APPLICATION OF EMPIRICAL EQUATIONS FROM LENGTH AT MATURITY TO PREDICT LIFE HISTORY INDICES OF *OREOCHROMIS NILOTICUS* LINNAEUS, 1758 (CICHLIDAE) CULTURED UNDER 24L: 0D PHOTOPERIOD

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Empirical equations were applied to the length, weight and age measurements at sexual maturity of sixty juveniles of *Oreochromis niloticus* reared in triplicates under 24L: 0D photoperiod for six months. Sexual maturity was determined at stage V of gonadal maturation. The mean length and weight at maturity was 12.40 ±0.2cm and 32.80 ± 0.5g respectively, while optimum temperature of the tanks was 28°C. Life history indices of the species estimated include optimum length (Lopt) which was 12.4 cm, natural mortality (M) which was low at 3.11, amount of food consumed Q/B, gross food conversion efficiency (GE) and life span (tmax) were estimated at 58.6, 0.034 and 1.8 years respectively. The von Bertalanffy growth parameter (K) was estimated at 1.67 from the t_{max}. These estimates of the life history parameters is useful in stock dynamics, set harvest limit, determine food utilization and quality, age structure, predict the growth responses, and hence sustainable exploitation and management of the species in aquaculture. Thus, the use of aquacultural data to estimate life history parameters of fish species is more desirable and reliable than data from wild fisheries as it could provide the opportunity to understand life history parameters which could be different from that of the wild.

Key words: *Oreochromis niloticus,* empirical equations, photoperiod, length, weight, life span, food.

INTRODUCTION

Fishes always have a definite course of life history which often starts from hatching of eggs or live births in some few groups to larva stages consisting of fry, fingerlings and juveniles and then to the adult stages. A fish could be said to be in the adult stage when it is sexually mature with the maturity defined as the time when ripe eggs and milt are produced. The length and weight at sexual maturity of a fish species is an important geometric measurement which can be used in predicting the course, pattern and estimating life history parameters of the species.

This is usually done by the use of spread sheet empirical equations where these geometrical measurements of the vital dimensions and morphometry of the fish are mathematically transformed to estimate and predict life history indices such as optimum length (l_{opt}), natural mortality (M), population food consumption (Q/B), gross food conversion efficiency (GE), von Bertalanffy growth factor (K), life span (t_{max}), and relative yield (Y/R).

ROM. J. BIOL. – ZOOL., VOLUME **59**, No. *2*, P. 163–172, BUCHAREST, 2014

The set of equations have been developed and used by several workers in estimating the life history parameters like growth (Froese & Pauly, 2000; Froese & Binohlan, 2003), food consumption (Palomares & Pauly, 1998), length (Binohlan & Froese, 2009), mortality (Pauly, 1980; Djabali *et al*., 1993), yield (Beddington & Kirkwood, 2005), modelling (Gislasom & Rice, 1998), stock assessment and biomass dynamics (Hillborn & Walters, 1992), and management (Froese & Binohlan, 2000) of different fish species.

The application of these equations has always been on capture and wild fishes with very few on cultured or aquacultural species especially fishes cultured under photoperiodic manipulations, which often reveal significant differences in the estimates. Lack of estimates of important life history indices especially for tropical aquacultural fish species has been a hindrance in the proper management of the species, one of which is the Nile tilapia (*Oreochromis niloticus*).

Photoperiodism or light manipulations have been recognised and used as a means of increased growth and attainment of early sexual maturity in many fish species (Bromage *et al.*, 2001; Boeuf & Le Bail, 1999), and could be used as a cheap means of rearing fish even at a larger scale with the use of solar powered lights to provide the 24L: 0D regime.

The Nile tilapia (*Oreochromis niloticus*) is one of the most cultured tropical fish in the world. This is due to its hardy nature, high protein content, ease of culture, ability to eat natural and artificial foods, disease resistance, and consumers' preference among other reasons (Mustapha *et al.*, 2012). *O. niloticus* have been shown to have significant length and weight growth and early age and sexual maturation when cultured under 24L: 0D photoperiod (Ridha & Cruz, 2000; El-Sayed & Kawanna, 2004; Campos-Mendoza *et al*., 2004; Rad *et al*., 2006; Mustapha *et al*., 2012).

The age and length at maturity is usually expressed as the age/length at which 50% of the population are mature (i.e. in late stages of gonadal development), determined by fitting a logistic function to proportional maturity data (King, 1995). *O. niloticus* have been shown to mature at a much smaller length, weight and age in tanks (Bolivar *et al.,*1993; Lorenzen, 2000).

The objective of this paper is to apply spread sheet empirical equations from length at maturity to predict some life history parameters of *Oreochromis niloticus* cultured under 24L: 0D photoperiodic manipulation.

MATERIAL AND METHODS

Sixty juveniles of *Oreochromis niloticus* were cultured in 24L: 0D photoperiod in triplicates with twenty juveniles of the species stocked in each tank measuring (1x1x0.5m) with a volume of 200 litres. Prior to the start of the experiment, the fish were acclimatized for one week under laboratory conditions. The three tanks were illuminated by 40W fluorescent lamps with light intensity of 400 lx at the water surface for 24 hours. The fish were fed with commercial feed at 5% body weight twice daily (8.00 am and 6.00 pm) for 180 days corresponding to the time when 50% of the fish reached sexual maturity.

The maturity of the fish was determined macroscopically through the analysis of the gonads appearances and relative size and weight of the gonads. The fish assumed sexual maturity at stage V of gonads maturation when the testes were soft and creamy-white in colour and the ovaries were enlarged and yellowish in colour, and with gentle pressing of the swollen bellies, the eggs and milt oozed out. The age, weight and length of the species at this time were recorded as the length, weight and age of first sexual maturity.

The water in the tanks was changed weekly and the water quality parameters like temperature, pH, dissolved oxygen and carbon dioxide were measured with Lamotte aquaculture lab model SCL-08.

The prediction of the life history indices of *Oreochromis niloticus* from length at first maturity was done using spread sheet empirical equations of Pauly (1980), Palomares & Pauly (1998), and Froese & Binohhlan (2000). Fish Base (Froese & Pauly, 2014), which is a global fish species data base which uses data of fish species as defaults for the various equations for estimating the life history parameters of many fish species history key facts. The actual measurements of the number, length, weight and age of *O. niloticus* at first maturity reared under the 24L: 0D photoperiod were used to replace the defaults of the equations in estimating the life history indices of the species. The life history parameters estimated include optimum length (L_{opt}), natural mortality (M), population food consumption (Q/B), gross food conversion efficiency (GE), life span (t_{max}), and von Bertalanffy growth parameter (K).

The estimation of optimum length (L_{opt}) from length at first maturity (L_m) was done according to the following equation:

$$L_{opt} = 10\text{^}(1.053 * \log10(L_m) – 0.0565)$$

$$95\%\ \text{Conf. Interv.} = L_{opt} +/- (1.993 * 0.139 * \text{SQRT}\ (0.0132 + (0.0962 * (\text{LOG10}(L_m) - 1.404)\text{^}2)))$$

The natural mortality estimates were done using temperature and weight growth parameters according to the following equation:

$$\log10 M = - 0.2107 - 0.0824 \log10 W_{inf} + 0.6757 \log10 K + 0.4687 \log10 T$$

where W_{inf} = live weight in grams

K = 1/year

T = temperature in degree Celsius

The estimation of the population food consumption (Q/B) was done using the equation

$$Q/B = 10^{(7.964 - 0.204 * LOG\ W_{inf} - 1.965 * 1000 / (T+273.15) + 0.083 * A + 0.532 * h + 0.398 * d)}$$

where Z = total mortality 1/year
W_{inf} = live weight in grams
T = temperature in degree Celsius
A = Aspect ratio of caudal fin
h and d = food type

Estimation of gross food conversion efficiency (GE) was according to this equation

$$GE = 10^{(-5.847 + 0.72 * LOG\ Z + 0.152 * LOG\ W_{inf} + 1.36 * 1000 / (T + 273.15) - 0.062 * A - 0.51 * h - 0.39 * d)}$$

where Z = total mortality 1/year
W_{inf} = live weight in grams
T = temperature in degree Celsius
A = Aspect ratio of caudal fin
h and d = food type

The life span (t_{max}) estimation from age at first maturity (t_m) was evaluated according to this equation:

$$\log t_{max} = 0.5496 + 0.957 * \log t_m$$

where t_m = age at first maturity

The von Bertalanffy growth parameter (K) was estimated from $t_{ma}x$ according to the equation:

$$K = 3 / t_{max}$$

where t_{max} = life span

The estimate of t_{max} from K was done using the equation:

$$t_{max} = 3 / K$$

where K = von Bertalanffy growth parameter.

The statistical analysis of the data which was expressed as means ±SE of the length and weight results. One-way ANOVA and Duncan's multiple range test were used to test for significant differences between the measurements in the replicate at $P<0.05$.

RESULTS

The mean length and weight at first maturity of *Oreochromis niloticus* cultured under 24L: 0D photoperiod is presented in Table 1. The mean length at first maturity was 12.40 ±0.2cm, while the mean weight at first maturity was 32.80 ± 0.5g. There was no significant difference (P>0.05) in the means of the length and weight among the replicates.

The mean range of water quality parameters in the tanks among the 3 replicates is presented in Table 2. Highest temperature recorded in the tank was 28°C, which is optimum for the species metabolic activities and it was used in the estimation of the life history parameters. The range of dissolved oxygen concentration was between 6.0–8.5 mg/l, carbon dioxide 0.01–0.05 mg/l and pH between 6.5–7.5 mg/l. There was no significant difference (P>0.05) in the means of the water quality parameters among the replicates tanks.

The estimates of some life history parameters from mean length and weight at first maturity of *Oreochromis niloticus* reared in 24L: 0D photoperiod is presented in Table 3.

Optimum length (L_{opt}) was estimated at 12.4 cm from the recorded length at first maturity of 12.4 cm with a 95% confidence limit between 11.13–13.7 cm. Natural mortality (M) was estimated to be low at 3.11, while the amount of food consumed Q/B and gross food conversion efficiency (GE) were estimated to be 58.6 and 0.034 respectively. The species is estimated to live for 1.8 years (t_{max}) with 95% confidence limit of between 1.2–2.9 years. Using the life span (t_{max}) estimates of 18 years, the von Bertalanffy growth parameter (K) was estimated at 1.67, while the t_{max} estimates from K was 1.8 years.

Table 1
Mean length-weight data at first maturity of *Oreochromis niloticus* cultured under OL: 24D photoperiod

Length-weight data at first maturity	Replicate 1	Replicate 2	Replicate 3
Initial total length (cm)	7.30 ± 0.1	7.30 ± 0.1	7.30 ± 0.1
Final total length at first maturity (cm)	12.40 ± 0.2	12.40 ± 0.2	12.40 ± 0.2
Initial live body weight (g)	7.05 ± 0.1	7.05 ± 0.1	7.05 ± 0.1
Final live body weight (g)	32.80 ± 0.5	32.82 ± 0.5	32.81 ± 0.5

Table 2
Mean range of water quality parameters of *Oreochromis niloticus* cultured under OL: 24D photoperiod

Water quality parameters	Replicate 1	Replicate 2	Replicate 3
Temperature (°C)	26-28	26-28	26-28
Dissolved oxygen (mg/l)	6.0-8.5	6.0-8.5	6.0-8.5
Carbon dioxide (mg/l)	0.01-0.05	0.01-0.05	0.01-0.05
pH	6.5-7.5	6.5-7.5	6.5-7.5

Table 3

Estimates of some life history parameters from mean length and weight at first maturity of *Oreochromis niloticus* cultured under 24L: 0D photoperiod

Life history parameters	Estimates
Optimum length (L_{opt})	L_m = 12.4 cm L_{opt} = 12.4cm S.E range (95%) = 11.13-13.7 cm L_m/L_{opt} = 0.997
Natural mortality rate (M)	W_{inf} = 32.80 K = 1.67 T = 28°C M = 3.11 M/K = 1.86
Amount of food consumed (Q/B)	W_{inf} = 32.80 T = 28°C A = 1.28 h = 1 d = 0 Q/B = 58.6
Gross food conversion efficiency (GE)	W_{inf} = 32.80 Z = 2 T = 28°C A = 1.28 h = 1 d = 0 GE = 0.034
Life span (t_{max})	t_m = 0.5 years t_{max} = 1.8 years S.E range = 1.2 – 2.9 years t_m/t_{max} = 0.27 years
Von Bertalanffy growth parameter (K)	t_{max} = 1.8 years K = 1.67
Life span from estimates of K	K = 1.67 t_{max} = 1.8 years

DISCUSSIONS

The understanding of the life history plasticity, i.e. the mechanisms that animals use to achieve optimum life history patterns (Thorpe *et al*., 1998), is required in order to manage this plasticity in cultured and exploited stocks (Lorenzen, 2000). The multiple regression models of fish growth described by Pauly *et al.* (1993), Prein & Pauly (1993) and Jackson & Wang (1998) allow analysis of a wide range of management impacts on growth, which may aid the improvement of semi intensive and intensive culture systems of fish. Froese & Binohlan (2003), Martinez-Andrade (2003), Binohlan & Froese (2009), Bethke & Bernrenther (2010), Gubiani *et al.* (2012), Giarrizzo *et al.* (2013) have used empirical equations to estimate longetivity, growth rate, mortality, optimum length, food consumption and food conversion efficiency in different species of fish. Prein (1993) describe the application of multiple regression models of fish growth to the analysis of tilapia growth in pond culture.

The estimates of the life history parameters of *Oreochromis niloticus* obtained using the empirical equations could help in sustainable exploitation of the species in aquaculture. The estimate of the optimum length (L_{opt}) which was directly proportional to the length at maturity shows that this size will support the optimum stock yield and productivity of the species in the culture medium. Froese & Binohlan (2000) reported that size at maturity of fish species is an important parameter to determine the levels of optimum fishery yield.

The natural mortality (M) estimate and growth rate (K) are highly dependent on each other of which M rates are approximately double the K values. This observation agrees with Ralston (1987) report that growth rate is a good predictor of mortality rate. Springborn *et al.* (1992) also used a population model based on the VBGF (K values) and an exponential mortality equation to predict the economically optimal harvesting time for *O. niloticus* cohorts in pond culture under two different fertilization regimes. Using these equations and the estimates recorded, *O. niloticus* in the 24L: 0D photoperiod culture was shown to have a relatively long life span, low growth rate (probably due to stunning) and low mortality rates. Application of these equations to estimate the mortality rate will ensure a good population and stock dynamics in ponds and thus help in setting the harvest limit to optimum and maximum sustainable yield. Lorenzen (1996) using empirical equations provided data of mortality of *O. niloticus* from pond and cage culture and showed that mortality rates are very low. He reported that the natural mortality rates in aquaculture are more strongly size dependent than in wild stocks.

The von Bertalanffy growth parameter (K) estimates can be used to determine the extent of sustainable exploitation of the species, age structure and predict the growth responses to water quality parameters in the culture tanks. Higher K estimate is an indication that the well being of the fish is excellent. The K estimate is related to the high Q/B and low GE estimates as well as the optimum water quality in the tank, low water depth and the small rearing unit. All these promoted the early sexual maturity of the fish. Similar high K values have been recorded for *O. niloticus* in aquaculture (Pauly *et al.*, 1988; Lorenzen, 2000; Gubiani *et al.*, 2012). Since age could be reliably measured in aquaculture, application of empirical equations to estimate growth (K) will provide an accurate and reliable estimate even more than that of the wild populations. According to Brothers (1979), estimate of growth rate relies on adequate age estimate.

The life span estimate of the species in 24L: 0D photoperiod culture put at 1.8 years and a range of 1.2–2.9 years could be described as relatively long considering the small size, high fecundity and early sexual maturation of the species. Thus the species could be described as an opportunistic strategist. The estimate of the life span will be very useful in the cropping and management of the species in aquaculture.

The food consumption per unit biomass (Q/B) indicates the number of times that a given population consumes its own weight per year (Pauly, 1986). However, estimates of Q/B ratio are lacking for most tropical fish species (Giarrizzo *et al*., 2013). The Q/B estimate in aquaculture is more reliable than that of the wild because of the species optimum temperature operating in the ponds. This estimate could then be used in the stock assessment of the species during rearing. Bethke & Bernrenther (2010) and Gubiani *et al.* (2012) have used empirical equations for the estimation of food consumption in different fish species cultured under different environmental conditions. The higher Q/B estimate recorded for *O. niloticus* in the 24L: 0D photoperiod culture reflects the low energy intake, fast life cycle and trophic level (herbivorous) of the species. Bethke & Bernrenther (2010) observed that Q/B values are higher in herbivorous than in carnivorous species. This empirical equation will be most useful in aquaculture in order to know the proper trophic status, feed utilization and conversion of species in culture.

The lower food conversion efficiency (GE) estimate was as a result of the feeding of the species with pelleted feed which allowed the species to completely utilize the feed. Jobbling (1986) and Bethke & Bernrenther (2010) showed that food conversion efficiency with a diet of pelleted feed was generally lower than that of natural food. The application of this empirical equation to determine the GE in aquaculture is desirable as it will show how well the species utilize the feed and the quality of the feed.

CONCLUSIONS

The use of empirical equations in estimating the life history parameters of *Oreochromis niloticus* in aquaculture will be very useful in assessing the stock dynamics, setting the harvest limit, determining the feed utilization and quality, knowing the age structure, predicting the growth responses, and hence sustainable exploitation and management of the species.

The use of aquacultural data to estimate life history parameters of *Oreochromis niloticus* is more desirable than data from the wild. This is because the methodology and results from aquaculture are more reliable than that from the wild fish capture which is sometimes based on few fishes, inadequate prediction of procedure, bias in gear selection and inadequate analysis of fish capture results.

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Received August 24, 2014

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