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POPULATION DYNAMICS OF KEELED MULLET, *LIZA CARINATA* AND GOLDEN GREY MULLET, *LIZA AURATA* AT THE BITTER LAKES, EGYPT

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Key words: Bitter Lakes; Mugilidae; age and growth; mortality and exploitation rates; recruitment; relative yield and biomass per recruit.

ABSTRACT

Age and growth, mortality, recruitment pattern, relative yield per recruit and relative biomass per recruit of Liza carinata and L. aurata from the Bitter Lakes were studied. Age was determined using the otolith's readings and the longevity of the two species was found to be three years. The parameters of the von Bertalanffy growth model were estimated as K= 0.60 year^{-1}, L_∞= 23.59 cm and t_o = -0.3 year for L. carinata and K = 0.63 year^{-1}, L_∞= 32.41 cm and t_o = -0.2 year for L. aurata. The total mortality coefficient (Z), natural mortality coefficient (M) and fishing mortality coefficient (F) were 4.2, 0.96 and 3.24 year^{-1} respectively for L. carinata and 2.91, 0.96 and 1.95 year^{-1} respectively for L.aurata. Exploitation rate E was 0.77 and 0.67 year^{-1} for L. carinata and L. aurata respectively. Relative yield per recruit and relative biomass per recruit analysis show that L. carinata and L. aurata stock in the Bitter Lakes are in a situation of economic overfishing. For the management purposes, the present level of exploitation rate should be reduced by about 49.4 and 43.3% for L. carinata and L. aurata respectively to maintain a sufficient spawning biomass.

INTRODUCTION

Mullets (family: Mugilidae) are extremely important fish, which are cultured in many countries due to their high quality flesh, superior growth and wide salinity and temperature tolerance (Ishak, 1985). Mullets are the most important species participating in the fishery of the Bitter Lakes where they contribute about 42.2% of the annual lake production (General Authority for Development of Fisheries Resources). Mullet's catch is composed mainly from *Liza carinata, L. ramada, L. aurata* and *Mugil cephalus*. *L. carinata* (59.84%) are the most dominant species in the mullet's catch followed by *L. ramada* (32.89%) then *L. aurata* (7.25%) while *M. cephalus* is rarely appear. Although the mullets contribute greatly in the economy of Egypt, very limited studies concerning their dynamics and management are available.

The present paper is an attempt for the management and provides a preliminary assessment of *L. carinata* and *L. aurata* in the Bitter Lakes.

MATERIAL AND METHODS

Material

Monthly random samples of *L. carinata* and *L. aurata* were collected from the landing site of the Bitter Lakes during the period from October 2002 to October 2003. The length frequency for more than 7000 *L. carinata* and 1000 *L. aurata* was grouped in

1cm length classes (Table 1). 900 and 425 specimens represented all length classes of the two species were taken as a sub-sample for age determination and estimation of length-weight relationship. The total length to the nearest mm and total weight to the nearest 0.1g were taken. Otoliths were obtained for age determination.

Methods

- Age was determined by using the otolith's reading method. 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. The total radius of the otolith "S" and the distance between the focus of the otolith and the successive annuli were measured to the nearest 0.001mm. The lengths of the previous ages were back - calculated using Lee's equation (1920) as follows:

$L_n = (L - a) S_n/S + a$

where L_n is the calculated length at the end of n^{th} year, L is the length at capture, S_n is the otolith radius to n^{th} annulus, S is the total otolith radius and a is the intercept of the regression line with the Y-axis.

-Length-weight relationship was estimated using the power equation $W= aL^b$ (Le Cren, 1951) where W is the total weight in g, L is the total length in cm.

-Gulland and Holt (1959) method was used to obtain the growth parameters (K, L_∞ and t_o) of the von Bertalanffy growth equation $L_t = L_\infty [1 - e^{-K(t - to)}]$ where L_t is the length at age t, L_∞ is the asymptotic length, K is the growth coefficient and t_o is the arbitrary origin of growth curve.

-Pauly and Munro (1984) formula was applied to estimate the growth performance index as $ø = \text{Log } K + 2 \text{ Log } L_\infty$.

-Beverton and Holt's (1956) equation to obtain the total mortality coefficient "Z" as $Z = K*(L_\infty - \acute{L})/(L_\infty - L')$

where $\acute{L}$ is the mean length of fish of length L' and longer, while L' is the lower limit of the length class of highest frequency.

-The natural mortality coefficient (M) was calculated using Rikhter and Efanov's (1976) formula as $M = (1.521/t_{mass})^{0.72} - 0.155$

where t_{mass} is the age of massive maturation

-The fishing mortality coefficient (F) was computed as F = Z – M while the exploitation rate was computed from the ratio F/Z (Gulland, 1971).

-Catch curve analysis (Pauly, 1984) to estimate the length at first capture.

- The recruitment patterns were obtained by projecting length frequencies backward onto a one-year time scale (FiSAT program).

-The relative yield per recruit (Y/R)' and relative biomass per recruit (B/R)' were estimated by using the model of Beverton and Holt (1966) as modified by Pauly and Soriano (1986) and incorporated in FiSAT software package (Gayanilo *et al.* 1997). This model is defined by:

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

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

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

Age and growth

Otoliths were used for age determination of *L. carinata* and *L. aurata* from the Bitter Lakes. Otoliths as a reliable and valid method for ageing *L. carinata* and *L. aurata* have been proven. Body length – otolith radius relationship (Fig. 1) showed a strong correlation between the body length and otolith radius. Also, the increase of fish size is accompanied by an increase in the number of annuli on the otoliths. On the other hand, marginal increment indicated that the annulus is formed once a year. Moreover, back - calculated lengths accord with the observed lengths for the different age groups (Table 2).

Table (1). Length frequency of *Liza carinata* and *Liza aurata* from the Bitter Lakes.

Length interval	**Number of fish**	
	Liza carinata	***Liza aurata***
8 – 8.9	36	--
9 – 9.9	125	--
10 – 10.9	386	3
11 – 11.9	569	6
12 – 12.9	787	6
13 – 13.9	1495	12
14 – 14.9	1926	15
15 – 15.9	1150	48
16 – 16.9	391	63
17 – 17.9	111	116
18 – 18.9	34	90
19 – 19.9	12	144
20 – 20.9	7	159
21 – 21.9	4	141
22 – 22.9		96
23 – 23.9		40
24 – 24.9		33
25 – 25.9		18
26 – 26.9		12
27 – 27.9		9
28 – 28.9		3
29 – 29.9		3
30 – 30.9		2
Total	7033	1019

The results indicated that, the maximum life span of *L. carinata* and *L. aurata* is three years. The lengths corresponding to the various ages of *L. carinata* are 13.10, 17.97 and 20.58 cm for the 1st, 2nd and 3rd year of life respectively. The lengths corresponding to the various ages of *L. aurata* are 17.91, 24.88 and 28.50 cm for the 1st, 2nd and 3rd year of life respectively. It is found that, the two species attain their highest increase in length during the first year of life, after which a gradual decrease in growth increment is noticed with further increase in age. Hashem *et al.,* (1973) found that *Mugil auratus* in Lake Borollus has length range of 15-24 cm and belongs to two age groups. Salem and Mohamed (1982) studied age and growth of *Mugil seheli* in Lake Timsah. They gave lengths of 11.93, 14.79 and 15.91 cm for combined sexes for age groups I, II and III respectively.

Length - weight relationship

Based on 900 *L. carinata* their total lengths varied from 8.8 to 21.8 cm and their weights ranged between 6 and 125 g and 425 *L. aurata* their lengths varied from 10.8 to 30 cm and their weights ranged between 10 and 245g, the length - weight relationship was calculated for combined sexes (Fig. 2) and the equations obtained are:

For *L. carinata* $W = 0.0094\ L^{3.0479}$

For *L. aurata* $W = 0.0083\ L^{3.0097}$

The calculated weights at the end of each year of life of the two species were estimated by applying the corresponding length-weight equations to the back-calculated lengths and the results are given in Table 3. The results indicated that the maximum value of annual increment in weight was observed at the end of the second year of life for the two species. On the basis of annual increase in weight, it would be economically important to protect the fish till their second year of life, after which they reach a good marketable size and 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. carinata

For growth in length:

$$L_t = 23.59\ (1 - e^{-0.6\ (t+0.3)})$$

For growth in weight:

$$W_t = 143.57\ (1 - e^{-0.6\ (t+0.3)})^{3.0479}$$

L. aurata

For growth in length:

$$L_t = 32.41\ (1 - e^{-0.63\ (t+0.2)})$$

For growth in weight:

$$W_t = 292.26\ (1 - e^{-0.63\ (t+0.2)})^{3.0097}$$

Growth performance index

Pauly and Munro (1984) have indicated a method to compare the growth performance of various stocks by computing the Phi index $ø = \log K + 2 \log L_\infty$. The obtained results indicated that the growth performance index (ø) of *L. carinata* and *L. aurata* was found to be 2.52 and 2.82 respectively. Based on the growth performance index estimation, the growth rate of *L. aurata* is higher than that of *L. carinata* in the 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 4.2, 0.96 and 3.24 $year^{-1}$ respectively for *L. carinata*. The same parameters were estimated as 2.91, 0.96 and 1.95 $year^{-1}$ respectively for *L. aurata*. Exploitation rate "E" is estimated to be 0.77 and 0.67 $year^{-1}$ for both species respectively (Table 4). The values of both fishing mortality and exploitation rates were relatively high indicating a high level of exploitation.

Length at first capture L_c

The length at first capture (the length at which 50% of the fish are vulnerable to capture) was estimated as a component of the length converted catch curve analysis (FiSAT). The value obtained was $L_{50\%} = 13.6$ cm for *L. carinata* and 18.28 cm for *L. aurata* (Table 4).

Recruitment patterns

The recruitment patterns of the stocks of *L. carinata* and *L. aurata* from the Bitter Lakes suggest that there is only one main pulse of annual recruitment (Fig. 3). This is in agreement with that obtained for *L. carinata* from Lake Timsah based on gonadal examinations (Salem and Mohammed, 1982).

Table (2). Back-calculated lengths (cm) at the end of different years of life for *Liza carinata* and *Liza aurata* from the Bitter Lakes.

Age (year)	*Liza carinata*				*Liza aurata*			
	Observed length	1	2	3	Observed length	1	2	3
	13.93	**13.10**			18.47	**17.91**		
17.97	18.48	13.03			25.29	17.79	**24.88**	
17.78	20.81	12.94		**20.58**	28.86	17.61	24.72	**28.50**
increment		13.1	4.87	2.61		17.91	6.97	3.62
%		63.65	23.66	12.68		62.84	24.46	12.7

Table (3). Calculated weights (g) at the end of different years of life for *Liza carinata* and *Liza aurata* from the Bitter Lakes.

Age (year)	*Liza carinata*			*Liza aurata*		
	1	2	3	1	2	3
I	**23.90**			**49.04**		
II	23.52	**62.64**		48.05	**131.88**	
III	23.02	60.64	**94.71**	46.61	129.34	**198.48**
increment	23.9	38.74	32.07	49.04	82.84	66.6
%	25.23	40.9	33.86	24.71	41.74	33.55

Relative yield per recruit (Y/R)' and relative biomass per recruit (B/R)'

Plot in relative yield per recruit (Y/R)' and biomass per recruit (B/R)' against exploitation rate (E) for *L. carinata* (Fig. 4) show that the maximum (Y/R)' was obtained at E_{MSY} = 0.86, as the exploitation rate increases beyond this value, relative yield per recruit decreases. 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 0.8 and 0.39 respectively. The results indicated that the present levels of E (0.77) was slightly lower than that which gives the maximum (Y/R)' but raising the exploitation rate to this value is unreasonable. The results show also that, the present level of exploitation rate (E = 0.77) is higher than the exploitation ate ($E_{0.5}$) which maintain 50% of the stock biomass ($E_{0.5}$ = 0.39).

In respect to *L. aurata* (Fig. 4), a maximum (Y/R)' can be obtained at E_{max} = 0.81. The values of $E_{0.1}$ and $E_{0.5}$ were 0.76 and 0.38 respectively. This means that, the exploitation rate of *L. aurata* should be reduced from 0.67 to 0.38 (43.3%) to maintain a sufficient spawning biomass.

The results of the relative yield per recruit analysis for both species indicate that additional fishing effort would provide very little additional catch, this means high costs and no economic return. It could be concluded that the *L. carinata* and *L. aurata* stocks in the Bitter Lakes are in a situation of economic overexploitation. For the management implications of the assessment, the present level of exploitation rate should be decreased by about 49.4 and 43.3 % for *L. carinata* and *L. aurata* respectively to maintain a sufficient spawning biomass for recruitment. This can be achieved by reducing the number of fishing days or the number of fishing trips or increasing the period of closing season.

Table (4). Populationparameters for *Liza carinata* and *Liza aurata* from the Bitter Lakes.

Population parameters	***Liza carinata***	***Liza aurata***
K	0.60	0.63
L_∞	23.59 cm	32.41 cm
W_∞	143.57 g	292.26 g
t_o	-0.3 year	-0.2 year
ø	2.52	2.82
Z	4.2	2.91
M	0.96	0.96
F	3.24	1.95
E	0.77	0.67
L_c	13.6 cm	18.28 cm
E_{max}	0.86	0.81
$E_{0.1}$	0.80	0.76
$E_{0.5}$	0.39	0.38

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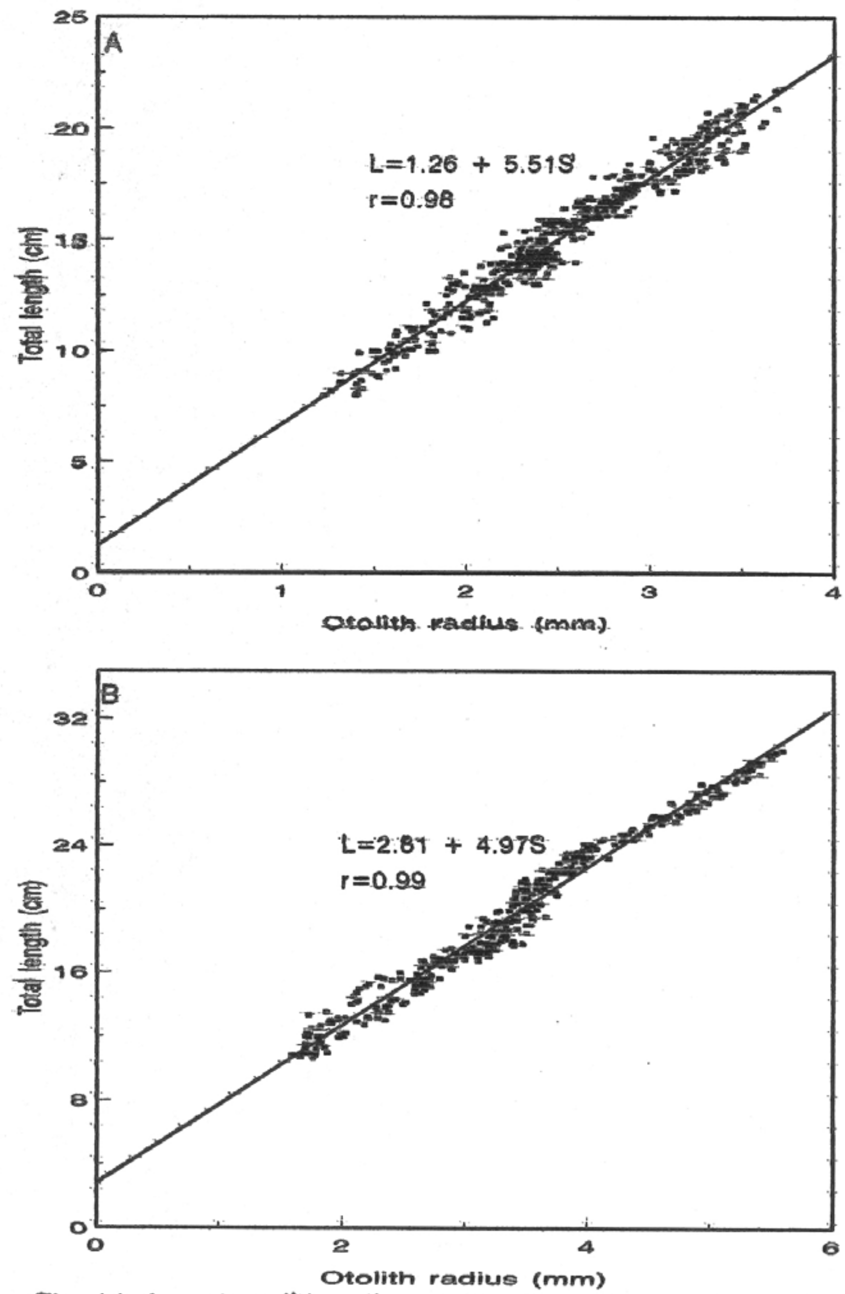

Fig. (1). Length-otolith radius relationship of *Liza carinata* (A) and *Liza aurata* (B) from the Bitter Lakes.

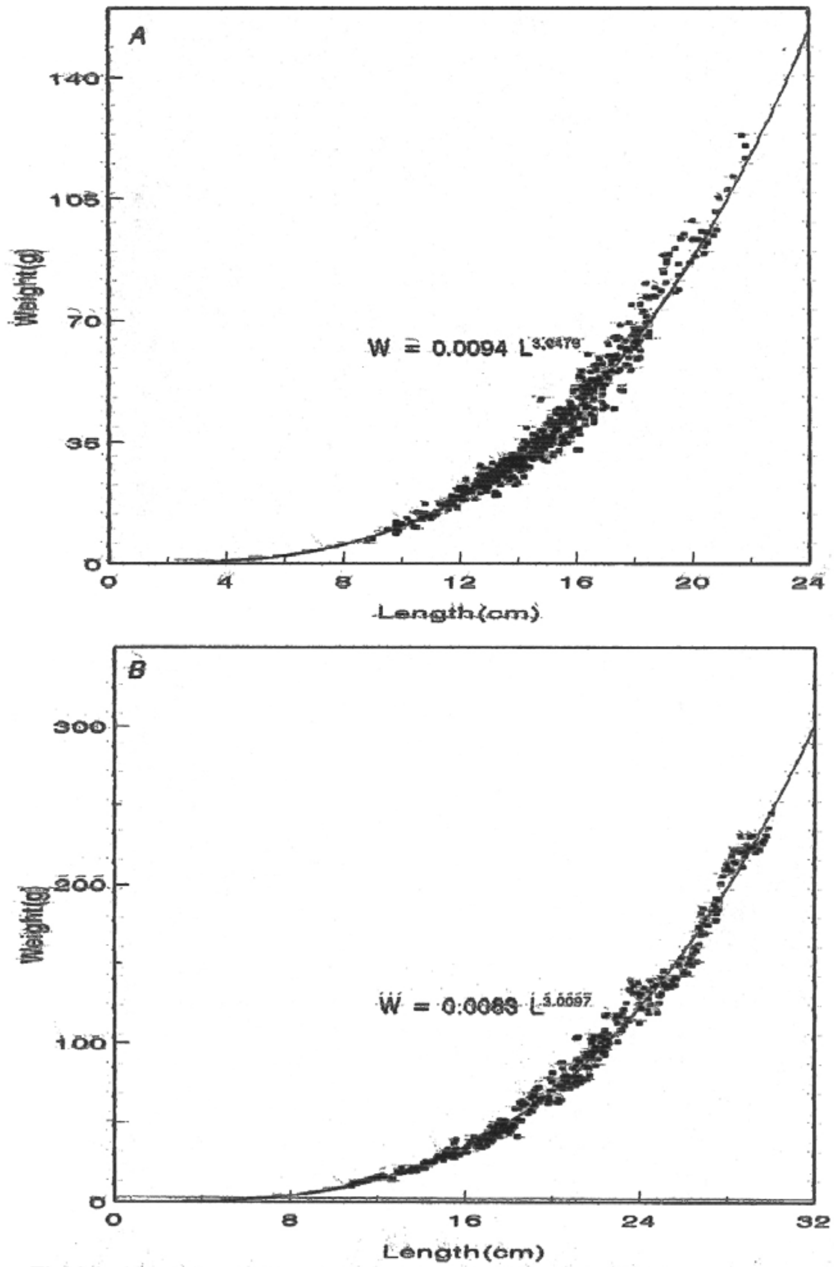

Fig.(2). Length-weight relationship of *Liza carinata* (A) and *L. aurata* (B) from the Bitter Lakes.

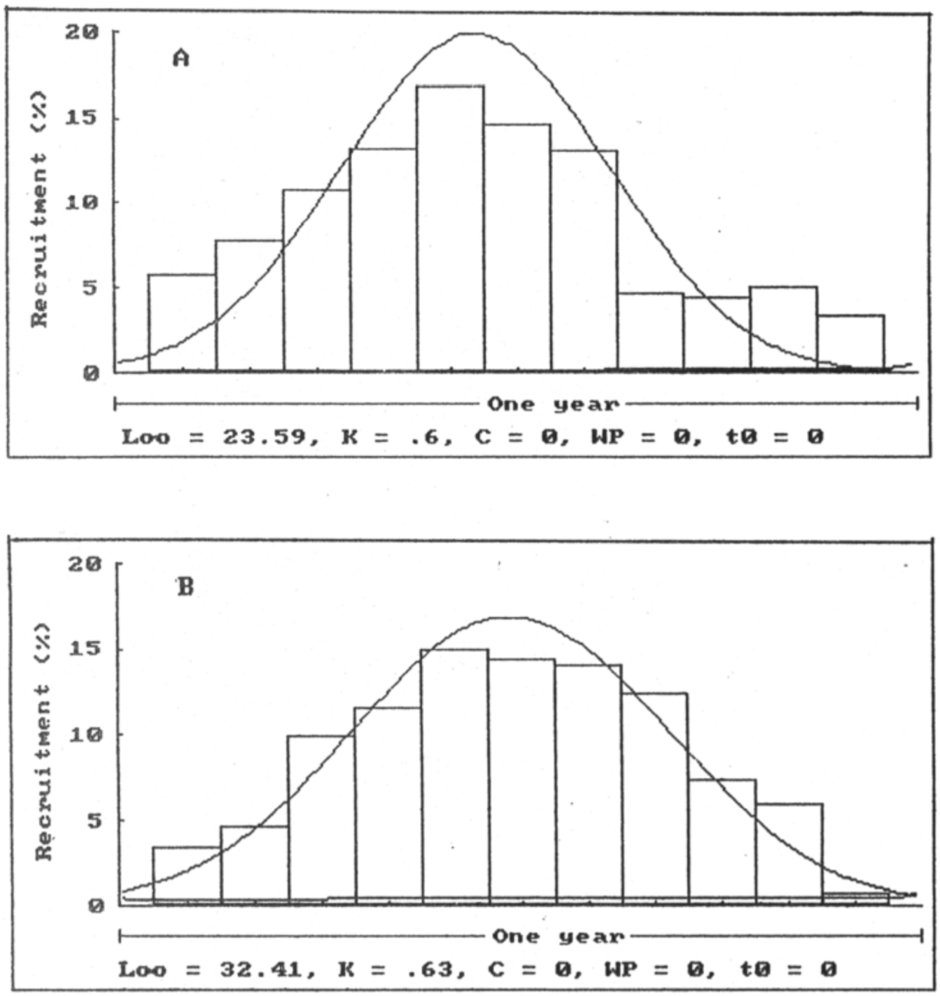

Fig.(3). Recruitment pattern of *Liza carinata* (A) and *L. aurata* (B) from the Bitter Lakes.

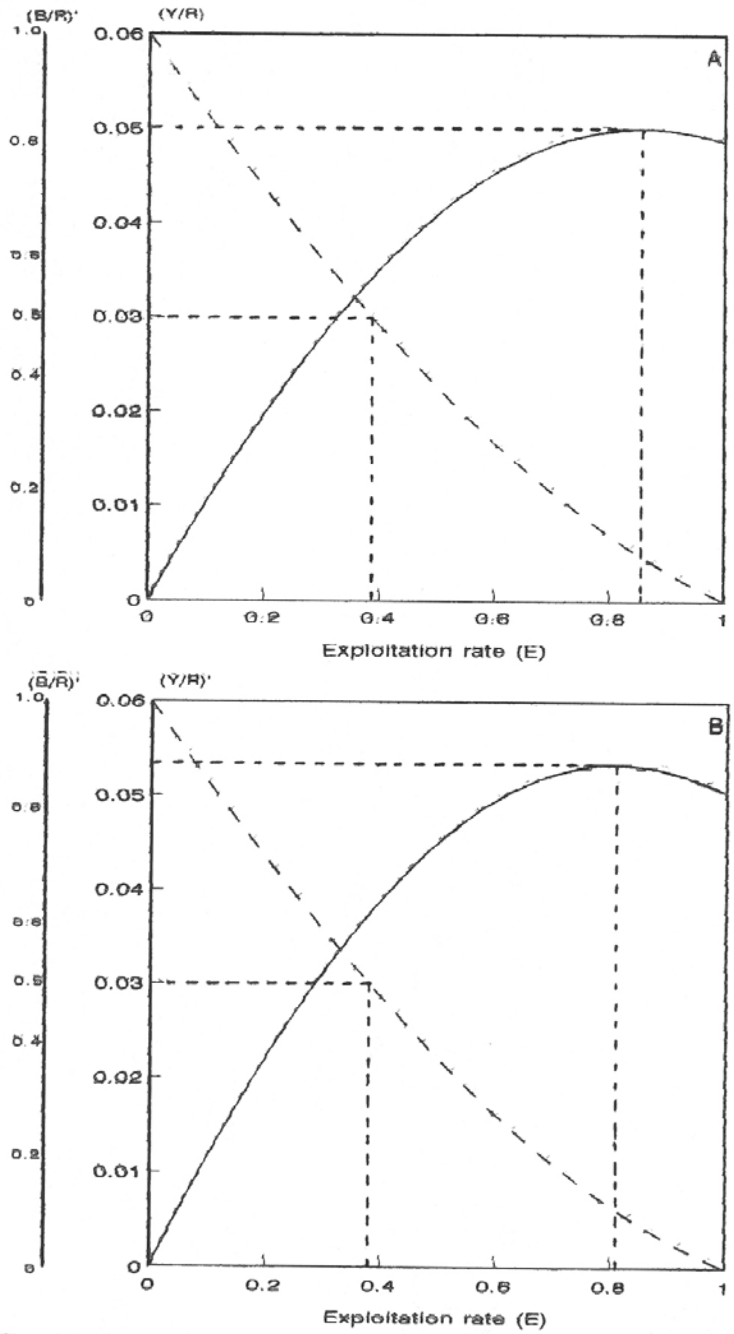

Fig. (4): Relative yield per recruit and relative biomass per recruit of *Liza carinata* (A) and *L. aurata* (B) from the Bitter Lakes.