= length frequency; ?= unknown method ; (p)= pantan; (e)= estuary. Improved from Oren (1981).

Table 2.- Growth rate (ageing by otholits) and Φ' of *M. cephalus*.

Modality	Criterion	k	L_∞ (cm)	t_0	Φ'
a).-					
	N	0.1002	63.95	-2.838	2.612549
	Std	0.0996	64.22	-2.839	2.613600
	Vc	0.1002	64.01	-2.833	2.613363
b).-					
	N	0.1011	63.67	-2.821	2.613093
	Std	0.1002	64.04	-2.828	2.613770
	Vc	0.1006	63.88	-2.826	2.613328

Criterion of ponderation: N=number of samples; Std=standard deviation; Vc=variation coefficient. Modalities: a). ussing the average lengths (age groups from "2" to "6"); b). ussing, in addition to, the age groups "0" and "1", obtained by back calculation.

Australia, Gulf of México, the Mediterranean Sea, the Indo-Pacific and the Black Sea. Therefore we can presume that there is a relationship between the *k* and L_∞ values in similar conditions. Although variations might be due to factors such as: the methods used to determined age (direct, indirect and tagging), the techniques used to estimate de von Bertalanffy equation (1938), or to the number of age groups resulted from the fishing pressure and that are present in the populations.

Total mortality

Total mortality and survival were estimated through the catch curves. Figures 2 and 3 show the catch curves for *M. cephalus* and *M. curema* respectively, with an ascendent curves (at the left), and a descendent curve (to the right). The ascendent curve correspond to the one to three years of *M. cephalus* and from zero to two years for *M. curema*. At these ages the recruitment to the nets were partial, therefore relative abundances were subestimated. The ascendent curves correspond to the ages were recruitment was complete, and it is possible to obtain by interpolation the total mortality value for the age groups from 4 to 6 years for *M. cephalus* and from 3 to 5 years for *M. curema*.

The regression lines obtained for the calculation of the slopes of the curves are given by the following equations:

M. cephalus: $\mathbf{y} = (0.27)\,\mathbf{x} + 4.27 \qquad r^2 = 0.82$

M. curema: $\mathbf{y} = (0.85)\,\mathbf{x} + 5.53 \qquad r^2 = 0.89$

Where **x** corresponds to the age groups and **y** to the neperian logarithms of the relative abundance for each age group.

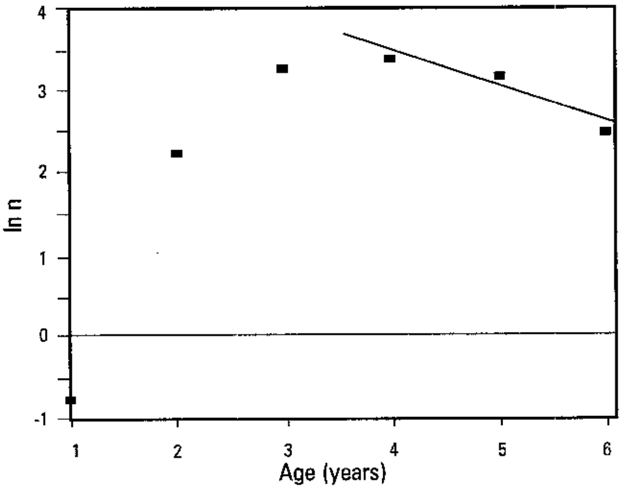

Fig. 2.- Catch curve of *Mugil cephalus*.

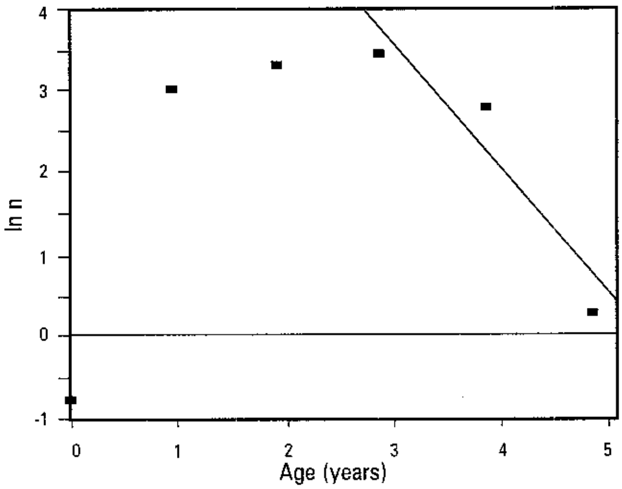

Fig. 3.- Catch curve of *Mugil curema*.

The total mortality value (Z) obtained for *M. cephalus* for the ages from 4 to 6 years is 0.27 and the survival rate is 0.73 and the total mortality value (Z) obtained for *M. curema* for the ages from 3 to 5 years is 0.85 and the survival rate is 0.15 (because M_t = 1 - S) it means that from each 100 individuals 27 die for natural mortality and fishing and survive 73 for *M. cephalus* and die 85 for natural mortality and fishing and survive 15 for *M. curema*.

These results show the total mortality value is higher for *M. curema* than for *M. cephalus* because the fishing effort is more intense for *M. curema*, and its population shows a reduction of the greater age groups (Ibañez, 1995). It is very important to mention, that in the case of *M. cephalus* the age groups from 2 to 5 years are the most exploited and the age groups 0 and 1 years are much less

Table 3.- Average, variance and ranges values of Φ' for *M. cephalus* in different areas.

Area	Australia	G. of Mexico	Mediterranean	Indo-Pacific	Black Sea
Average	3.106	2.770	2.995	3.150	2.960
Variance	0.0062	0.0170	0.0235	0.0429	0.0578
Range	3.25-3.01	2.95-2.61	3.39-2.81	3.44-2.97	3.3-2.79

exploited, but in the case of *M. curema* the commercial catch is very intense in all the age groups, it means, from 0 to 4 years (Ibañez, 1995).

A reduction of the total mortality value for *M. curema* could be obtained, decreasing the fishing intensity, in this way the resource could be protected from over-exploitation and will increase the fishery yield, because the catabolic index *k* will increase the biomass of the population, giving greater lengths and for consequence greater weights at a considered age.

Natural mortality

Estimation of natural mortality by Taylor's method.

Table 4 shows growth, longevity and natural mortality values for the studied populations. The natural mortality rate for *Mugil cephalus* is 0.106 and for *M. curema* is 0.160, the natural mortality rate is higher in *M. curema* than in *M. cephalus*, which is in relationship with the values of the *k* constant of the von Bertalanffy's growth equation (1938). The *k* value is higher in *M. curema* than in *M. cephalus*, for this reason the individuals of *M. curema* will reach faster lengths close to L_∞, and will show a lower longevity and a higher natural mortality rate.

Table 4.- Growth parameters, longevity and natural mortality for the populations of *M. cephalus, M. curema* and their sexes.

Population	L_∞ (mm)	k	$A_{0.95}$ (years)	M
M. cephalus				
Species	642.4	0.0993	28.32	0.106
Females	622.9	0.1074	26.24	0.114
Males	603.9	0.1054	26.46	0.113
M. curema				
Species	461.4	0.1406	18.68	0.160
Females	454.6	0.1355	19.17	0.156
Males	411.8	0.1865	14.04	0.213

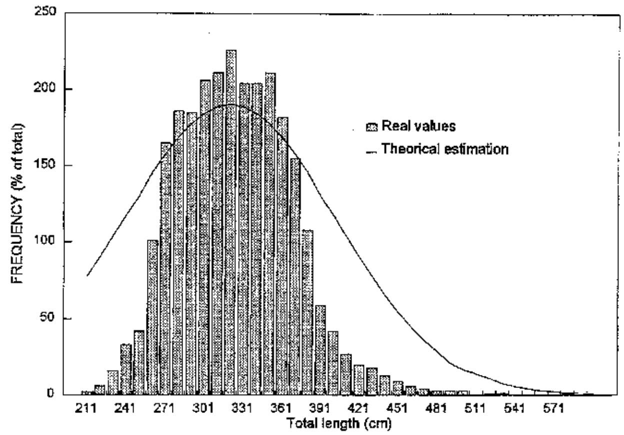

Fig. 4.- Selectivity curve for *Mugil cephalus*, ussing gill net of 35 mm mesh size.

Also table 4 shows the natural mortality rate for sexes. In *M. cephalus* the *k* value is not very different between sexes, because the natural mortality and the growth rate are in a direct relationship between them and in a inverse relationship with the longevity and L_∞, for males and females of this specie the longevity and natural mortality values are very similar. For *M. curema* the males show a higher growth rate, a lower longevity value and a higher natural mortality rate than females.

Selectivity

For Mugilids fisheries in the studied area two kinds of hand-made nets are employed: the gill net and the cast net. The study of the selectivity of these nets is very difficult because the variability of the net dimensions is very high,

Table 5.- Selectivity data of *Mugil cephalus* and *M. curema*, using gill net.

	M. cephalus	*M. curema*
Mesh size	35 mm	30 mm
Dimension: fall/long	1.5m/500m	1.5m/300m
Number of lances	36	48
Fishing duration	360 hrs.	480 hrs.
Numer of samples:		
interval 21-75%	1633	
interval 27-66%		1708
Total number of samples	2653	3629
Size interval:		
21-75%	181-351 mm	
27-66%		232-272 mm

in particular the mesh size, for this reason, for the study of net selectivity in this paper the gill nets of 35 mm of mesh size for *M. cephalus* and 30 mm of mesh size for *M. curema* were only considered (Table 5). These gill nets are the most employed and efficient for the capture of the studied Mugilids. Although these estimations do not represent the total of the selectivity, they are the two who have less bias of all.

The mentioned gill nets also capture another commercial fish species, the most important for their high proportion in the capture are: *Cynoscion arenarius* (11.9%), *Archosargus probatocephalus* (11.7 %), *Centropomus undecimalis* (10.7%), *Cynoscion nebulosus* (10.2%) and *Diapterus olisthostomus* (9.3%). For this reason the Mugilids fisheries are considered as multiespecifics and the selectivity studies should be realized for each one of the captured species. The application of a particular mesh size in a fishery regulation is easiest and more efficient when it is applied for a monoespecific population, because just one selectivity value has to be applied (Gallardo, 1984). However, in the studied area, the fishery exploitation occurs at the same time on several species who have different growth rates and in consequence different selectivity values, for this reason it was necessary to take the mesh size who captures the fish of highest commercial value, in this case, *M. cephalus* and *M. curema*.

The selectivity curves obtained in this study for *M. cephalus* and *M. curema* are shown in the figures 4 and 5, because of the variations in the size sample the normal curves do not completely fit to the obtained data. The lengths with the highest capture probabilities for *M. cephalus* range from 271 to 371 mm, while for *M. curema* range from 232 to 292 mm, approximately.

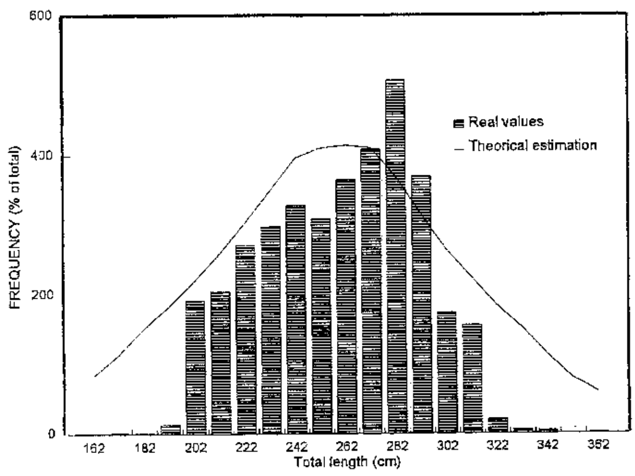

Fig. 5.- Selectivity curve for *Mugil curema*, ussing gill net of 30 mm mesh size.

The average selection length (l_c, length at 50% of the individuals who enter to the net are captured) for *M. cephalus* is 323 mm and 257 mm for *M. curema*, which correspond to age groups of 4 and 2 years respectively. The lengths of the first sexual maturity for *M. cephalus* are: females 299 mm (3 years), males 280 mm (3 years) and for *M. curema* are: females 208 mm (1 year), males 181 mm (0 years) (Ibañez, 1995). As a consequence, the gill nets of 35 mm of mesh size for *M. cephalus* and 30 mm of mesh size for *M. curema* capture individuals who has spawned for once, maybe this is the reason these fisheries have not completely disappeared although their volumes of capture decrease each year.

CONCLUSIONS

The total mortality coefficient (Z) of *Mugil cephalus* for the age groups 4 to 6 years is 0.27 and the survival coefficient is 0.73

The total mortality coefficient (Z) of *Mugil curema* for the age groups 3 to 5 years is 0.85 and the survival coefficient is 0.15

The natural mortality rates (M) are: 0.106 for *M. cephalus* and 0.160 for *M. curema*.

The natural mortality rates (M) for sexes of *M. cephalus* are: 0.114 for females and 0.113 for males.

The natural mortality rates (M) for sexes of *M. curema* are: 0.156 for females and 0.213 for males.

The average selection length for *M. cephalus* is 323 mm employing a gill net of 35 mm of mesh size, this gill net captures individuals who has spawned for once.

The average selection length for *M. curema* is 257 mm. employing a gill net of 30 mm of mesh size, this gill net captures individuals who has spawned for once.

For *M. curema* a greater yield fishery could be obtained increasing the mesh size of the gill nets.

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