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Changes in some biological parameters of the silver cyprinid, *Rastrineobola argentea* (Pellegrin, 1904) in the Nyanza Gulf of Lake Victoria, Kenya

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Abstract

The study examined length–weight relationship, condition factor, size at 50% maturity and fecundity of *Rastrineobola argentea* in the Nyanza Gulf of Lake Victoria, Kenya. The 500 fish examined had a mean length of 39.4 ± 0.3 mm SL, ranging from 17 to 55 mm SL and weighed between 0.08 and 2.44 g. The length–frequency analysis indicated a unimodal distribution between 35 and 40 mm SL, with a modal length at 37 mm SL. The fish exhibited a positive allometric growth pattern (b = 3.4). The condition factor for all fish was 1.02. Male fish showed a decreasing trend in condition factor with increasing body length, while females exhibited an increasing trend. The length at 50% maturity was estimated at 43 and 44 mm SL for males and females, respectively. The smallest mature male was 41 mm SL and 42 mm SL for females, with 100% maturity already exhibited at 49 mm SL. Fecundity varied from 235 eggs for 33 mm SL to 2,309 eggs for 54 mm SL fish. positive linear relationships were found between fecundity against standard length and ovary weight. Comparisons with previous studies in this lake over time indicated a decrease in length at maturity and an increase in fecundity, which are strategies to maximize reproductive success. The findings of this study provide useful information for managing the fishery.

KEYWORDS
condition, fecundity, maturity, silver cyprinid

1 | INTRODUCTION

The Silver Cyprinid (Pellegrin, 1904) is a small zooplanktivorous fish endemic to Lake Victoria. The *Rastrineobola argentea* fishery in the past was considered to be insignificant, only being exploited at the rural level to contribute to the diet and livelihoods of marginalized communities. This assumption no longer holds today; however, since this is now one of the most important Lake Victoria fisheries (Obiero et al., 2015; Ogello, Obiero, & Munguti, 2013). The Nile perch fishery is mainly for export, and the catch of Nile tilapia has significantly decreased. The *R. argentea* fishery provided employment to many women living along the lake region, unlike the male-dominated Nile perch fishery. *R. argentea* is a major source of protein for the fishing communities, and also a major constituent in the manufacture of commercial animal feeds. The critical habitats for *R. argentea* include the shoreline, sheltered bays and river mouths, which are also known to be their breeding and nursery grounds. Its diet consists primarily of zooplankton and insects (Getabu, Tumwebaze, & MacLennan, 2003; Yongo, Manyala, Kito, et al., 2016; Yongo, Manyala, Njiru, et al., 2016). Observations of the size at massive maturity of *R. argentea* in Lake Victoria vary, depending on the region of the lake being considered (Bayona et al. 2001; Manyala, Nyawade, & Rabuor, 1992; Okedi, 1973; Wandera, 1993; Wanink, 1998; Yongo, Manyala, Njiru, et al., 2016). Compared with other species, *R. argentea* has the highest fecundity, although its absolute fecundity has halved

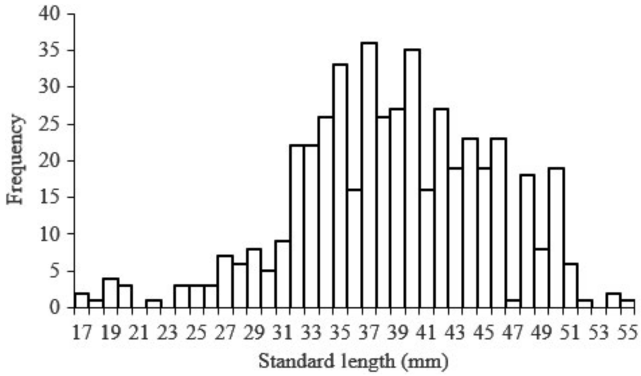

FIGURE 1 Length frequency distribution of *Rastrineobola argentea* in the Nyanza Gulf

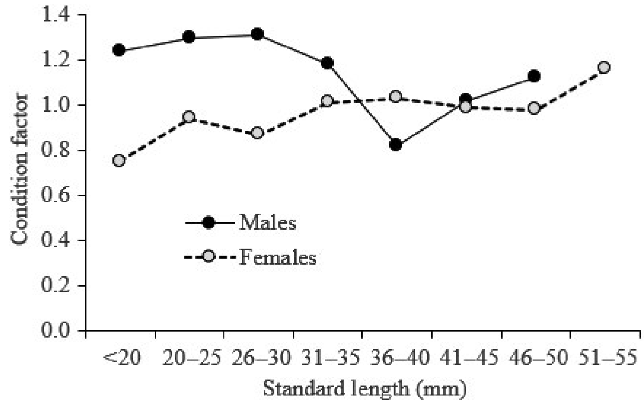

FIGURE 3 Changes in condition factor of male and female *Rastrineobola argentea* in relation to size

since the introduction of Nile perch (Manyala & Ojuok, 2007). Lake Victoria faces many challenges, including the use of destructive and illegal gears and methods, resulting in a major decrease in the annual fish yields from the lake. Since *R. argentea* breeds in the shallow inshore areas, which also serves as their nursery grounds (Wanink et al. 1999), use of such gear leads to destruction of their nursery grounds (Ogutu-Ohwayo, Wandera, & Kamanyi, 1998). The rampant use of mosquito nets (<5 mm) catches juvenile and immature fish. Further, the quality of the lake water is affected by the numerous farms along the Nyanza Gulf, which make it one of the most polluted areas of the lake (Ojwang et al., 2014). It also exhibits very high turbidity levels. Increased nutrient loads to the lake have caused increased eutrophication within the Nyanza Gulf.

This study examined length–weight relationship, condition factor, size at massive maturation and fecundity of *R. argentea* in the Nyanza Gulf of Lake Victoria, Kenya. Although similar studies have previously been done, more studies on the biological aspects are still needed for *R. argentea*, noting the silver cyprinid is one of the major fisheries that supports millions of livelihoods in the region and beyond. Indeed, researchers have discovered biological changes in most fisheries attributable to fishing effects and some environmental challenges. Thus, it is important to conduct additional studies to determine how the biological aspects of different fishery are changing with time, indicating the importance of this study.

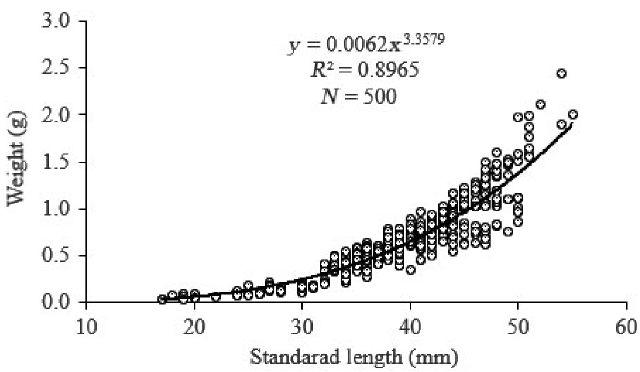

FIGURE 2 Length–weight relationship of *Rastrineobola argentea* in the Nyanza Gulf

2 | MATERIALS AND METHODS

A total of 500 fish samples from commercial catches were collected during November 2016 to February 2017) within the Nyanza Gulf of Lake Victoria. The samples were preserved in 5% formalin prior to laboratory analysis. The standard length (mm) and weight (g) of the samples were recorded, and the sex and maturity determined under microscope using identification keys developed by Manyala et al. (1992) as outlined by Yongo, Manyala, Njiru, et al. (2016)). A correlation analysis was performed to determine the relationship between fecundity and (a) standard length and (b) ovary weight

1. The length at 50% maturity (L_{M50}) was estimated by fitting frequency data of mature individuals by length to a logistic curve;
2. The length–weight relationship was estimated using the formula:

$$W = a \times TL^b \quad (1)$$

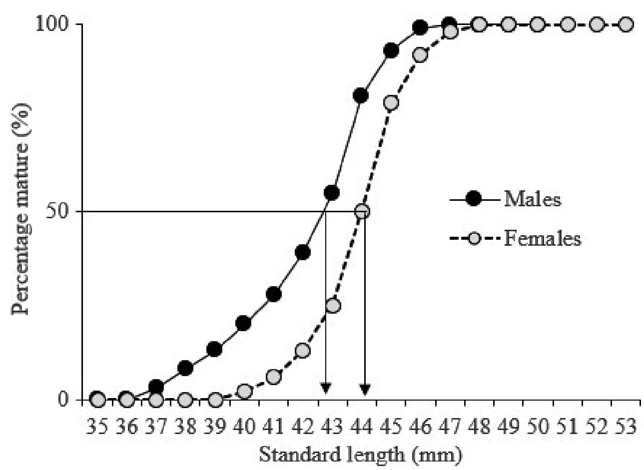

FIGURE 4 Length at 50% maturity of male and female *Rastrineobola argentea* in the Nyanza Gulf

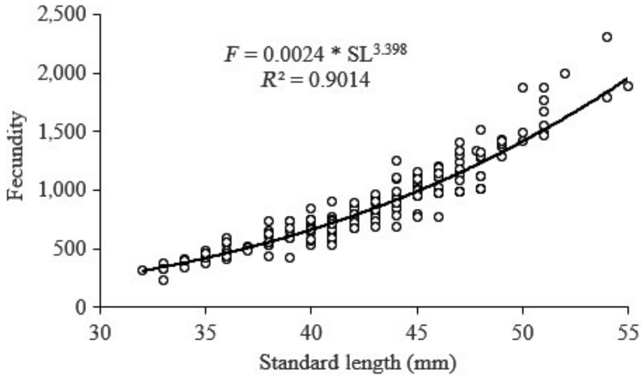

FIGURE 5 Relationship between fecundity and standard length of *Rastrineobola argentea*

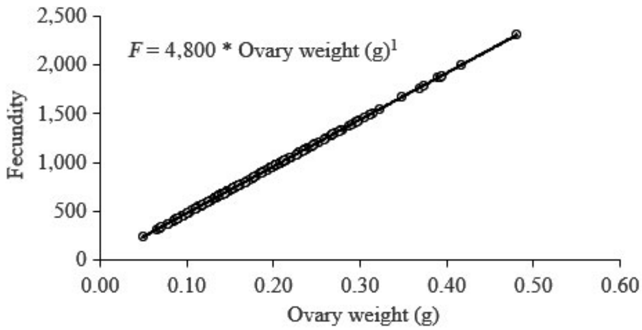

FIGURE 6 Relationship between fecundity and ovary weight of *Rastrineobola argentea*

3. The relative condition factor was calculated as

$$K = \frac{W}{a \times TL^b} \quad (2)$$

4. Fecundity was determined using the gravimetric method. All the eggs were weighed, and random samples were weighed and counted. The total number of eggs in the ovaries was calculated from this formula of Yelden and Avsar (2000):

$$F = \frac{nG}{g} \quad (3)$$

where F = fecundity; n = number of eggs in sub-sample; G = total weight of the ovaries; and g = weight of the sub-sample (g).

TABLE 1 Fecundity of *Rastrineobola argentea* in Lake Victoria during various periods

Fecundity (F)	Region	Author
$F = 5.9 \times 10^{-3} \times TL^{2.95}$	Mwanza Gulf (Tanzania)	Wanink (1989)
$F = 3.3 \times 10^{-7} \times TL^{5.38}$	Nyanza Gulf (Kenya)	Manyala et al. (1992)
$F = 9.2 \times 10^{-3} \times SL^{2.97}$	Mwanza Gulf (Tanzania)	Wanink (1998)
$F = 2.4 \times 10^{-3} \times SL^{3.40}$	Nyanza Gulf (Kenya)	Present study

3 | RESULTS

Of the total of 500 fish collected during this study, 216 (43%) were males and 265 (53%) were females, giving an overall sex ratio of 1.0:1.23 (male: female). The length and weight of fish examined ranged between 17–55 mm SL and 0.08–2.44 g, respectively. The mean (±*SE*) length of all fish was 39.4 ± 0.3 mm SL. The length–frequency analysis indicated a unimodal distribution between 35 and 40 mm SL, with the modal length at 37 mm SL (Figure 1). The fish exhibited a positive allometric growth pattern (b = 3.4, R^2 = 0.90; Figure 2). The mean (±0.01) relative condition factor was 0.92, 1.11 and 1.02 for males, females and combined sexes, respectively. Male fish exhibited a decreasing trend in condition factor with increasing size, while females showed an increasing trend with increasing length (Figure 3). The length at 50% maturity was estimated at 43 and 44 mm SL for males and females, respectively (Figure 4). The smallest mature male was 41 mm SL and 42 mm SL for females. There was already 100% maturity at 49 mm SL. The fecundity varied from 235 eggs for a 33 mm SL female fish, to 2,309 eggs for a 54 mm SL female fish. Linear relationships were found between fecundity and (a) standard length (p < .05, Figure 5) and (b) ovary weight (p < .05, Figure 6).

4 | DISCUSSION

The mean length of the fish caught has decreased from 48 mm SL in the 1980s (Ogutu-Ohwayo et al., 1998) to 39 mm SL in the present study. The findings in regard to the condition factor and sex ratio of *R. argentea* in this study are comparable to those of Yongo, Manyala, Njiru, et al. (2016)) in the Nyanza Gulf of Lake Victoria. *R. argentea* feed more

TABLE 2 Size at maturity of *Rastrineobola argentea* in Lake Victoria during various periods

Males	Females	Region	Author
55 mm SL	47 mm SL	Musoma (Tanzania)	Okedi (1973)
34 mm SL	36 mm SL	Nyanza Gulf (Kenya)	Manyala et al. (1992)
40–41 mm SL	43–44 mm SL	Pilkington Bay (Uganda)	Wandera (1993)
46 mm SL	33 mm SL	Mwanza Gulf (Tanzania)	Wanink (1998)
44 mm SL	39 mm SL	Mwanza Gulf (Tanzania)	Bayona et al. (2001)
36–39 mm SL	35–42 mm SL	Nyanza Gulf (Kenya)	Yongo, Manyala, Njiru, et al. (2016))
43 mm SL	44 mm SL	Nyanza Gulf (Kenya)	Present study

on zooplankton, including Copepods and Cladocerans, some of which are abundant in this region, thereby possibly improving their condition (Yongo, Manyala, Kito, et al., 2016; Yongo, Manyala, Njiru, et al., 2016; Yongo & Outa, 2017). The increased condition of female and decreased conditions for males with increasing size, however, could be attributable to gonadal development and spawning conditions. In fact, the condition of fish is affected by changes in food availability, environmental quality, season and reproduction status, among other factors (Yongo, Outa, Kito, & Matsushita, 2017). Previous studies on the fecundity of *R. argentea* are summarized in Table 1. Fecundity values in the present study of 235 eggs for a 33 mm SL and 2,309 eggs for a 54 mm SL are higher than those reported by Manyala et al. (1992), who estimated fecundity of *R. argentea* at 1,350 eggs for specimens of 60 mm TL and 170 eggs for specimens of 41 mm TL. The fecundity of *R. argentea* is believed to increase with increased fish size (Cowx, Rollins, & Tumwebaze, 2008), with the increased fecundity of *R. argentea* possibly being a strategy to maximize reproductive success in response to overexploitation of the fish stocks in Lake Victoria. *R. argentea* now grows faster, attaining maturity more rapidly (Yongo, Manyala, & Agembe, 2018). Several earlier studies reported size at maturity for *R. argentea* in Lake Victoria from 1973 to the present study, as presented in Table 2. The size at first maturity in the Tanzanian waters of Lake Victoria in 1973 was calculated at 55 mm SL for males, while females matured at 47 mm SL (Okedi, 1973). Twenty-five years later in 1998, the size at maturity for *R. argentea* declined to 46 mm SL and 33 mm SL for males and females, respectively (Wanink, 1998). The size at maturity in 2001 declined to 44 mm SL for males and 39 mm SL for females (Bayona et al. 2001). In the Kenyan waters of the lake, the size at maturity for *R. argentea* changed from 34 mm SL (males) and 36 mm SL (females) in 1992 (Manyala et al., 1992) to 43 mm SL (males) and 44 mm SL (females) in the present study. The spatial variation in size at maturity may reflect differences in fishing effect and environmental quality. Accordingly, the findings of the present study have provided useful information for managing the fishery over time.

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