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FISHERIES MANAGEMENT OF THE THINLIP GREY MULLET *LIZA RAMADA* AND GOLDEN GREY MULLET *LIZA AURATA* FROM LAKE BARDAWIL, EGYPT

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ABSTRACT

Monthly samples of *Liza ramada* and *L. aurata* were collected from Lake Bardawil during the period from April to December 2004, to study their population dynamics and to assess the fishery status of their stocks. The total length of *L. ramada* and *L. aurata* ranged from 16.9 to 42 cm and 16 to 30.5 cm respectively. Otoliths were used to estimate their ages. The age distribution covered age groups I to V for *L. ramada* and I to III for *L. aurata* with age groups II and I being the most frequent for *L. ramada* and *L. aurata*, respectively. The von Bertalanffy growth equations were $L_t = 44.14\ (1-e^{-0.51(t-0.29)})$ for *L. ramada* and $L_t = 33.77\ (1-e^{-0.61(t-0.34)})$ for *L. aurata*. The respective instantaneous annual rates of total, natural and fishing mortality were 1.22, 0.16 and 1.06 year^{-1} for *L. ramada* and 1.36, 0.22 and 1.14 year^{-1} for *L. aurata*. Exploitation rate was estimated as 0.87 and 0.84 year^{-1} for *L. ramada* and *L. aurata* respectively. The estimated lengths at first capture were 18.45 and 16.92 cm, while the length at first sexual maturity was 28.71 and 23.11 cm for *L. ramada* and *L. aurata* respectively. The relative yield per recruit and relative biomass per recruit analysis indicated that the stocks of *L. ramada* and *L. aurata* at Lake Bardawil were over-exploited and their respective current exploitation rate should be reduced by about 54% and 52.4% and their respective length at first capture should be raised to 30 and 25 cm respectively, to conserve the reproducible part of their population.

INTRODUCTION

Mullets (family: Mugilidae), are the most important fish resources in Lake Bardawil. where they contributed about 33.5% of the total fish production in the lagoon (GAFRD. 2004). Three species namely: *Mugil cephalus, Liza ramada* and *L. aurata* are the main constituents of the commercial catch of mullets in the lake. Mullets are exploited by veranda or bouss fishing method in the Lake.

Because of the economic importance of mullets, their biology in different Egyptian water bodies has been extensively studied (Rafail, 1968; El-Sedafy, 1971; Fayek, 1973; El-Maghraby *et al.*, 1973; Hashem *et al.*, 1973; Hashem *et al.*, 1977; Salem and Mohammed, 1982; Hosny and Hashem, 1995). On the other hand, very limited studies were done about their dynamics and management (Mehanna, 2004; El-Gammal and Mehanna, 2004; Mehanna and Amin, 2005).

The present work is yet the first attempt to assess the stock of *L. ramada* and *L. aurata* in Lake Bardawil and aims to develop an appropriate management plan to maintain this valuable fish resource.

MATERIAL AND METHODS

Monthly fish samples of *L. ramada* and *L. aurata* were collected from the commercial catch of Lake Bardawil during the period from April to December 2004. The total length to the nearest mm and total weight to the nearest 0.1g were determined for each specimen. Sex and otoliths were taken for each fish. Annual rings on otoliths were counted, using optical system consisting of Nikon Zoom- Stereomicroscope and Heidenhain's electronic bidirectional read out system V R X 182, under transmitted light.

To estimate the relation between total length (L) and total weight (W), the variables were log-transformed to meet the assumptions of normality and homogeneous variance. A linear version of the power function $W = a L^b$ was fitted to the data. Confidence intervals (CI) were calculated for the slope to see if it was statistically different from 3.

Von Bertalanffy growth parameters were estimated using the back-calculated lengths computed from otolith reading method, by applying the Chapman (1960) plot as $L_{t+1} - Lt = L_\infty [1 - e^{-K}] - [1 - e^{-K}] L_t$, where L_t is the length at age t, L_∞ is the asymptotic length and K is the growth coefficient.

The growth performance index (ø) was estimated, using Pauly and Munro (1984) formula as $ø = \text{Log } K + 2 \text{ Log } L_\infty$.

Total mortality coefficient (Z) was estimated, using the semilogarthmic regression method of Ricker (1975), which is based on age composition data and represented by $\ln N_t = \ln N_0 - Zt$, where N_t is the number of fish belonging to age t and N_0 is the number of first fully recruited age group. The natural mortality coefficient (M) was calculated, using Ursin (1967) formula as $M = W^{-1/3}$, where W is the mean weight of the whole sample. The fishing mortality coefficient (F) was computed as $F = Z - M$, while the exploitation rate was computed from the ratio F/Z (Gulland, 1971).

The length at first capture (L_c) was estimated by the catch curve analysis (Pauly, 1984 a & b), while the length at first sexual maturity L_{50} (the length at which 50% of fish reach their sexual maturity) was estimated by fitting the maturation curve between the observed points of mid-class interval and the percentage maturity of fish corresponding to each length interval. Then L_{50} was estimated as the point on X-axis corresponding to 50% point on Y-axis.

Relative yield per recruit Y'/R and relative biomass per recruit B'/R were estimated, using the model of Beverton and Holt (1966) as modified by Pauly and Soriano (1986). This model is defined by:

$$(Y'/R) = E\, U^{M/K} \left[1 - (3U/1+m) + (3U^2/1+2m) - (U^3/1+3m)\right]$$

$$(B'/R) = (Y/R)'/F$$

where (Y'/R) is the relative yield per recruit
(B'/R) is the relative biomass per recruit
M is the natural mortality coefficient
F is the fishing mortality coefficient
K is the growth parameter
E is the exploitation rate or the fraction of deaths caused by fishing

$m = (1-E)/(M/K) = (K/Z)$

$U = 1 - (L_c/L_\infty)$

RESULTS AND DISCUSSION

Description of fishery

Lake Bardawil (33° 0' East 31° 9' North) is a shallow, hyper-saline lagoon occupying much of the Mediterranean coast of Sinai. The lake measures about 85 km in length, has a maximum width of 22 km, and ranges in depth from 0.3 - 3 m. It is separated from the sea by a sandbar that varies in width between 100 m and 1 km (Fig. 1). The lake shore is mainly bare sand, with scattered saltmarshes and mudflats. The sandy lake-bottom is covered by scattered patches of algae. Originally, Bardawil was connected to the sea via one small natural inlet at its eastern extremity (Bughaz Zaranik), usually becoming inundated with seawater only during winter when storms often breached the unstable sandbar. During summer, most of the lake is isolated from the sea and water evaporated, leaving behind large areas of sabkha. Several man-made inlets have been dredged along the sandbar since 1905, in an effort to allow the permanent inundation of the lagoon and maintenance of salinity levels suitable for the development of fisheries. Today, there are two man-made inlets (Bughaz I, II), which are continually being blocked through sedimentation (BirdLife international, 2005). Lake Bardawil is the source of an important local fishery, with a mean annual fish production of about 2514 ton (GAFRD annual reports, 1985-2004) and employing some 3,000 fishermen. Fishing is suspended between January and April, in order to allow fish stocks to recuperate. A number of fishing methods are used in the lake; including dabba, veranda or bouss, dahbana nets and el-tair nets. Lake Bardawil constituted about 1.5% of the total production from Egyptian lakes (Fig. 2).

Catch composition

The catch of the lake is composed mostly of the high-value saltwater fish such as *Mugil cephalus*, *Liza ramada* and *L. aurata* (family: Mugilidae); *Sparus aurata* (Sparidae), *Dicentrarchus labrax* and *D. punctatus* (Moronidae); *Solea* spp. (Soleidae); *Argyrosomus regius* (Sciaenidae); *Epinephelus* spp. (Serranidae) and *Siganus* spp. (Siganidae). Also, crustacea are represented in the catch by shrimps mainly *Metapenaeus stebbingi* and crabs mainly *Portunus pelagicus* (Fig. 3).

Age and growth

Otoliths were used for age determination of *L. ramada* and *L. aurata* from Lake Bardawil. Otoliths as a reliable and valid method for ageing the two species have been proven. Body length – otolith radius relationship (Fig. 4) showed a strong correlation. Also, the increase of fish size is accompanied by an increase in the number of annuli on the otoliths. On the other hand, back- calculated lengths accord with the observed lengths for the different age groups (Table 1).

The longivity of *L. ramada* and *L. aurata* extends to five and three years respectively, with their respective age groups II and I being the most frequent (Fig. 5). The back – calculated lengths at the end of each year of life were 21.09, 30.05, 36.33, 39.26 and 41.08 cm for 1^{st} to 5^{th} year of life for *L. ramada* and 18.77, 25.59 and 29.31 cm for 1^{st} to 3^{rd} year of life for *L. aurata*. Age readings indicated that both species attain their highest growth rate in length during the first year of life, after which a gradual decrease in growth increment was observed with further increase in age. The estimated lengths at different ages of the two species in different Egyptian water bodies are summarized in Table (2).

Length – weight relationship

A total of 837 *L. ramada* of total length varied from 16.9 to 42 cm, with weights ranging between 40 and 725 g and 1018 *L. aurata* of total length ranged between 16 and 30.5 cm, with weights varying from 28 to 250 g were used to estimate the length - weight relationship (Fig. 6). The length – weight equations were estimated as:

L. ramada $W = 0.0052\ L^{3.134}$ $(r^2 = 0.98)$

L. aurata $W = 0.0086\ L^{2.9356}$ $(r^2 = 0.96)$

An isometric growth was observed for both species, where CI was 3.191 – 3.078 for *L. ramada* and 2.887 – 2.993 for *L. aurata*. It was found that growth in weight is very slow during the first year and thereafter growth in weight increases with age until it reaches its maximum value at age group III for *L. ramada* and age group II for *L. aurata*. On the basis of annual increase in weight, it would be economically important to protect the fish till their third year of life for *L. ramada* and second year of life for *L. aurata*, to reach a good marketable size that performed at least one spawning activity.

Growth Parameters

The constants of the von Bertalanffy's growth model were estimated (Table 4) and the obtained equations were:

L. ramada

For growth in length $L_t = 44.14\ (1 - e^{-0.51(t+0.29)})$

For growth in weight $W_t = 742.86\ (1 - e^{-0.51\ (t+0.29)})^{3.134}$

L. aurata

For growth in length $L_t = 33.77\ (1 - e^{-0.61\ (t+0.34)})$

For growth in weight $W_t = 264.03\ (1 - e^{-0.61\ (t+0.34)})^{2.9356}$

Growth performance index

Pauly and Munro (1984) have indicated a method to compare the growth performance of various stocks by computing the Phi index ø. The obtained results indicated that the values of growth performance index of *L. ramada* and *L. aurata* were 3.00 and 2.84 respectively. The ø values obtained were consistent with other estimates. It was found that ø = 2.66

for *L. ramada* at Lake Burullus, 2.91 at Wadi El-Raiyan lakes and 2.98 at Lake Timsah. Based on the calculated growth performance index, the growth rate of *L. ramada* in Lake Bardawil is slightly higher than that in other three lakes. Also, the same trend was observed for *L. aurata* (the growth performance index was 2.82 at Bitter Lakes).

Mortality and exploitation rates

The total mortality coefficient Z, the natural mortality coefficient M and the fishing mortality coefficient F were estimated as 1.22, 0.16 and 1.06 $year^{-1}$ respectively for *L. ramada*. The same parameters were estimated as 1.36, 0.22 and 1.14 $year^{-1}$ respectively for *L. aurata*. The exploitation rate E was estimated as 0.87 and 0.84 $year^{-1}$ for both species respectively (Table 4). Gulland (1971) suggested that the optimum exploitation rate for any fish stock is about 0.5 at F=M and more recent, Pauly (1987) proposed a lower optimum F that equals to 0.4 M. The current estimated fishing mortality and exploitation rates for both species were relatively high, indicating a high level of exploitation.

Length and age at first capture

The length at first capture (the length at which 50% of the fish is retained by the gear and 50% escape) was estimated as L_c = 18.45 and 16.92 cm for *L. ramada* and *L. aurata* respectively. The corresponding ages were 0.77 and 0.80 year for the two species respectively.

Length and age at first sexual maturity

The size at 50% maturity was estimated at 28.71 and 23.11 cm TL for *L. ramada* and *L. aurata* respectively (Fig. 7), that is equivalent to an age of about 1.77 and 1.55 years respectively. The smallest length recorded in the catch L_r was 16.9 and 16 cm for *L. ramada* and *L. aurata* respectively, which are smaller than the L_{50} and the length at first capture was smaller than L_{50}. This means that the exploited stocks of *L. ramada* and *L. aurata* should be protected in order to share at least once in the spawning activity.

Per - recruit analysis and management

Plot in relative yield per recruit (Y'/R) and biomass per recruit (B'/R) against exploitation rate (E) for *L. ramada* (Fig. 8) shows that the maximum (Y'/R) was obtained at E_{MSY} = 0.64. Both of $E_{0.1}$ (the level of exploitation at which the marginal increase in yield per recruit reaches 1/10 of the marginal increase computed at a very low value of E) and $E_{0.5}$ (the exploitation level which will result in a reduction of the unexploited biomass by 50%) were estimated. The obtained values of $E_{0.1}$ and $E_{0.5}$ were 0.56 and 0.4 respectively. The results indicated that the present level of E (0.87) was higher than that which gives the maximum (Y'/R). The results show also that, the present level of exploitation rate is higher than the exploitation rate ($E_{0.5}$) which maintains 50% of the stock biomass.

For *L. aurata* (Fig. 9), a maximum (Y'/R) can be obtained at E_{max} = 0.66. The values of $E_{0.1}$ and $E_{0.5}$ were 0. 6 and 0.4 respectively. This means that. the exploitation rate of *L. aurata* should be reduced from 0.84 to 0.4 (52.4%) to maintain a sufficient spawning biomass.

To determine the most appropriate length at first capture for *L. ramada* and *L. aurata* at Lake Bardawil, the relative yield-per-recruit was estimated by applying different values of L_c (25 and 30 cm for *L. ramada* and 20 and 25 cm for *L. aurata*). The results (Figs. 10 & 11) indicated that with increasing L_c a higher (Y'/R) can be obtained. For *L. ramada*, when we use L_c = 25 and 30 cm, the maximum (Y'/R) was obtained at E= 0.71 and 0.76 (still less than the current E) respectively. This means that, the present level of L_c is not the optimum L_c of this fish species and it must be increased to 30 cm. The values obtained for $E_{0.5}$ were 0.42 and 0.44 for L_c = 25 and 30 cm respectively. The same trend was observed for *L. aurata*, when L_c increased to 20 and 25 cm, the maximum (Y'/R) was obtained at E= 0.71 and 0.80 (less than the current E) respectively. The values obtained for $E_{0.5}$ were 0.42 and 0.45 for L_c = 20 and 25 cm respectively.

The results showed that the stocks of *L. ramada* and *L. aurata* at Lake Bardawil were overexploited. For the management purpose, the current exploitation rate must be reduced from 0.87 to 0.4 (54%), to maintain a sufficient spawning biomass and the length at first capture should be raised from 18.45 to about 30 cm for *L. ramada* and the current E must be reduced from 0.84 to 0.4 (52.4%) while the present L_c should be increased to about 25 cm for *L. aurata.*

It could be concluded that the main management problems facing the fisheries development in Lake Bardawil are over-exploitation, due to the high fishing pressure, destructive and illegal fishing and mesh size methods, and lack of information on fishery status in terms of biological, ecological, social and economic policy. So, fishery management plan in Lake Bardawil should include:

- Controlling mesh size of nets used and prohibition of the destructive gears.

-Re-evaluating of the time of closed season to conserve the spawning stock biomass of mullets during their spawning migration from and to the lake.

- Setting of a total allowable catch.

- Making an accurate data base about lake fishery, involving good records for fishery statistics to facilitate the evaluation and managing of this valuable fish resource.

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Table (1). Back-calculated lengths (cm) at the end of different years of life of *Liza ramada* and *Liza aurata* from Lake Bardawil.

Age (yr)	*Liza ramada*						*Liza aurata*			
	Observed length	1	2	3	4	5	Observed length	1	2	3
I	21.92	**21.09**					19.49	**18.77**		
II	30.86	20.92	**30.05**				26.25	18.59	**25.59**	
III	36.95	20.94	29.88	**36.33**			29.89	18.55	25.44	**29.31**
IV	39.91	20.81	29.76	36.25	**39.26**					
V	41.55	20.73	29.71	36.16	39.11	**41.08**				
Incr.		21.09	8.96	6.28	2.93	1.82		18.77	6.82	3.72
%		51.34	21.81	15.29	7.13	4.43		64.04	23.27	12.69

Table (2). Lengths (cm) at different ages for *Liza ramada* and *L. aurata* from some Egyptian water bodies.

Locality	L_1	L_2	L_3	L_4	L_5	L_6	L_7	L_8	Author
Liza ramada									
Medit. Coast	14.7	23.8	31.4	37.7	41.7	46.2			Rafail, 1968
Nozha hydrodrom									Hashem *et al.*, 1977
Male	16.8	24.2	33.2	--					
Female	18.1	26.8	36.4	44.5					
Lake Timsah									Salem & Mohammed, 1982
Male	19.4	23.0	25.0	--	--	--			
Female	21.6	25.4	29.9	32.1	34.9	41.8			
Lake Borollus	12.8	17.5	23.1	29.0	32.0	34.7			Hosny & Hashem, 1995
Wadi El-Raiyan	20.1	28.6	34.6	39.1	42.9	45.8	47.8	48.9	El-Gammal&Mehanna, 2004
Lake Timsah	19.9	29.2	35.5	38.9	41.1				Mehanna&Amin, 2005
Lake Bardawil	21.1	30.1	36.3	39.3	41.1				Present study
Liza aurata									
Lake Burollus	15.0	24.0							Hashem et al., 1973
Bitter Lakes	17.9	24.9	28.5						Mehanna, 2004
Lake Bardawil	18.8	25.6	29.3						Present study

Table (3). Calculated weights (g) at the end of different years of life for *Liza ramada* and *L. aurata* from Lake Bardawil.

Age (yr)	*Liza ramada*					*Liza aurata*		
	1	2	3	4	5	1	2	3
I	73.39					47.08		
II	71.56	222.62				45.77	116.96	
III	71.77	218.70	403.53			45.48	114.96	174.21
IV	70.38	215.96	400.75	514.57				
V	69.54	214.82	397.64	508.43	593.09			
Incr.	73.39	149.23	180.91	111.04	78.52	47.08	69.88	57.25
%	12.37	25.16	30.50	18.72	13.24	27.03	40.11	32.86

Table (4). Population parameters for *Liza ramada* and *L. aurata* from Lake Bardawil.

Population parameters	*Liza ramada*	*Liza aurata*
K $year^{-1}$	0.51	0.61
L_∞ cm	44.14	33.77
W_∞ g	742.86	264.03
t_0 year	-0.29	-0.34
ø	3.00	2.84
Z $year^{-1}$	1.22	1.36
M $year^{-1}$	0.16	0.22
F $year^{-1}$	1.06	1.14
E $year^{-1}$	0.87	0.84
L_c cm	18.45	16.92
E_{max}	0.64	0.66
$E_{0.1}$	0.56	0.60
$E_{0.5}$	0.40	0.40

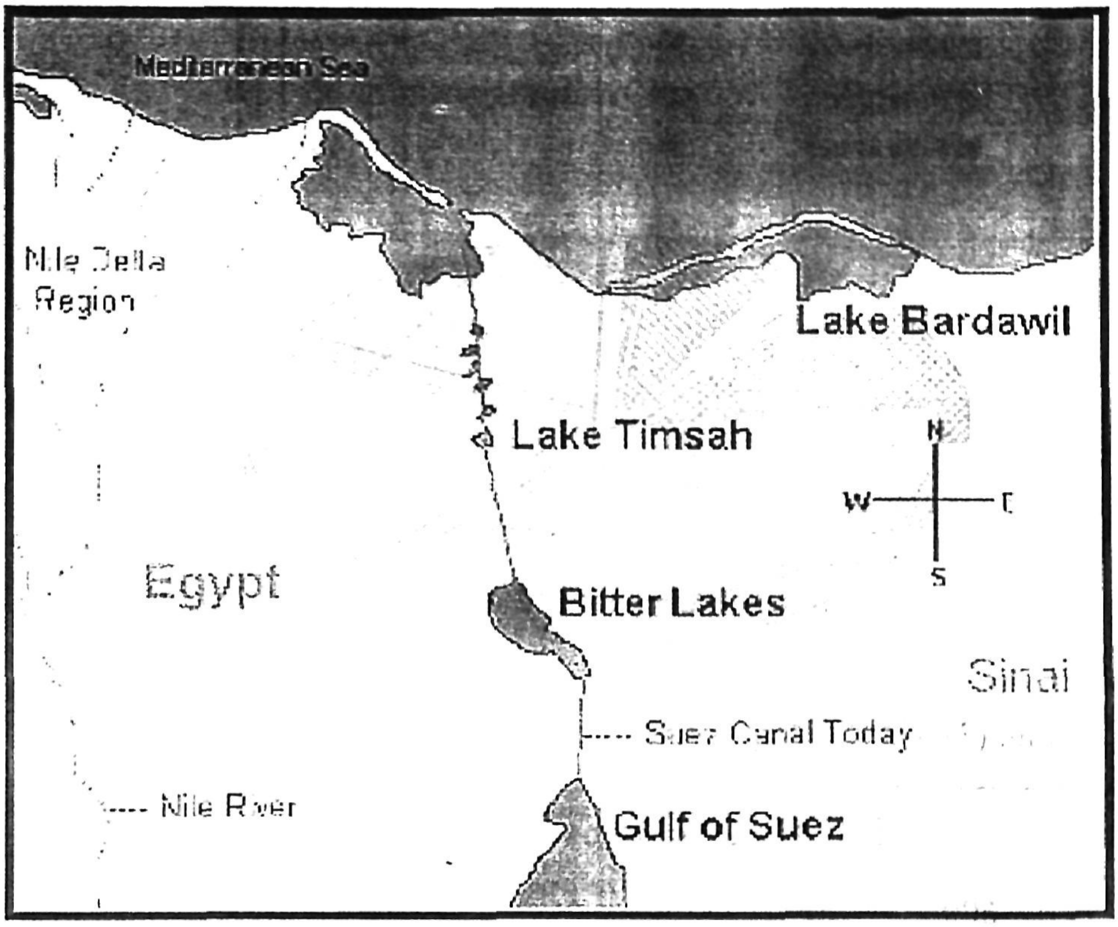


Fig. (1). Lake Bardawil.

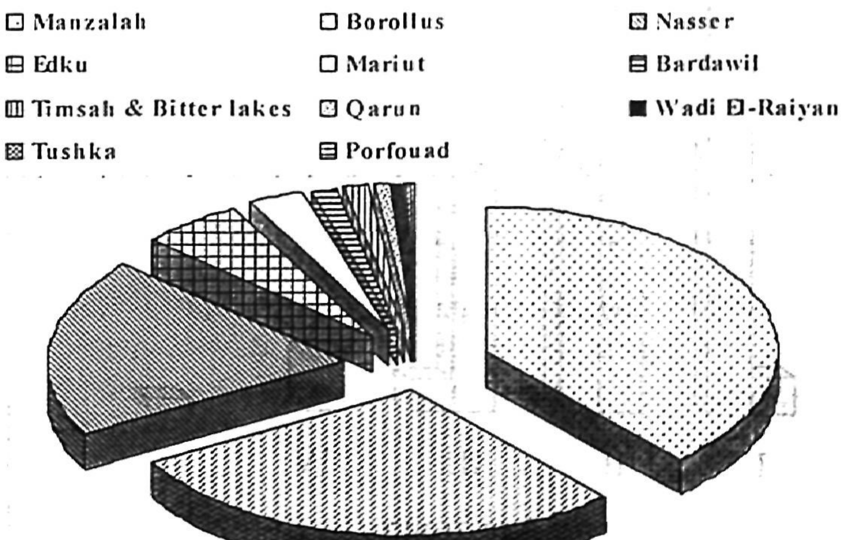


Fig. (2). Fish production from the Egyptian Lakes (1985-2004).

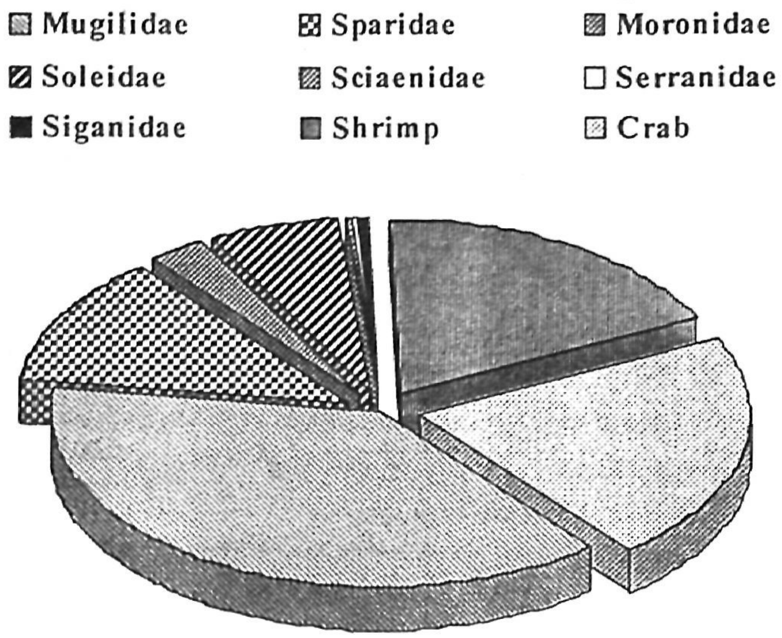


Fig. (3). Catch composition of Lake Bardawil (1985-2004).

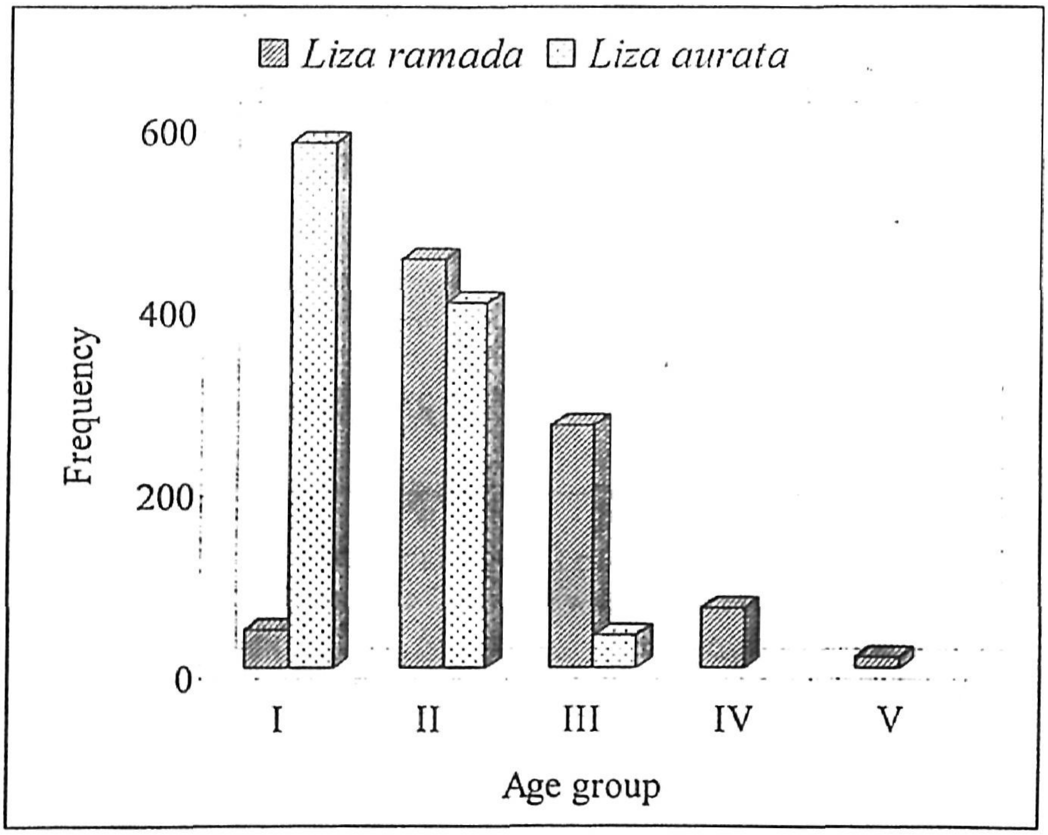
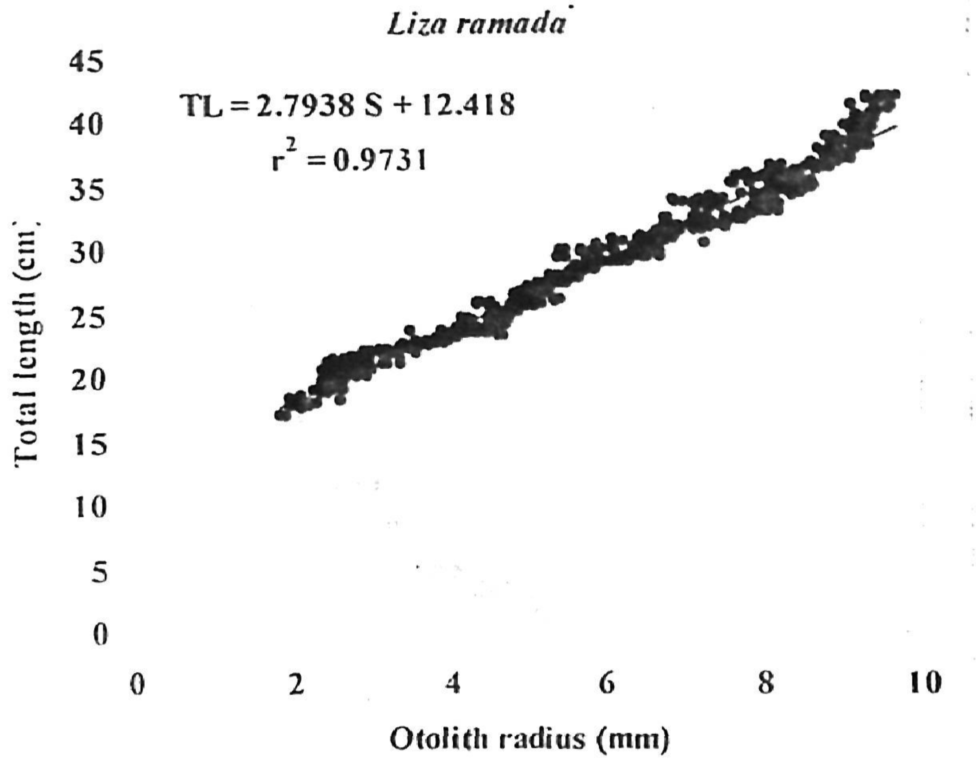


Fig. (4). Age composition of *Liza ramada* and *L. aurata* from Lake Bardawil.



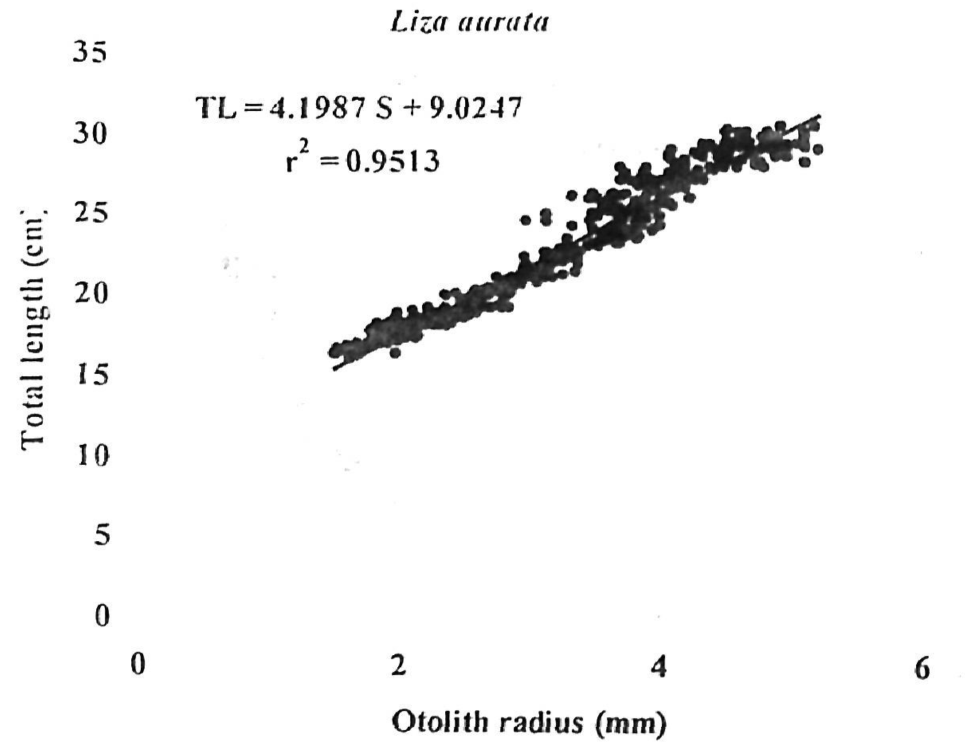


Fig. (5). Total length-otolith radius relationship of *Liza ramada* and *L. aurata* from Lake Bardawil.

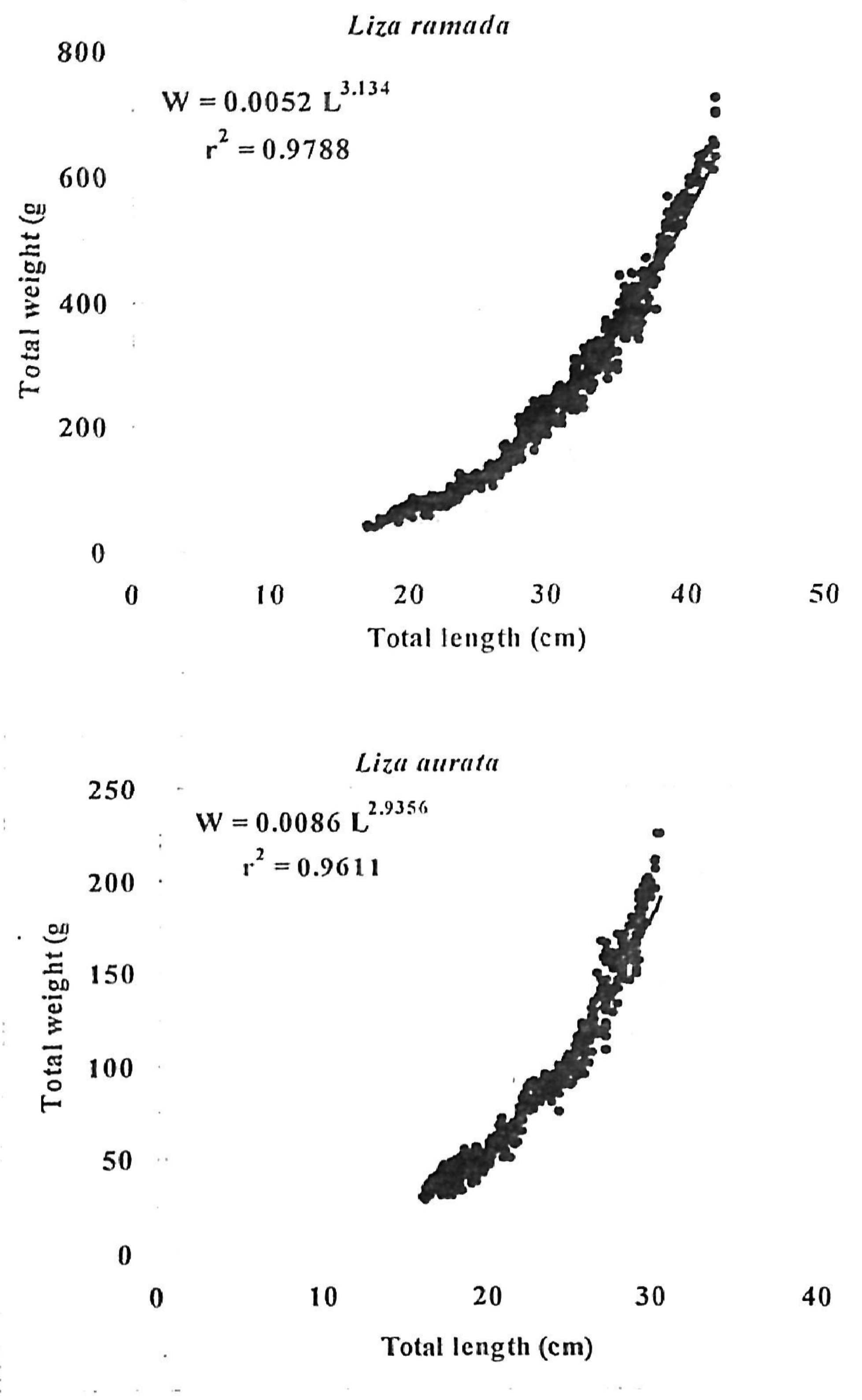
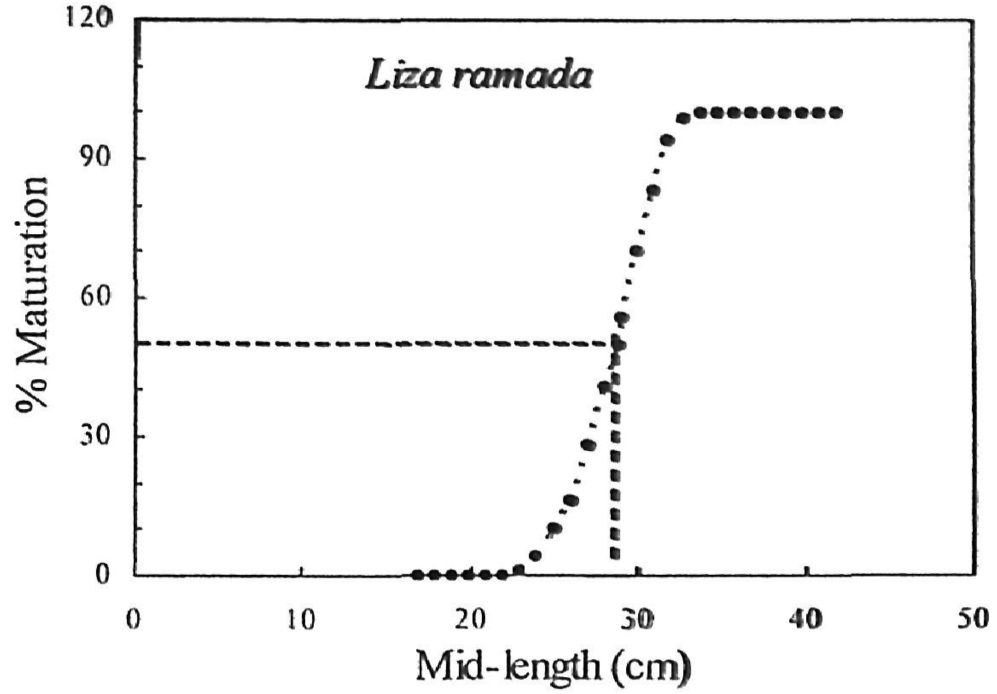


Fig. (6). Total length-total weight relationship of *Liza ramada* and *L. aurata* from Lake Bardawil.



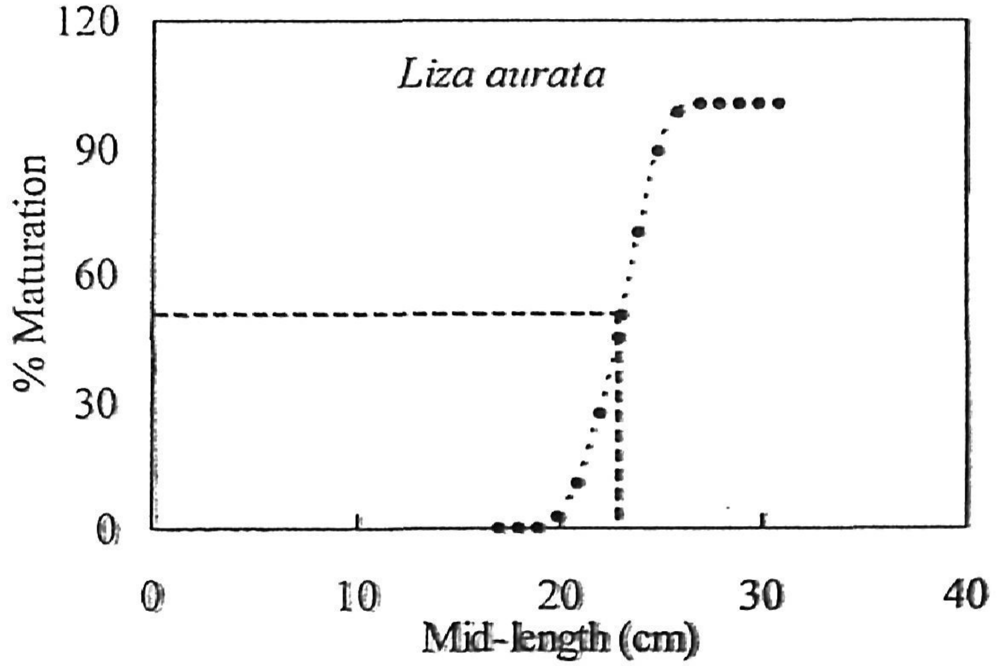


Fig. (7). Length at first sexual maturity of *Liza ramada* and *L. aurata* from Lake Bardawil.

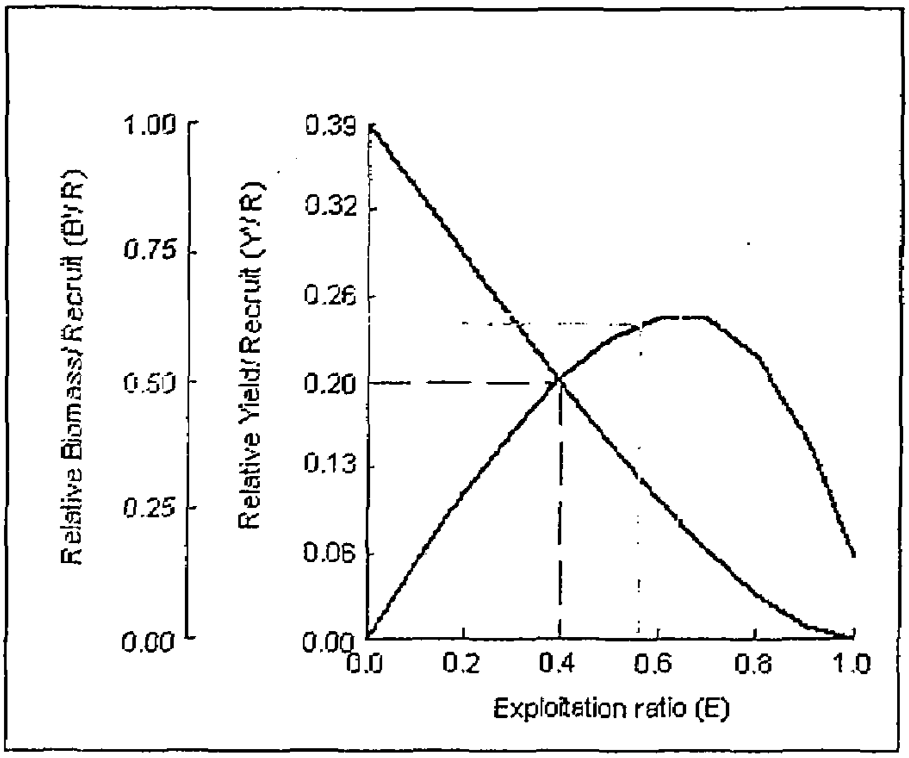


Fig. (8). Per-recruit analysis of *Liza ramada* from Lake Bardawil.

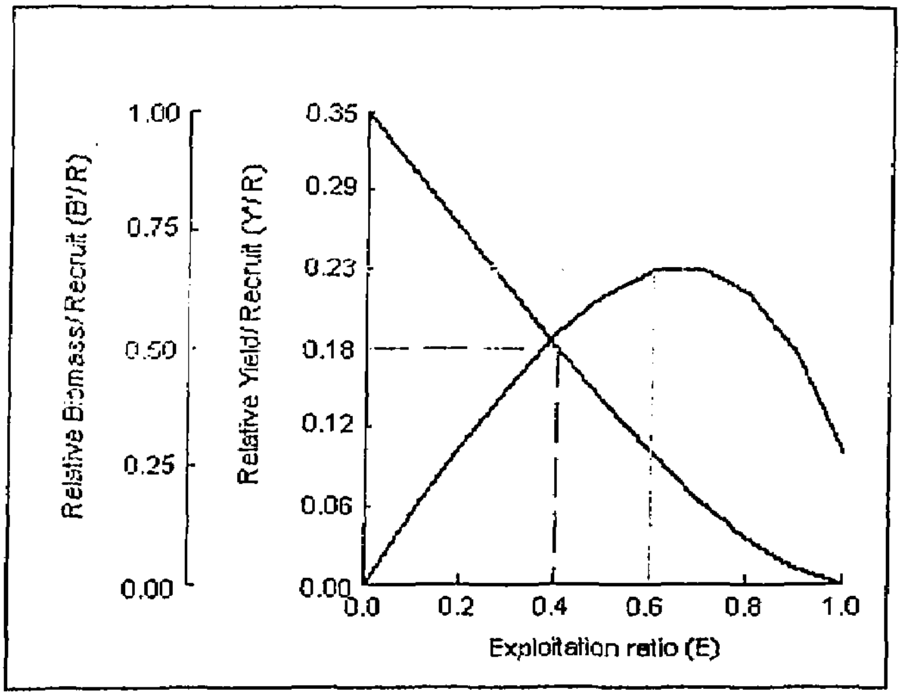


Fig. (9). Relative yield and biomass per recruit analysis of *L. aurata* from Lake Bardawil.

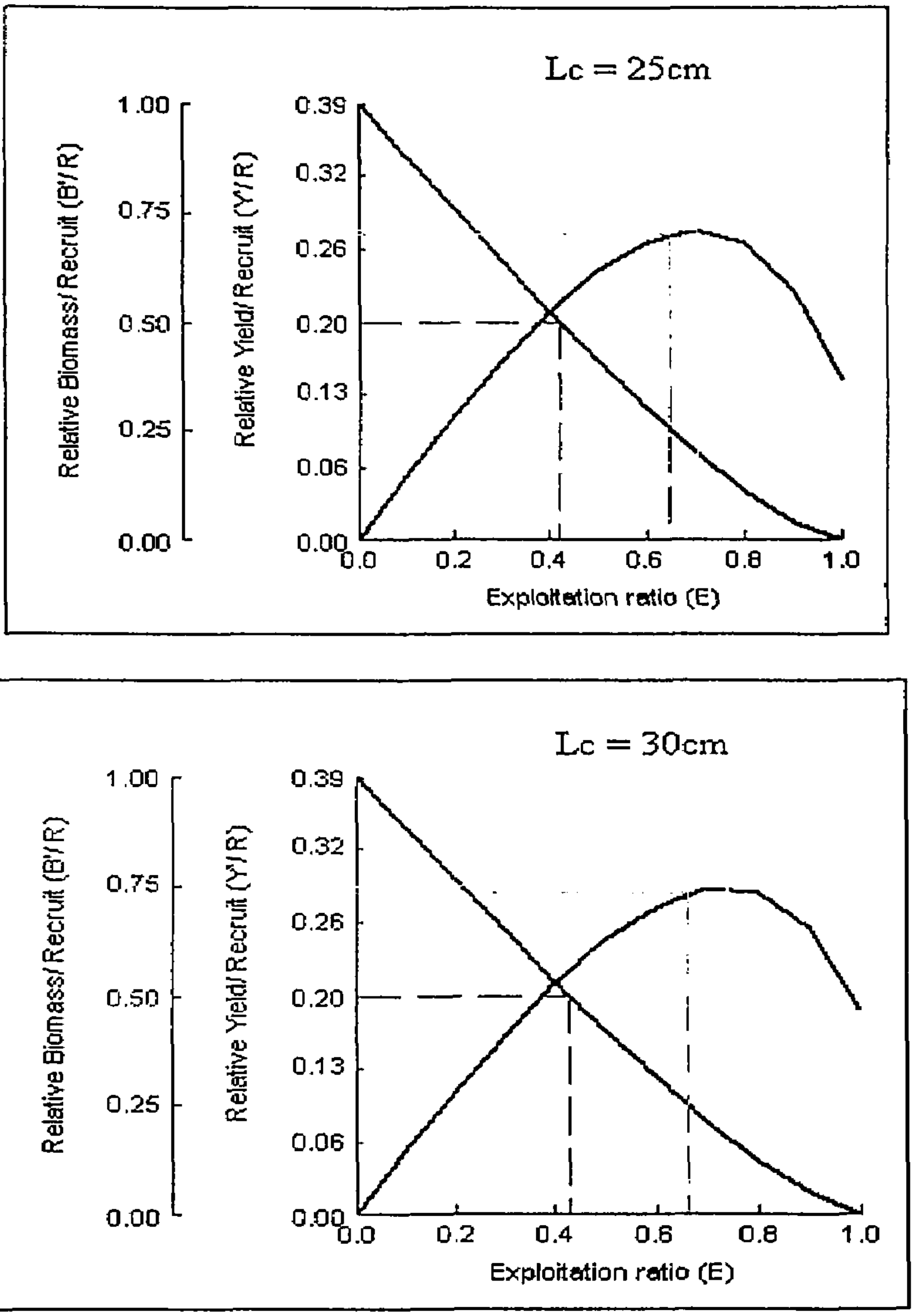
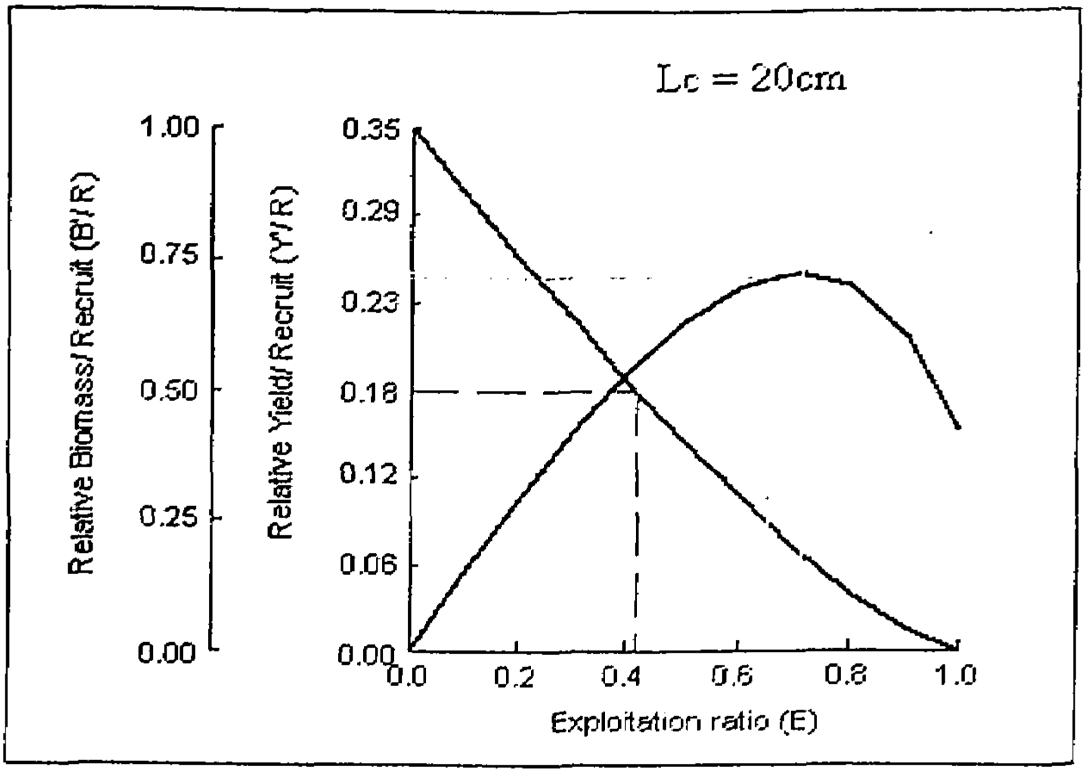


Fig. (10). Relative yield and biomass per recruit analysis of *L. ramada* from Lake Bardawil with different L_c.



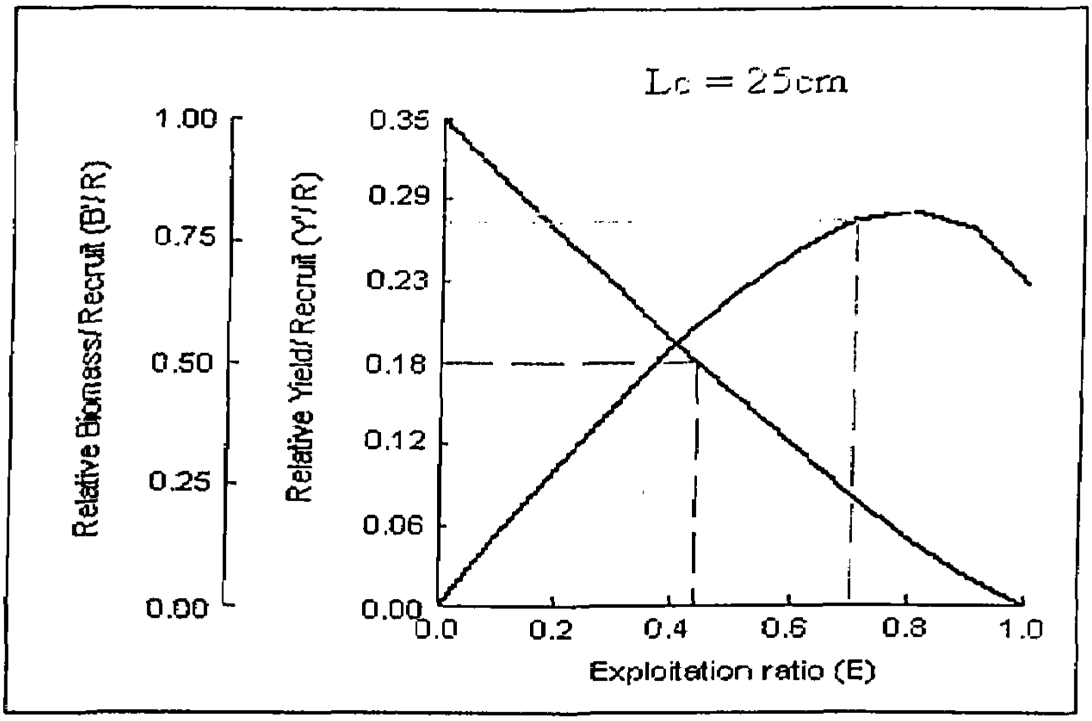


Fig. (11). Relative yield and biomass per recruit analysis of *L. aurata* from Lake Bardawil with different L_c.