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SOME ASPECTS OF REPRODUCTIVE BIOLOGY OF THE CRUCIAN CARP *CARASSIUS CARASSIUS* (L., 1758) (PISCES: CYPRINIDAE) IN LAKE ZIWAY, ETHIOPIA.

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ABSTRACT: Some aspects of reproductive biology of *Carassius carassius* (L.) such as sex ratio, breeding season, size at first maturity and fecundity were studied from 539 fish samples collected from October 2003 to September 2004 in Lake Ziway, Ethiopia. The overall sex ratio (male: female) was 1.1.7 and deviated significantly from the hypothetical distribution of 1:1 (x^2 =35.9, p< 0.001). Sex ratio was significantly different in all size classes >35.0 cm total length (TL) in November and December 2003 and in January, March and April 2004. The size at first maturity (L_{m50}) of males was 26.8 cm TL while L_{m50} of females was 30.5 cm TL. *C. carassius* had an extended breeding period from December to June, with peak spawning in February for both sexes when 75.0% males and 71.4% females had ripe gonads. The main pulse in breeding activity occurred during the early rains. The total number of eggs in the ovaries ranged between 81,674-10,616 with the mean number of 194,900 eggs female^{-1}. Ripe ovaries contained 748-1,442 eggs g^{-1} of preserved wet weight with a mean number of 981. Fecundity was positively related to TL (R^2 = 0.66, p<0.05) and total weight (TW) (R^2 = 0.71, p<0.05). *C. carassius* conformed to the general pattern of reproduction in a tropical environment where breeding activity started during the early rains. In order to protect the spawning population, fishing pressure should be minimized during breeding time at shallow littoral regions.

Key words/phrases: Breeding season, Commercial fishery, Fecundity, Introduced species, Size at first maturity.

INTRODUCTION

The Crucian carp *Carassius carassius* (L., 1758) is a freshwater cyprinid that is widely distributed in Eurasia: Spain across Europe, and north-central Asia to Northern China (Vostradovisky, 1973; Economids, 1991; Kottelat, 1997). It occurs in shallow ponds, lakes rich in vegetation and slow moving rivers (Vostradovisky, 1973). It burrows in mud in the dry season or winter (Allardi and Keith, 1991) and tolerates cold, organic pollutants and low oxygen concentration in water (Blazka, 1958; Vostradovisky, 1973). Since it is a fast growing and hardy fish that can withstand adverse environmental

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conditions, it has been successfully introduced into fresh waters throughout the world (Welcomme, 1988; Seegers *et al*., 2003). *C. carassius* is an exotic fish species introduced in Lake Ziway (FAO, 1997) in late 1980's by Ministry of Agriculture staff with the intention of increasing fish production by introducing a macrophyte feeder into the system where the niche was not occupied by any of the indigenous fish. The ecological impact of such an introduction could be undesirable because the species is known to be a potential pest in many countries for which data are available. At present *C. carassius* is one of the commercially important fish species in Lake Ziway.

Various workers have studied reproductive biology of *C. carassius* in some European and Asian water bodies (Vestradovsky, 1973; Laurila *et al*., 1987). The available information indicates that *C. carassius* spawns clear to pale yellow eggs on dense vegetation in shallow water (Laurila *et al*., 1987). In many parts of Europe spawning takes place in March-June where ripe females release 10,000-300,000 eggs (Maitland and Campell, 1992; Billard, 1997; Spratte and Hartmann, 1997)

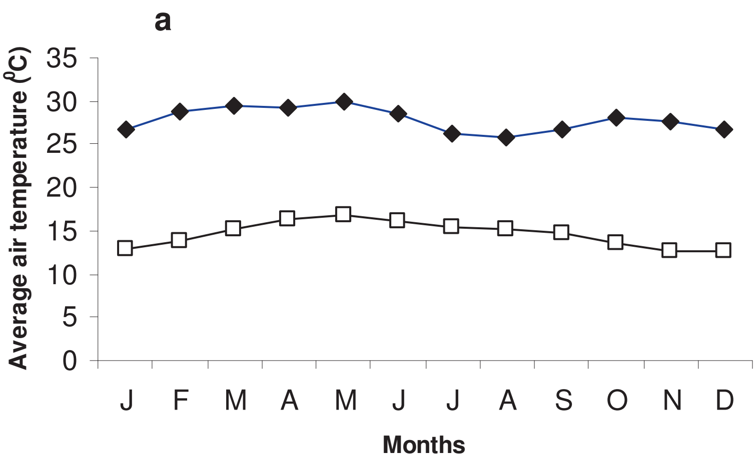
So far no published work is available on the biology and ecology of *C. carassius* in Lake Ziway. This paper deals with some aspects of reproductive biology (sex ratio, breeding season, size at first maturity and fecundity) of *C. carassius* in the lake with the aim of providing the necessary scientific information for proper utilization and management of the stock.

MATERIALS AND METHODS

Study area

Lake Ziway (Lat.: $7^0$52'-$8^0$8' N; Long.: $38^0$40'-$38^0$56' E) is the most northern lake in the closed Ziway-Shala basin in the central rift valley region of Ethiopia. It has an area of 434 km^2, a maximum depth of 7 m and a mean depth of 2.5 m (Wood and Talling, 1988). It is located at an altitude of 1636 m and about 160 km south of the capital city of Addis Ababa. The major effluents of the lake are Rivers Meki and Katar that flow in at the north and northeast end of the lake, respectively. Bulbula River is the major outflow of the lake that drains into the terminal, Lake Abijata.

Lake Ziway region is semi-arid to arid with a maximum air temperature of 28^0C and a minimum air temperature of 12.5^0C and frequent winds throughout the year (Fig. 1a). Precipitation rarely exceeds 600 mm per annum with a major peak occurring between July and August and a minor peak between February and May (Daniel Gamachu, 1977; Fig. 1b). The water level of the lake, that is lowest between February and April and highest between August and December, depends on the rainfall on the distant highlands of the western and eastern regions (Demeke Admassu, 1998).



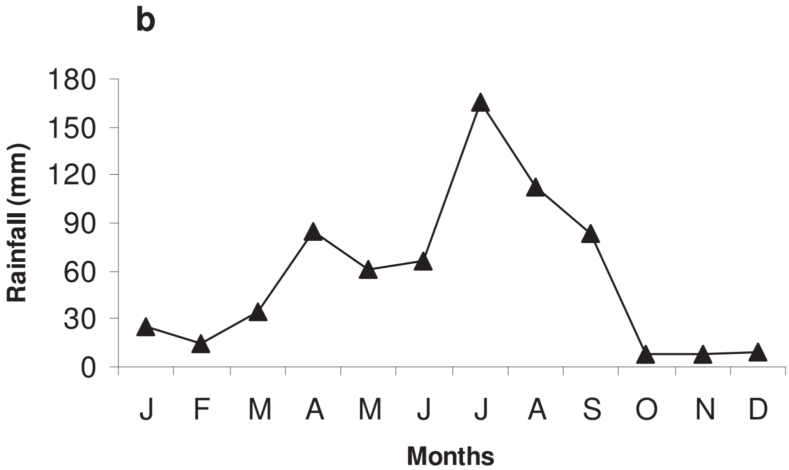


Fig. 1. Monthly mean maximum (♦) and minimum (□) air temperature (a) and monthly total rainfall (b) around Lake Ziway from 2001-2004.

The commercially important fish species of Lake Ziway are the Nile tilapia *Oreochromis niloticus* (L.), Tilapia zilli (an introduced exotic species), the African catfish *Clarias gariepinus* (Burchell), and *C. carassius*. *Clarias gariepinus* was probably introduced accidentally in 1980's while live fish were being transported from the neighboring lake, Lake Langeno, to the filleting and cold storage site located at the proximity of Lake Ziway. *C. carassius* is an exotic species introduced into the lake at about the same period as *Clarias gariepinus*.

Sampling

Samples of *C. carassius* were obtained between October 2003 and September 2004 from the commercial landings. The fishermen used beach seines of 40–70 mm stretched mesh sizes to capture fish from the littoral region of the lake. Total length (TL) of all fish sampled was measured to the nearest millimeter and their total weight (TW) was measured to the nearest 5 g. The fish were dissected and sex and sexual maturity of each fish was determined by visual examination of the gonads and by use of a five-point maturity scale based on the method of Holden and Raitt (1974). According to this scale fish are categorized as immature (I), developing virgin or recovering spent (II), ripening (III), ripe (IV) and spent (V). Ripe ovaries were weighed to the nearest 0.1 g and preserved in Gilson's fluid as in Bagenal and Braum (1978).

Size at first maturity

Length at which 50% of both sexes reach maturity (L_{m50}) was determined from the percentages of mature fish that were grouped in 5-cm length classes as described by the logistic function (Echeverria, 1987).

$$P = \frac{e^{(\alpha + \beta L)}}{(1 + e^{\alpha + \beta L})} \qquad (1)$$

where P= estimated proportion of mature fish, L= total length (centimeters), and α and β= coefficients. Equation (1) can be transformed into logarithmic form as follows:

$$\ln P/1\text{-}P = \alpha + \beta L \qquad (2)$$

The JMP program (Lehman and Sall, 1998) was used to calculate the observed mature proportion, its predicted probability and coefficients of the logistic equation. The value of L_{m50} was estimated from the negative ratio (*i.e.* -α/β) by substituting P= 0.5 in equation (2).

Breeding season

The breeding season was determined from the percentages of fish with ripe gonads taken each month. Since fish with ripe gonads could be found at any time of the year, breeding season was taken as the period of the year where 48.2%-71.4% of the males and 55.0%-75.0% of the females were in breeding condition. Gonado-Somatic Index (GSI), gonad weight as a percentage of total body weight was calculated for both sexes (Bagenal and Braum, 1978). A chi-square test was used to determine if the sex ratio varied between different size classes and months of the year (Frank and Althoen, 1994).

Fecundity

Fecundity was estimated by weighing all the eggs in the ovaries and weighing three sub-samples of 1g of eggs from various parts of the ovaries and calculating the average number of eggs per g wet weight. The total number of eggs per ovary was determined by multiplying the mean number of eggs per gram by the total weight of each ovary (Snyder, 1983). The relationship between fecundity and some morphometric measurements, TL and TW were determined using least squares regression.

RESULTS

Sex ratio

Of the 539 fish samples of *C. carassius*, 200 (37.1%) were males while the remaining 339 (62.9%) were females. The overall sex ratio of males to females was 1:1.7. This ratio was significantly different from the hypothetical ratio of 1:1 (x^2 = 35.9, P<0.001). Sex ratio was also calculated for different size classes (Table 1) and months of the year (Table 2). The sex ratios were not significantly different from unity for all size classes below 35 cm TL whereas significantly more females were caught in all size classes above 35 cm TL (Table 1). There were no significant differences between the sex ratios of fish caught in February and May-October (Table 2). The ratios of males to females were significantly different than 1:1 in January, March-April and November-December (Table 2). The smallest male captured during the investigation was 17.7 cm TL and 79 g TW while the largest male caught was 47.8 cm TL and 1,386 g TW. The smallest female sampled was 17.5 cm TL and 68 g TW while the largest female caught was 47.5 cm TL and 1,679 g TW.

Table 1. Number of males and females and the corresponding sex ratios in samples of *C. carassius* from Lake Ziway.

Length (cm)	Males	Females	Sex-ratio (male: female)	Chi-square
15.0-19.9	5	4	1: 0.80	0.12
20.0-24.9	7	13	1: 1.86	1.80
25.0-29.9	15	8	1: 0.53	2.18
30.0-34.9	58	47	1: 0.88	1.15
35.0-39.9	88	131	1: 1.61	12.33***
40.0-44.9	26	127	1: 5.35	77.65***
45.0-49.9	1	9	1: 9.00	6.40*
Total	200	339	1: 1.70	35.85***

Samples were grouped in 5.0-cm size classes. *-significant (P<0.05), ***- very highly significant (P<0.001).

Table 2. Number of males and females and the corresponding sex ratios of *C. carassius* in different months of the year from Lake Ziway.

Month	Males	Females	Sex-ratio (male: female)	Chi-square
J	7	29	1: 4.17	13.44***
F	4	7	1: 1.75	0.82
M	22	43	1: 1.86	6.78**
A	28	51	1: 1.71	6.70**
M	29	21	1: 0.69	1.28
J	22	18	1: 0.86	0.40
J	15	23	1. 1.53	1.68
A	14	20	1: 1.43	1.06
S	5	11	1: 2.20	2.25
O	16	29	1: 1.81	3.76
N	23	56	1: 2.57	14.82***
D	15	31	1: 2.07	5.57*
Total	200	339	1: 1.70	35.85***

*- significant (P<0.05), **- highly significant (P<0.01), ***- very highly significant (P<0.01).

Size at first maturity

The percentages of male and female *C. carassius* having gonad stages III, IV and V (Holden and Raitt, 1974) in different length groups were plotted against length for each sex using the data from the breeding season (December 2003 to June 2004). The average length at which 50% of the males reached maturity was 26.8 cm TL while the length at which 50% of the females attained sexual maturity was 30.5 cm TL (Fig. 2). The smallest male found with ripe gonads was 21.4 cm TL and weighed 121 g while the smallest female in breeding condition was 23.6 TL and weighed 190 g,

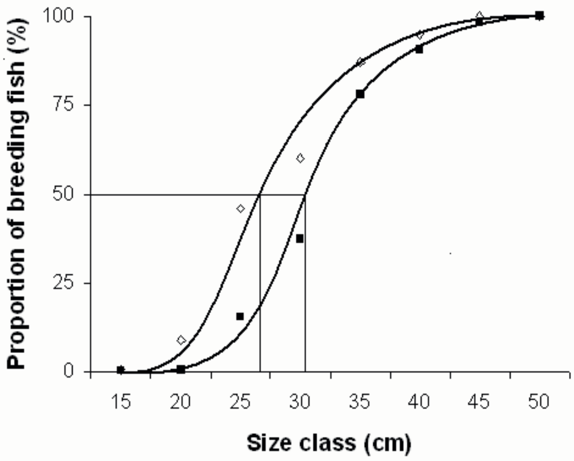


Fig. 2. Size at first maturity of *C. carassius* obtained by determining the average size at which 50% of the fish of both sexes reach maturity (◊ - males, ■ - females).

Breeding season

The breeding season of *C. carassius* was determined from percentages of fish with ripe gonads taken monthly from October 2003 to September 2004. Although breeding continued throughout the year, the most intense breeding activity occurred from December 2003 to June 2004 (Fig. 3a). During high breeding time 48.2%-71.4% of the males and 55.0%-75.0% of the females were found with ripe gonads (Fig. 3a). The proportion of fish with ripe gonads was relatively low during the other months (i.e. July-November 2004) during which time 14.3%-37.5% of the males and 9.5%-41.4% of the females had ripe gonads (Fig. 3a).

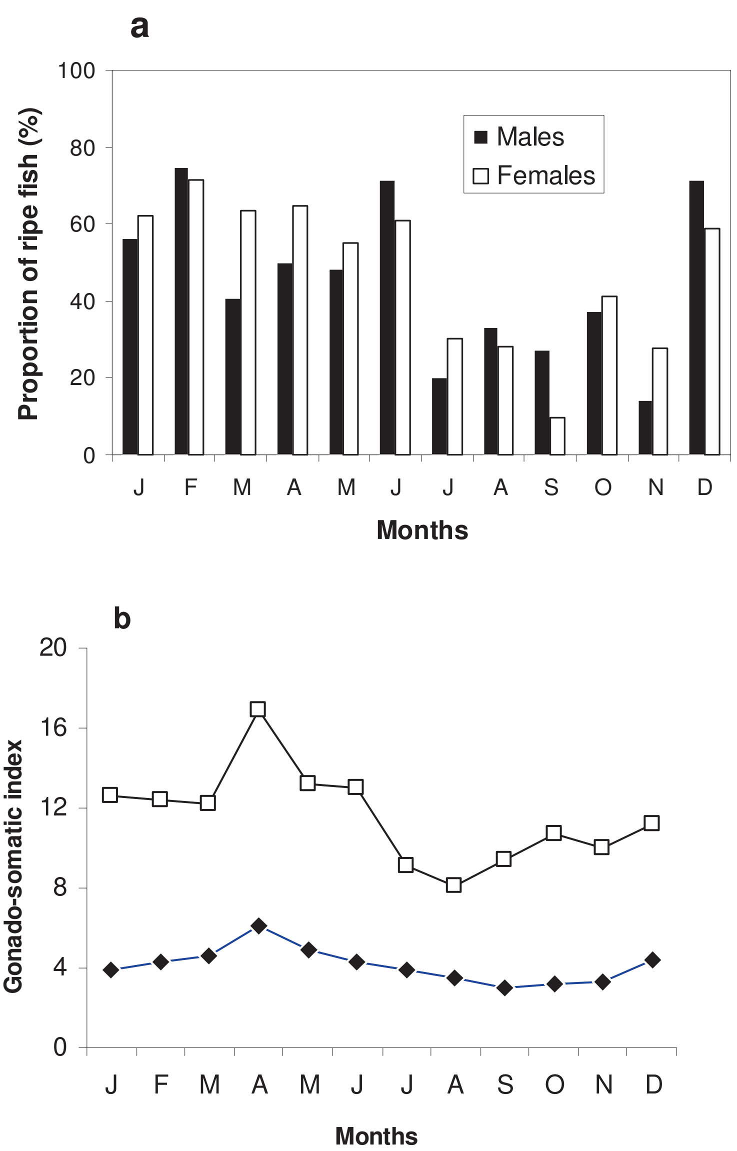
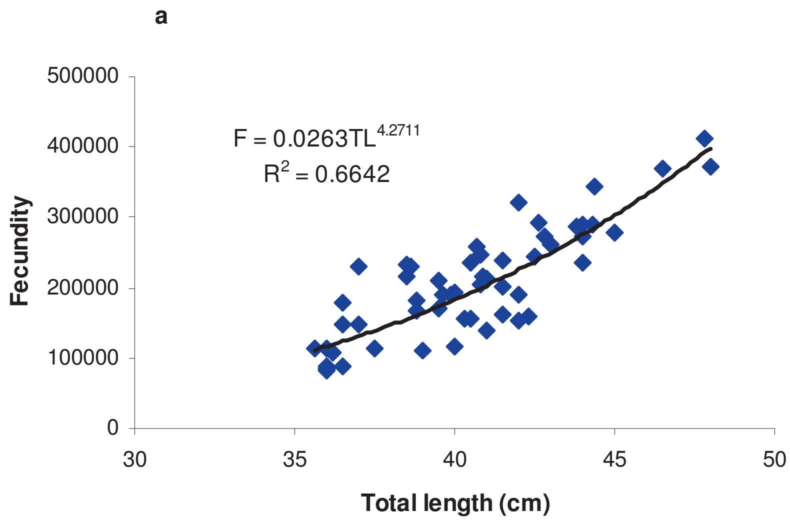


Fig. 3. The breeding season of *C. carassius* in Lake Ziway as indicated by the proportion of ripe fish (a) and the average monthly Gonado-Somatic Index (GSI) (♦ - males, □- females) from October 2003 to September 2004 (b).

Fecundity

Based on 55 mature females, the mean fecundity was 194,900 and ranged between 81,674 and 410,616. The relationships between F and TL (Fig. 4a) and between F and TW (Fig. 4b) were curvilinear ($F= 0263TL^{4.2711}$,

R^2=0.6654; F= 33.575TW $^{1.246}$, R^2= 0.7134). Ripe ovaries contained 748-1,442 eggs g^{-1} of preserved wet weight with a mean of 981 eggs.



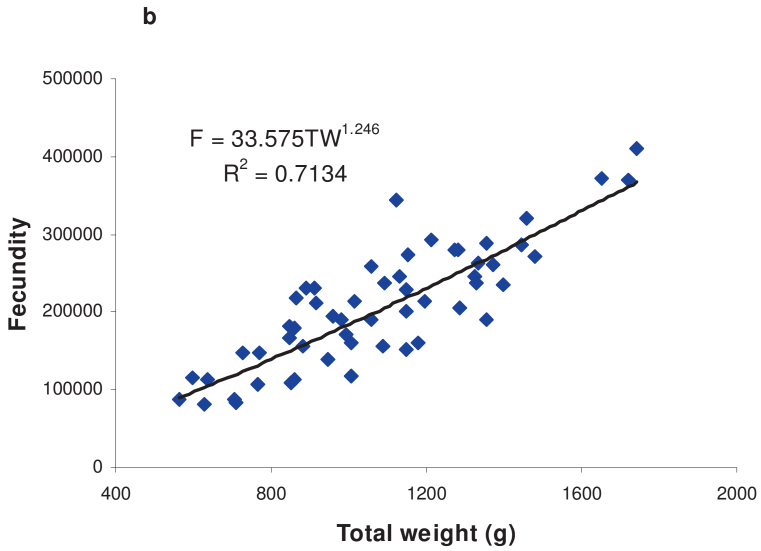


Fig. 4. Relationship between fecundity and total length (a) and between fecundity and total weight (b) of *C. carassius* from Lake Ziway.

DISCUSSION

The overall sex ratio of *C. carassius* was significantly different from 1:1 during the present study. Significantly more female than male fish were observed within the larger size classes (> 35 cm TL). This could be because of the difference in growth rate of both sexes where females attain larger size than males. Other biological mechanisms such as differential maturity rates, differential mortality rates, or differential migratory patterns between the male and female sexes may also cause unequal sex ratios at different size classes (Sandovy and Shapiro, 1987; Matsuyama *et al*., 1988). Sexual dimorphism is common in many fish species both in tropical and temperate areas. Elias Dadebo *et al*. (2003) reported the same phenomena of predominantly higher proportion of females in larger size classes in another cyprinid fish *Labeo horie* (Heckel) in Lake Chamo. Further investigation should be done in order to identify the causes of unequal sex ratio of *C. carassius* at larger size classes in Lake Ziway.

C. carassius in Lake Ziway exhibited a long breeding season where intensive breeding activity occurred during the months of December to June. During the other months, even though considerable proportions of fish were found in breeding condition, their proportion was much lower than the main breeding season. Several environmental factors could be responsible for the high breeding activity of *C. carassius* in Lake Ziway during the months of December to June. The beginning of the rainy season, subtle change in temperature, rise in water level and the subsequent lowering of water conductivity were implicated as the triggering factors for spawning of many tropical fish species (Rinne, 1975; Dadzie and Okach, 1989; Elias Dadebo, 2000; Elias Dadebo *et al*., 2003).

The sizes at 50% maturity of *C. carassius* (26.8 cm for males and 30.5 cm for females) were much higher than those reported by other investigators in European water bodies (Piironen and Holoainen, 1988; Balik *et al*., 2004). Size at maturity is negatively correlated to the degree of fishing mortality. As the fishing mortality increases, fish populations respond to the new environmental circumstances by changing their life-history pattern in order to compensate for the losses imposed by fishing activity (Wootton, 1998). Such a large discrepancy in the size of first maturity in the two environments could be due to the difference in fisheries activity. For instance, in Lake George (Uganda) size at maturity of tilapia (*O. niloticus*) was lowered following years of intensive fishing activity (Gwahaba, 1973). No study is available that relates the size at first maturity of *C. carassius* to the degree of fishing activity in Lake Ziway.

Fecundity increased in proportion to 4.27 power of the length and 1.25 power of the weight (Fig. 3a, b). In many tropical freshwater fish species, fecundity is increased in proportion to 2.81-3.96 power of total length (Lowe-McConnell, 1975). Bagenal and Braum (1978) reported that the value of *b* (slope of the fitted line) is about 3 when fecundity is related to the length and about 1 when it is related to weight. *C. carassius* in Lake Ziway conforms to the general pattern of relationship of fecundity to length and weight of many tropical fish species. Variability was high when fecundity was related to length and weight of *C. carassius* in Lake Ziway. This indicates that other factors were also involved in affecting fecundity, in addition to morphometric measurements of fish, such as availability of food and egg size (Bagenal and Braum, 1978).

In summary, *C. carassius* conforms to the general pattern of breeding in tropical environment where relatively higher proportions of fish were in breeding condition during the early rains. Inundation of the littoral regions during the rainy season, low conductivity of the water, subtle changes in temperature are all implicated as possible factors affecting reproductive activities of the fish. Experimental studies are needed to identify the relative importance of these factors as reproductive cues. In order to protect the breeding population of *C. carassius*, fishing should be restricted in the shallow littoral areas during the peak spawning months of December to June. July to November could be an open fishing season for *C. carassius* in Lake Ziway, as relatively few fish are reproducing during this time of the year. Since females start reproduction at larger size than males, capture size of the stock should be determined taking into consideration the size at first maturity of females, which is 30.5 cm TL.

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