



Aspects of Growth and Reproductive Biology among Three Tilapiines on Lake Kariba

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ABSTRACT

The growth and reproductive biology for three Tilapiine species, *Oreochromis andersonii*, *Oreochromis niloticus* and *Coptodon rendalli* on Lake Kariba was studied during 2017. The introduction of *O. niloticus* on Lake Kariba has been widely associated with the decline in preponderance of indigenous Tilapiines. The aim of this study was to compare reproductive and growth aspects between exotic *O. niloticus* and two other indigenous tilapiine species. Samples were collected from four sites at Sinazongwe District, Zambia. Specimens were weighed (g), measured in total length (mm), sexed, and ovaries in ripe/ ripe-running stages collected then preserved in 5% formalin solution. Scales were also collected from specimens and used in aging the fish. The von Bertalanffy growth functions (VBGF) for *O. andersonii*, *O. niloticus* and *C. rendalli* revealed intrinsic growth rates (K) of 0.147yr⁻¹, 0.180yr⁻¹ and 0.791yr⁻¹, respectively. The growth performance index (Φ') was highest in *C. rendalli* (4.98), then *O. niloticus* (4.58) and least in *O. andersonii* (4.36). The average observed fecundity for *C. rendalli* was 5,135 oocytes, ranging between 3,828-6,941 oocytes; lower fecundities of 2,923 (1,306-3,455) oocytes and 1,650 (934-3,062) oocytes were respectively observed for *O. niloticus* and *O. andersonii*. The differences in fecundity were significant, $p < 0.05$, [ANOVA: $F(2,18) = 23.80$; $p = 0.000$]. *Coptodon rendalli* exhibited stronger growth and reproductive characteristics than *O. niloticus* and *O. andersonii*, respectively.

1. Introduction

Although Zambia possesses a rich biodiversity of ichthyofauna from ten (10) major fishery areas, these remain susceptible to the emerging threat of introduced species. The Middle Zambezi, for instance has approximately forty species of fish which are not excluded from the threats posed by species introductions. The protection of biodiversity therefore depends on bolstering the science of invasion biology, and ensuring that its findings quickly lead to more effective policies to reduce harmful impacts (UCS, 2001).

The ecological impacts of invasive species on inland water ecosystems vary significantly depending on the invading species, the extent of the invasion, and the vulnerability of the ecosystem being invaded. Tilapia introductions have been blamed for eutrophication (Armantrout, 1998), whereas Starling et al. (2002) demonstrated a linkage between high Tilapia biomass and increase in total phosphorous (resulting from phosphorous release due to bioturbation and excretion), chlorophyll a, and cyanobacteria concentrations. These impacts may simultaneously influence more than one aspect of ecology, including individual level (life history, morphology, and behaviour), population dynamics (abundance, population growth, and recruitment), genetics (e.g hybridisation), communities (species richness, diversity, trophic status) and ecosystem processes (Hurlbert, 1972; Parker et al., 1999).

The combined impacts of introduced species may, in the worst-case scenario, promote biotic homogenisation in which an increase in genetic similarity, taxonomic and functional biota is observed (McKinney and Lockwood, 1999).

The species investigated in this study belong to a group of Cichlids referred to as Tilapiines representing three genera: *Oreochromis*, *coptodon* and *Tilapia*. The species of *Coptodon* and *Tilapia* are substrate spawners exhibiting insignificant sexual dimorphism. The exotic *O. niloticus* is native to the Nile basin, Rift valley lakes of East Africa, parts of West Africa and the Middle East (Trewavas, 1983). *Oreochromis andersonii*, on the other hand is indigenous to the Zambezi river system.

This study was aimed at comparing the reproductive and growth parameters of introduced and indigenous tilapiine species, with the findings meant to stir management decisions during translocation, restocking and aquaculture programs.

2. Materials and Methods

2.1 Study Area

Lake Kariba lies in the Gwembe Valley of Zambia's Southern Province at latitude 16°28' - 18°06' South, and longitude 26°40' -29°03' East, with a main axis running in the SW-NE direction where it borders with Zimbabwe. Sinazongwe District is located at 17°15'0" South, 27°28'0" East. Sampling was conducted from four sites, namely Zongwe River Estuary (17°16'04.2"S, 027°26'58.8"E), Sikalamba River Estuary (17°13'03.4"S, 027°30'58.7"S), Nzenga Fishing Village (17°15'51.8"S, 027°26'13.5"E) and Nan'gombe River Estuary (17° 08' 44.9" S, 027° 33' 50.5 E).

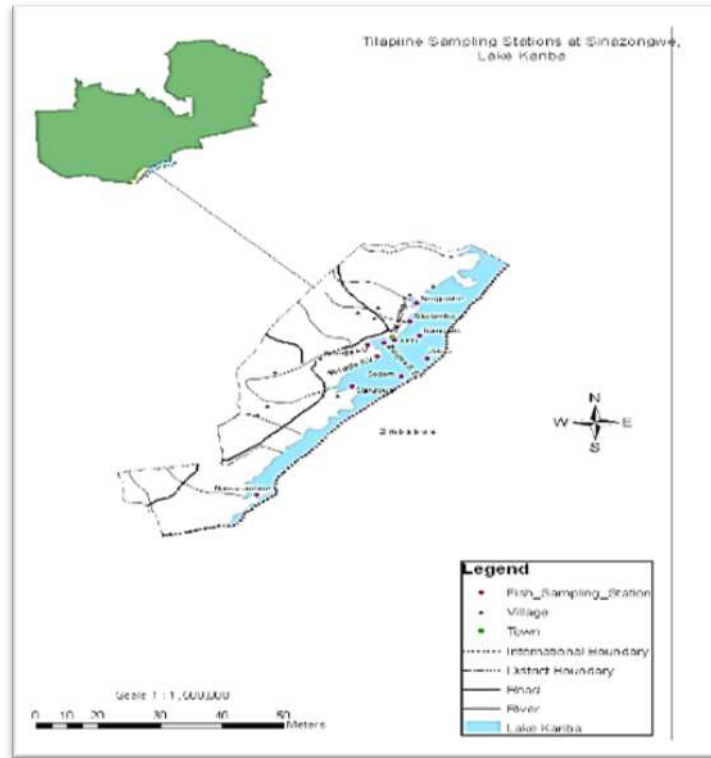


Figure 1: Sampling stations on Lake Kariba

2.2 Data collection and analyses

Growth rate

This was determined by measuring the morphometric parameters, that is: standard length (SL) and total length (TL). The lengths obtained were entered and processed using MS-Excel™. Graphical representations were made by plotting the most suitable morphometric dimensions, TL (mm), against age (years) to indicate growth rates per target species from which asymptotic length (L_{∞}), and growth coefficient (K) were derived as determined by the von Bertalanffy Growth function (VBGF) (von Bertalanffy, 1938; Sparre and Venema, 1998) (see Equations 1, 2)

$$L_t = L_{\infty} (1 - e^{-k(t+t_0)}) \quad (1)$$

Asymptotic lengths were estimated as:

$$L_{\infty} = L_{\max} / 0.95 \quad (2)$$

Where L_{\max} is the largest observed length in a sampled species (Pauley, 1984a).

Age

Determination of age was performed by back-calculations based upon the linear regression model (Lee, 1920) which assumed that fish TL is directly proportional to scale radius and number of cumulated annuli (Dahl, 1909). Scales from the specimens were read using a dissecting microscope. Scale radii at time of annulus formation (S_i) followed:

First annulus (age one): $S_1 = S_a$

Second annuli (age two): $S_2 = S_a + S_b$

nth annuli (age n): $S_n = S_a + S_b + \dots + S_n$ (3)

Growth performance (Φ') was estimated using the empirical equation (Pauly and Munro, 1984) for each of the target species (see Equation 4):

$$\Phi' = \log_{10}(K) + 2 \log_{10}(L_{\infty})$$
 (4)

Where: K and L_{∞} are the Von Bertalanffy's Growth parameters.

Fecundity

Fecundity was estimated as the number of oocytes belonging to the size class of the greatest dimension (i.e all specimens in immediate pre-spawning (IV) /ripe or ripe-running stage). Enumeration of oocytes followed the gravimetric method (Gaikwad et al., 2009; Hunter and Goldberg, 1980); the sampled gonad weight (SGW) of enumerated oocytes (x1) were extrapolated to total gonad weight (TGW) in order to approximate the absolute fecundity (x2) for each selected female target species (see Equation 5):

$$x_2 = \frac{TGW(mg).x_1}{SGW(mg)}$$
 (5)

Ten (10) sampling replications were carried out on each ovary per target female Tilapiine specimen at ripe/ ripe-running stage of sexual maturity.

3. Results

The oldest samples were aged 6 years from *O. niloticus* and *C. rendalli* whilst 5 years was the oldest seen in *O. andersonii*. Samples younger than 2 years were difficult to age due to indistinct annuli formation. The VBG curves summarised in Figure 2 indicate that *C. rendalli* had the fastest growth rate with a growth coefficient (K) of 0.79. Intrinsic growth for *O. niloticus* was higher ($K = 0.180$) than and *O. andersonii* ($K = 0.147$).

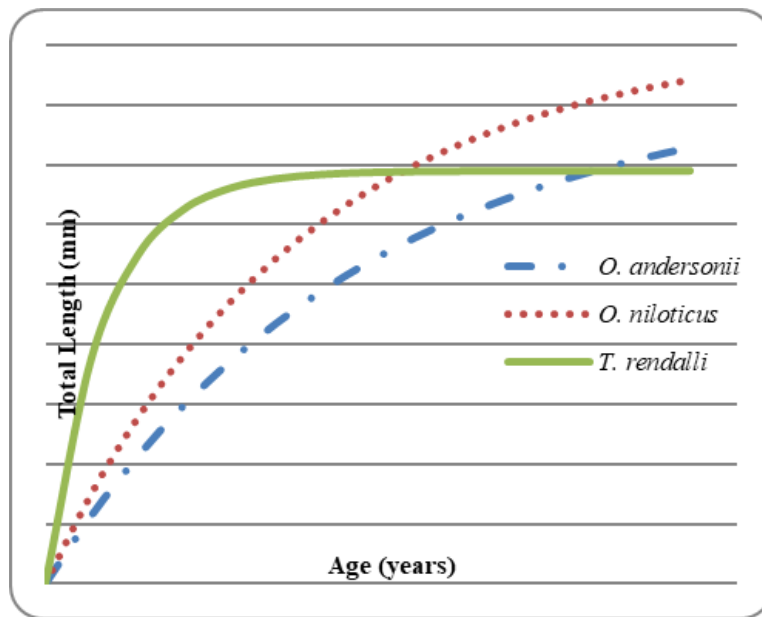


Figure 2: von Bertalanffy Growth curves for studied Tilapiines described by models:

$L_t = 393.68(1 - e^{-0.147(t+3.137)})$ - *O. andersonii*; $L_t = 458.00(1 - e^{-0.180(t+3.002)})$ - *O. niloticus*; $L_t = 350.52(1 - e^{-0.791(t+1.047)})$ - *C. rendalli*

However, it was observed that the greatest attainable length (L_{∞}) occurred in *O. niloticus* (458.0 mm). *Oreochromis andersonii* had $L_{\infty} = 393.68$ mm whereas *C. rendalli* had $L_{\infty} = 350.52$ mm. Table 1 summarises the observed VBG parameters, including growth performance indices (Φ') for the studied species.

Table 1: von Bertalanffy Growth Parameters for Tilapiine species

Species	t_0	K (yr ⁻¹)	L_{∞} (mm)	Φ'
<i>Oreochromis andersonii</i>	-3.1366	0.1468	393.68	4.36
<i>Oreochromis niloticus</i>	-3.0023	0.1798	458.0	4.58
<i>Coptodon rendalli</i>	-1.0470	0.7905	350.52	4.98

The fecundity of *C. rendalli* was the highest among the Tilapiines, followed by *O. niloticus* and *O. andersonii* (Figure 3). The observations were significantly different at $p < 0.05$ [ANOVA: $F(2,18) = 23.80$; $p = 0.000$]. Bonferroni post hoc all pair-wise comparison revealed that the fecundities for each species were significantly different from the other. The ripe/running females of *Oreochromis niloticus* had greater average TL, TW than *O. andersonii* and *C. rendalli*, respectively. The gonad weights for *O. niloticus* were also heavier; those of *C. rendalli* were however heavier than those for *O. andersonii* (Table 2).

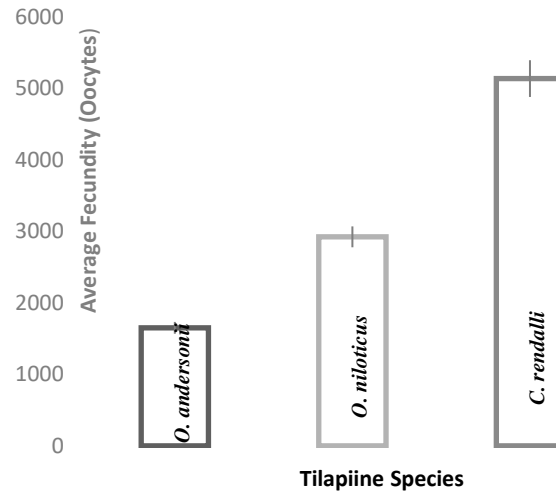


Figure 3: Average fecundity for Tilapiines (\pm S.E)

Table 2: Average sizes and weights for sampled female Tilapiines with ripe and ripe-running gonads; TL- Total length, TW- Total weight, GW- Gonad weight (for both ovaries).

	<i>O. andersonii</i>	<i>O. niloticus</i>	<i>C. rendalli</i>
TL (mm)	289.33	309.83	268.56
TW (g)	604.18	705.06	435.27
GW (g)	6.48	12.57	10.49
n	9	12	9

Oocytes from the *Oreochromis* species depicted stronger prolate-spheroid shape than those of *C. rendalli* which tended to be less prolate. Effective diameters were observed to be greatest for *O. niloticus* (7.567 ± 0.387 mm), and least for *C. rendalli* (1.531 ± 0.056 mm) as indicated in Table 3.

Table 3: Average oocyte size for Tilapiines (\pm SE)

	<i>O. andersonii</i>	<i>O. niloticus</i>	<i>C. rendalli</i>	Statistical significance (P-value)
Average Oocyte Length (mm)	2.458 ± 0.009	2.850 ± 0.720	1.736 ± 0.003	<0.05
Average Oocyte Width (mm)	1.852 ± 0.006	2.266 ± 0.005	1.682 ± 0.029	<0.05
Average Effective Diameter (mm)	4.994 ± 0.327	7.567 ± 0.387	1.531 ± 0.056	<0.05

Discussion

Pauly (1979) referred to K as a stress-factor indicator for how population characteristics and environmental parameters (such as high temperature, low density of feed, disease and status in some pecking order) may affect the growth performance of a fish species. *Coptodon rendalli* showed an increase in the values of K and Φ' from 0.145yr^{-1} to 0.791yr^{-1} , and 2.533 to 4.97, respectively (compared with Kolding et al, 1992). The asymptotic length for the species declined from 380mm to 298mm (in the present study). The increase in K could be attributed to stresses resulting from elevated fishing pressure which stands at 7.41Kg/boat/day (DoF Ann. Report, 2015). Another possible explanation could be climo-hydrological variations; these observations have had direct impacts on the flooding regime in the littoral nesting grounds of the Lake which are key to *C. rendalli* reproduction. Detailed review of Lake Kariba water level variations have been presented in the Zambia-Zimbabwe Joint Annual Reports.

The observed K for *C. rendalli* at Lake Kariba, Sinazongwe was higher than at Lake Chicamba, Mozambique where values of $0.636 \pm 0.06 \text{ yr}^{-1}$ were observed (Weyl and Hecht, 1998). It was difficult to compare differences in fishing pressure in the two Lakes because catch-effort data was unavailable for Lake Chicamba. The asymptotic length of *C. rendalli* at Lake Chicamba was equally lower than that from the present study, 238.74mm (Weyl and Hecht, 1998). The differences in the performance of *C. rendalli* from Weyl and Hecht, (1998) and the present study could be a result of the choice of hard parts used in the aging of the specimens; use of scales has been noted to overestimate intrinsic growth rates (Hammers and Miranda, 1991). The success in use of otoliths is variable; Bwanika (2007) noted this challenge in attempting to age Nile Tilapia on Lakes Nabugabo and Wamala, arising from weakly defined annuli on the sagittal otoliths. Never the less, the sheer sizes of the two Lake systems, having a bearing on the nutrient quality and loads, could explain the observed growth disparities; Lake Kariba (5,364Km²) and Lake Chicamba (116Km²), (Bowen, 1982).

The average fecundity for *O. andersonii* at Lake Kariba was 1,650 oocytes (934-3,062 oocytes), much higher than Kefi et al., (2011) 178-1,355 oocytes (under controlled laboratory conditions), FishBase (2014) 349-730 oocytes and Gopakrishnan (1988) 634 oocytes. The average number of oocytes for *O. niloticus* in Lake Kariba at Sinazongwe ranged from 1,306 to 3,455 oocytes, higher than what was observed in Opa Reservoir where fecundity ranged from 73-1,810 oocytes (Komolafe and Arawomo, 2002), and in Lake Naivasha, 300-2,800 oocytes (Babiker and Ibrahim, 1979). The present study's numbers were equally higher than those observed by Duponchelle and Legendre (2000) where absolute fecundity ranged between 160 to 717 oocytes in *O. niloticus* on Lake Ayame. The observed sizes of *O. niloticus* oocytes from the present study compared favourably with those in Bakhoun (2002) and Kariman & Salma (2008) at Lake Edku, and Abu-Zabal, Egypt.

The average fecundity in *C. rendalli* was the highest among the studied species 3,828-6,941 oocytes, comparable with Chandrasoma and De Silva's (1981) observation of 760-6,160 oocytes and, Bromage and Coward (2000) who observed 5,000-6,000 oocytes.

The observed oocyte sizes plus fecundities for the studied species are consistent with other researchers' observations. It may, therefore hold that the larger oocytes in *O. niloticus* confers advantages of having larger fry which exploit wider prey size range. Further benefits could include better chances of survival and avoidance of predators whilst in the spawning/ nursery grounds. The combination of large oocyte size, greater K and Φ' could partly explain the commonness of *O. niloticus* at Lake Kariba, Sinazongwe. However, the study's observations on growth and reproduction of *O. niloticus* at Lake Kariba may be affected by presence of cage-fishing facilities at Siansowa and Siavonga District thereby confounding observations by silently contributing escapees to the numbers of *O. niloticus* being observed on the Lake; the establishment and abundance of the Nile tilapia on Lake Kariba may have been aided. It is therefore imperative that further investigation on augmentation of Nile tilapia population from cage escapees is conducted. What is certain, however is that *O. niloticus* is an established species not only at Sinazongwe, but the entire Lake Kariba.

The observations made between the genera, *Oreochromis* and *Coptodon* were consistent with life history traits for mouth brooders and substrate spawners, respectively. In substrate-spawners, both parents guard the brood, with the emerging young forming schools which follow the parents. Conversely, in mouth-brooders, only the female of the species provides care for the brood (Peters, 1983); this trait among the males could allow them more mating time, thereby helping in the spread. Lowe (1955) confirmed differences in the fecundity and oocyte sizes between *Tilapia* (*Coptodon*) and *Oreochromis* species.

Conclusion

Coptodon rendalli had the highest growth rate and growth performance among the studied Tilapiines on Lake Kariba. This however, was not reflective of catch-observations at the sampled stations where *O. niloticus* was the most common species landed (Figure 4).

The success of *O. niloticus* in invading and establishing itself on Lake Kariba did not absolutely reflect on the species' inherently strong life-history strategies, instead, a number of external human driven influences may have aid its current and future spread on Lake Kariba.



Figure 4: Landing a fish-catch comprising entirely of *O. niloticus* is not uncommon on Lake Kariba

There is need to further investigate the impacts of activities such as cage fish farming, and the use of *O. niloticus* on such facilities at Sinazongwe, Siansowa and Siavonga. There is sufficient reason to suspect augmentation of Nile Tilapia population from aquaculture cage-escapees. In an effort to enhance fish production through aquaculture, whilst at the same time ensuring protection of native fish biodiversity, the study recommends for use of *C. rendalli* and *O. andersonii* in fish-cage facilities at Lake Kariba.

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