Aspects of the reproductive biology of *Oreochromis macrochir* (Boulenger) and *Oreochromis niloticus L.*) (Cichlidae) in Lake Chivero, Zimbabwe.

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ABSTRACT

Oreochromis niloticus and *O. macrochir* are alien species introduced into Lake Chivero, Zimbabwe with the former becoming the more successful of the two. Their reproductive biology was investigated to determine if it could account for this difference. Both species bred primarily during summer (August to April) although some male *O. niloticus* with active gonads were found throughout the year. Males of *O. macrochir* tended to show some breeding activity over a longer period than females but were inactive during winter. The length at maturity of males was similar in both species but females of *O. niloticus* matured at a smaller size (19.8cm) than females of *O. macrochir* (22.3cm). The mean relative fecundity of *O. niloticus* was significantly higher than that of *O. macrochir*. This might be one of the few factors that might account for its relative success in the lake.

KEY WORDS: Breeding, Fecundity, Competition, Seasonality, Maturity.

INTRODUCTION

In the last 100 years Africa has experienced about 150 introductions of freshwater fishes (Welcomme, 1988). Some 50 species of fish have been involved in these introductions (Welcomme, 1988) and there is growing concern about their biological impact.

While many of these introductions have been successful in increasing fish yields, they often carry a high ecological cost (Marshall, 2000).

Sometimes these costs are obvious, as in the introduction of the Nile perch, *Lates niloticus* (L.) into Lake Victoria (Kudhongania and Chitamwebwa, 1995), but more often they are obscured by a lack of knowledge about the biology of the alien species or the systems into which they have been introduced.About 26 exotic species have been introduced into Zimbabwe, and another 11 indigenous ones have been translocated within the country (Marshall, 1999).

Not all were successful and although only about 17 species have established wild populations this is still about 11 % of the country's fish fauna. The impact of some species such as kapenta, *Limnothrissa miodon* (Boulenger) and largemouth bass, *Micropterus salmoides* (Lacepède) has been investigated (Marshall, 1991; Gratwicke & Marshall, 2001) but more information on the biology of alien species is still needed. The green-headed tilapia, *Oreochromis macrochir* (Boulenger), occurs in the upper Zambezi and Okavango systems, the Cunene and Kafue Rivers, and the Zambian Congo system (Chambeshi and Luapula Rivers and Lakes Bangweulu and Mweru). It was brought to Zimbabwe for aquaculture purposes in the 1950s and was stocked in many reservoirs throughout the country (Toots, 1970). The Nile tilapia, *O. niloticus* (L.), is a nilotic species whose distribution extends from the Senegal River to the Nile, and south to Lake Tanganyika (Trewavas, 1983). It has been introduced to waters all over the tropics (Moreau, 1997) and was brought to Zimbabwe in the 1980s. *O. niloticus* grows more rapidly and to a larger size than any of the indigenous Zimbabwean tilapias and has become the main commercial fish in Lake Chivero (Mhlanga *et al*, 2006).

Lake Chivero (formerly known as Lake McIlwaine) was created in 1952 as the principal water supply for the city of Harare and is located about 37km southwest of the city. At full capacity it has a surface area of 26.30km^2 and a mean depth of 9.4m. Sewage and industrial effluent are discharged into some of its tributaries and it has been eutrophic since the 1960s (Munro, 1966). Since then, the Lake has suffered from water quality problems caused by algal blooms, which occasionally result in severe fish kills (Marshall, 1997; Moyo, 1997). There are about 28 fish species in the Lake, of which seven are introduced, and it supports productive fisheries activities (Marshall, 2005).

The two most important alien species are *O. macrochir*, introduced in 1957 to improve fishing, and *O. niloticus* whose origin is uncertain; anglers may have stocked it around 1990 since it was first recorded in the Lake in 1992 (Zengeya and Marshall, 2007).

Soon after its introduction *O. macrochir* displaced the native *O. mossambicus* (Peters), which had never been very numerous, and by the 1970s it had become the most important species in the Lake, making up over 70% of the commercial catch (Marshall, 1982). However, *O. niloticus* rapidly supplanted it and by 2003 this species made up about 80% of the gill-net catch in proportion to *O.macrochir* (Brendonck *et al*, 2003). This seems to be a very rapid rate of increase considering that the two species might be expected to compete with each other, but the factors that allowed *O. niloticus* to be so successful in the Lake have not been investigated. Biological differences between them may be significant and a comparative study of the two species has been initiated, with this paper reporting some aspects of their reproductive biology. An earlier investigation examined the breeding biology of *O. macrochir* (Marshall, 1979) and most recently their diets were compared (Zengeya and Marshall, 2007) but not much is known about the biology of *O. niloticus* in the Lake. This paper investigates the biology of two alien cichlids that are now widely distributed in Zimbabwe.

MATERIALS AND METHODS

Fish were caught with a fleet of gill-nets, ranging from 25 mm to 150 mm mesh size, increasing by 12 mm increments, set once a month over a period of 13 months from December 2000 to December 2001. In the laboratory, all fish were measured to standard length and weighed. The state of their gonads was noted and their appearance used to determine their maturation stages according to the criteria in Table 1. Breeding seasonality was determined by plotting the proportion of males and females with active gonads against time. The length of first sexual maturity, i.e. the length at which 50% of all individuals have active gonads during the months when most breeding activity occurs, was determined by plotting the percentage of individuals with active gonads against standard length (in 5-cm size classes). The ovaries were cleaned and preserved in 5% formaldehyde for two days after which they were transferred and stored in 70% alcohol. The number of eggs in the ovaries was estimated by counting and weighing 200 eggs and then calculating the total proportionally by:

$$N = (W_o/W_s) \times 200$$

where: N = total number of eggs, W_o = weight of the ovary (g) and W_s = weight of 200 eggs (g) (Bagenal & Braum, 1968). Relative fecundity was calculated as the number of eggs per gram body weight.

RESULTS

The catch was dominated by *O. niloticus*, which was about twice as numerous as *O. macrochir* in the gill-nets (Table 2). The sex ratio of *O. niloticus* (1.1 females: 1 male) was not significantly different ($P > 0.05$), but in *O. macrochir* (1.4 females: 1 male) the number of females was significantly greater ($P < 0.05$). In both species the main breeding season was during spring and summer, from August to April. Some male *O. niloticus* with active gonads could be found throughout the year but the period of greatest activity (> 30% active) was from September to December (Figure 1a). The activity of females was also greatest between September and December with very few active females being recorded in other months, and none in mid-winter (May-July).

The seasonal pattern of breeding in male *O. macrochir* was similar to that of the female *O. macrochir,* both being most active between August and December (Figure 1b). As in *O. niloticus,* the males tended to show some breeding activity over a longer period than the females, but were inactive in mid-winter. *Oreochromis niloticus* females matured at a slightly smaller size (19.8 cm) than those of *O. macrochir* (22.3 cm) but the length, 23.4 and 23.7cm respectively, at maturity for males of both species was similar ($P > 0.05$). Females of *O. niloticus* matured at a slightly smaller size than the males but there was no difference between male and female *O. macrochir* (Figure 2).

The relationship between fecundity and standard length was similar in both species and a single regression line could be fitted to both sets of data (Figure 3). The females of *O. niloticus* were generally larger than those of *O. macrochir* and therefore produced more eggs. The mean relative fecundity (2.54 eggs g^{-1}) of *O. niloticus* was significantly higher ($P < 0.01$) than that of *O. macrochir* (1.81 eggs g^{-1}) (Figure 4).

DISCUSSION

In both species the main breeding season was from August to February, which corresponds to spring and summer in Zimbabwe. This is broadly similar to earlier findings on *O. macrochir* in Lake Chivero (Marshall, 1979), except that a higher proportion of males remained in breeding condition throughout the year. The marked seasonality of breeding activity in *O. macrochir* was in contrast with the situation in Lake Liambezi (upper Zambezi system) where they remained in breeding condition throughout the year (van der Waal, 1985). The factors that stimulate breeding seem to be an increase in water temperatures and the onset of the rains. Lowe-McConnell (1959) suggested that rainfall is the most important external factor stimulating breeding activity in tilapias although Fryer (1961) found no relationship between rainfall and reproductive activity in *O. variabilis* (Boulenger).

Temperature is an important factor because tilapias require water above 20°C in order to breed, although some can do so when it is as low as 16°C (Philippart & Ruwet, 1982). This explains the fall in breeding activity between March and September when the temperature of Lake Chivero falls below 16°C (Marshall & Falconer, 1973).

The length at which fish attain sexual maturity can be highly variable, depending on factors such as environmental conditions, population density, or the effect of fishing. The length at maturity in several wild populations of *O. niloticus* in East Africa, for example, varied by as much as 24 cm (Lowe-McConnell, 1982). The length at which *O. macrochir* reached sexual maturity was rather greater than it had been in the 1970s (23.7 *vs* 18 cm in males, 22.3 *vs* 17 cm in females) (Marshall, 1979) but the biological significance of this is unclear. The lack of any difference between the two species in Lake Chivero suggests that early maturity may not be a factor contributing to the success of *O. niloticus*. *Oreochromis niloticus* is known to grow more rapidly than other tilapias (Njiru *et al.*, 2004) and might therefore mature earlier than *O. macrochir*.

This is suggested by the fact that females of *O. niloticus* were found to be larger than those of *O. macrochir* (Figure 3) and were therefore more fecund even though the relationship between fecundity and length was the same in both species. Mean relative fecundity was about 40.6 % higher in *O. niloticus* and was the only characteristic identified in this study that may give it a competitive advantage against *O. macrochir*. Other factors such as competition for nesting sites, the frequency of breeding during the year, and brooding efficiency may also differ in the two species and will have to be further investigated.

Oreochromis niloticus has been shown to have a competitive advantage in lakes dominated by blue green algae such as *Microcystis* (Zanebe, 1999; Getachew, 1988) which was shown to be abundant in Lake Chivero (Magadza and Ndebele, 2006). This might also have given it a competitive advantage over *O. macrochir* in the lake but further investigation would be needed.

Oreochromis macrochir and *O. niloticus* share the same general biology as invasive species. They are hardy and can thrive in a wide range of water qualities (Philippart and Ruwet, 1982). They have rapid growth rates, ability to withstand crowding, good productivity per unit volume of water and economic and efficient food conversion (Caulton, 1982; Bowen *et al.* 1995). When introduced they occupy all available spawning sites and grow to large sizes which may cause them to displace native fish (Trewavas, 1983).

They also have a short generation time, multiple broods each year and can conversely delay reproduction and breed at smaller sizes when conditions are unfavourable (Trewavas, 1983; Lowe- McConnel, 1987). Further comparative studies between the two species in each of these aspects may give valuable insight and understanding as to why *O. niloticus* has been more successful in Lake Chivero compared to *O. macrochir*.In this study both fish were found to breed in the same seasons and their length at sexual maturity was found to be the similar. However, *O. niloticus* was found to have a higher mean relative fecundity compared to *O. macrochir*. This might be one of the few factors that might account for its relative success in the Lake Chivero.

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.TABLES

Table 1: The criteria used to determine the condition of the gonads in Oreochromis niloticus and O. macrochir from Lake Chivero (Marsh, Marsh & Ribbink, 1986).

Stage	Males	Females
Immature	Testes translucent and almost COlourless	Eggs elongate and pale yellow in colour
Inactive	Testes lobules flaccid and dull coloured	Eggs irregular in size and orange in colour
Active	Testes opaque and creamy, full of sperm	Eggs ovoid in shape, dull yellow in colour and easily counted
Spent	Testes thin, flaccid and irregular in shape	Ovaries thin and opaque. Red eggs dominant with a few bright orange ones

Table 2: The numbers of O. niloticus and O. macrochir caught in the gill nets in Lake Chivero, December 2000 to December 2001.

	O. niloticus		*O. macrochir*	
Month	Males	Females	Males	Females
December 2000	22	14	10	15
January 2001	62	54	13	20
February	19	32	8	9
March	15	12	17	19
April	27	27	15	21
May	33	38	8	19
June	18	27	10	17
July	28	8	2	17
August	15	27	18	9
September	14	32	6	20
October	22	35	12	12
November	29	35	22	28
December	27	24	10	11
Total	331	365	141	192

FIGURES

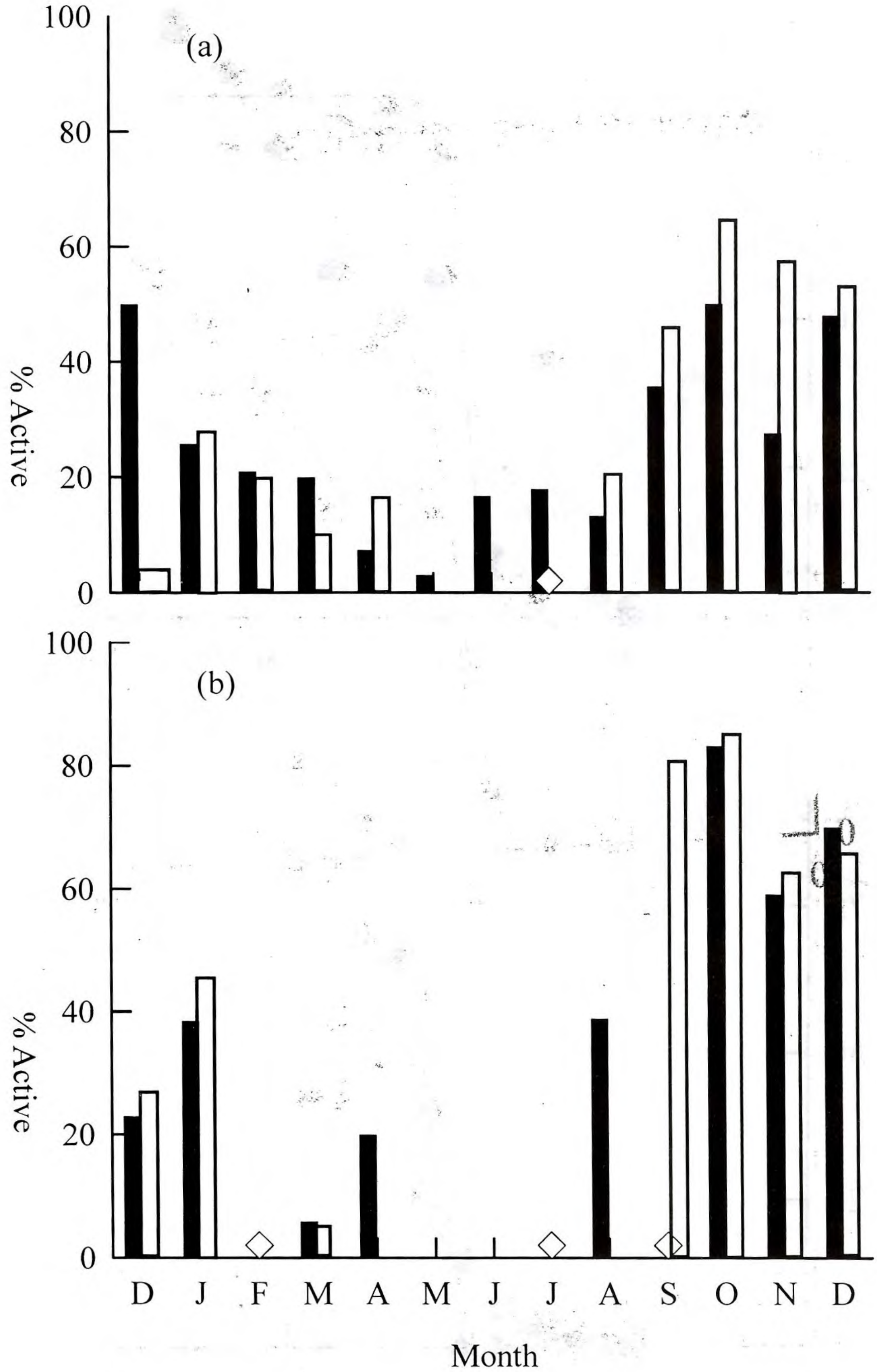

Figure 1: The proportion (%) of (a) *O. niloticus* and (b) *O. macrochir* in breeding condition in Lake Chivero, December 2000 to December 2001. Solid bars = males; open bars = females; ◊ = less than 10 fish caught

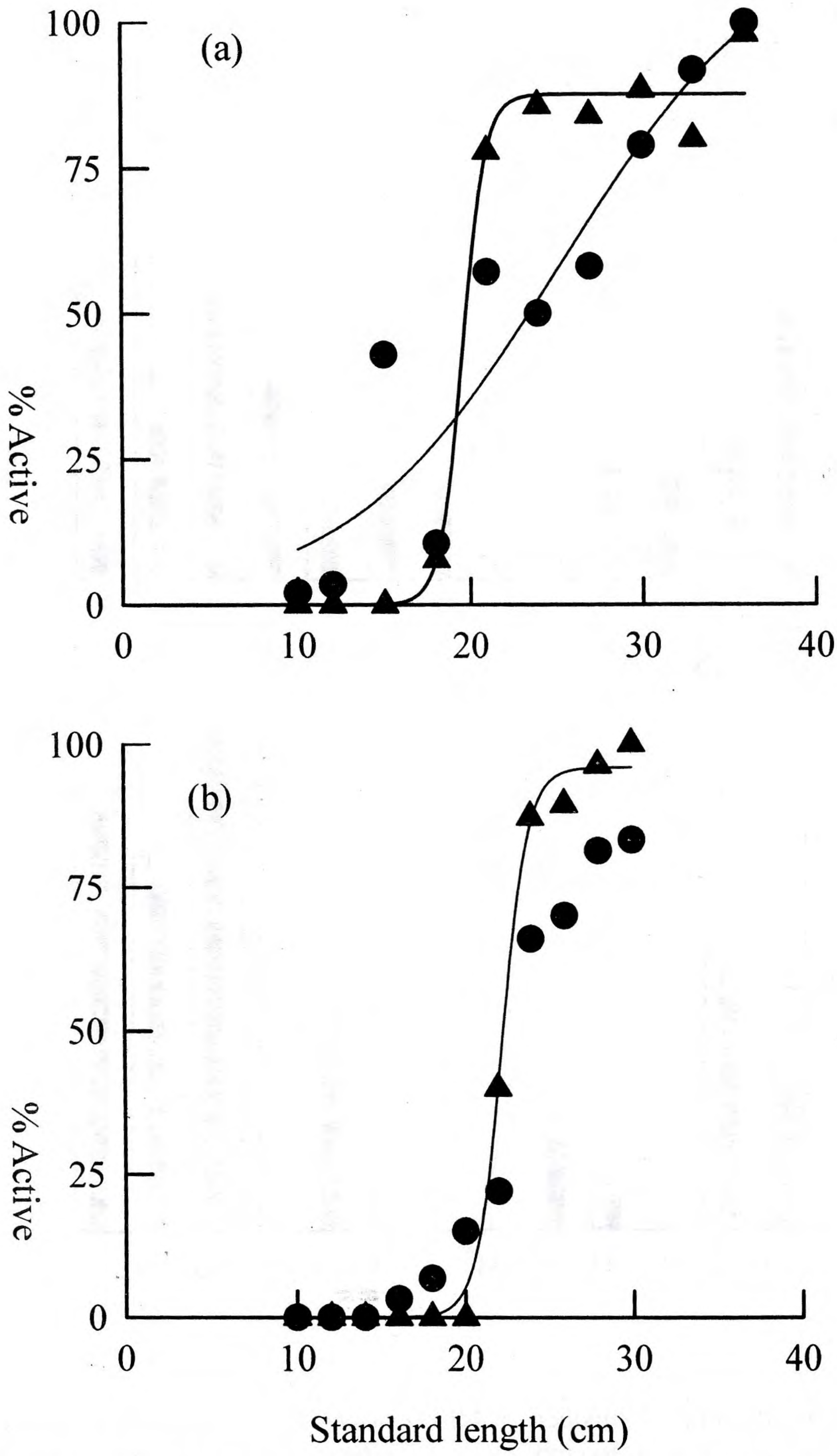

Figure 2: Length of first sexual maturity in (a) *O. niloticus* and (b) *O. macrochir* in Lake Chivero. ● = males; ▲= females.

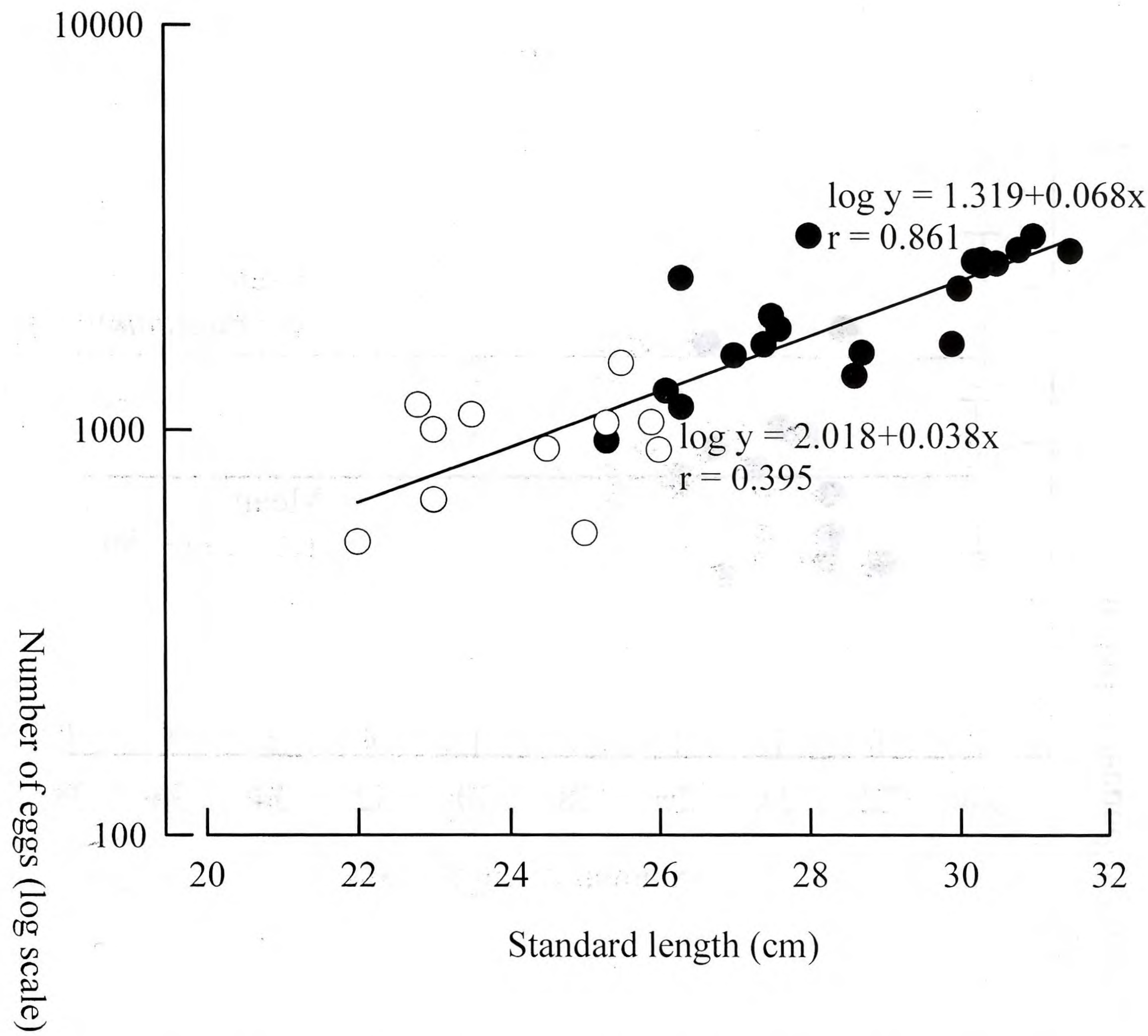

Figure 3: The relationship between fecundity and standard length in *O. niloticus* (○) and *O. macrochir* (●) in Lake Chivero.

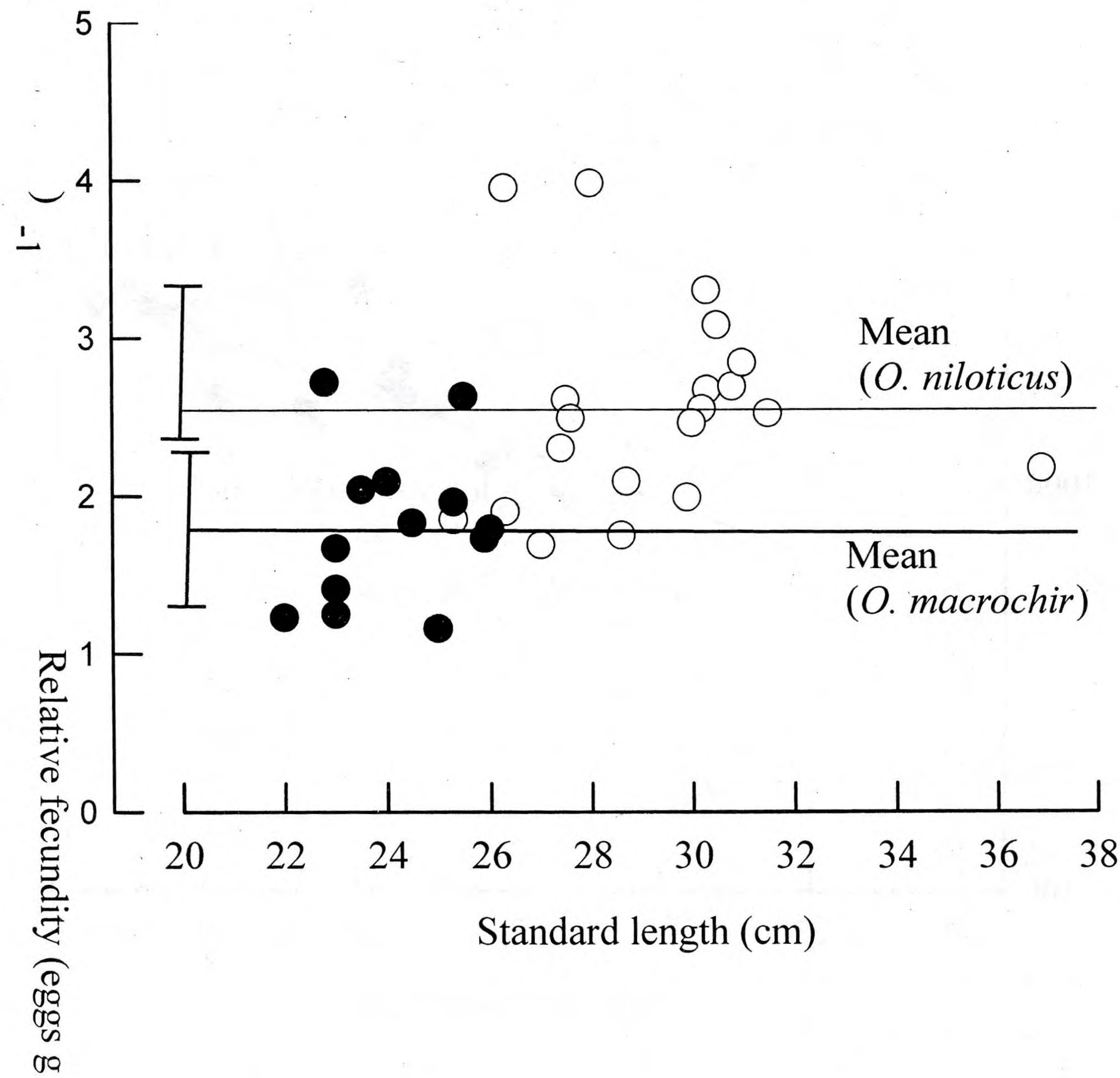

Figure 4: The relative fecundity (eggs per gram body weight) of *O. niloticus* (○) and *O. macrochir* (●) in Lake Chivero. The vertical lines around the mean indicate standard deviation.

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