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Estimation of Some Life-History Parameters from Length at First Maturity of African Catfish *Clarias Gariepinus* (Burchell, 1822) Cultured Under 0l: 24d Photoperiod Using Empirical Equations

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ABSTRACT Estimation of some life history parameters such as length (L), weight (W), mortality (M), population food consumption (Q/B), gross food conversion efficiency (GE), von Bertalanffy growth factor (K) and life span (tmax) using empirical equations was conducted on *Clarias gariepinus* reared in triplicate in the 0L: 24D photoperiod. The mean length and weight at first maturity was 45.7 ±0.2cm, and 728.13 ± 0.5g respectively. Highest temperature recorded was 27 °C. Estimate of optimum length (Lopt) was 49.1 cm, mortality was 2.37/year and 1.18 for the 6-month cultured period, food consumed and gross food conversion efficiency was 8.7 and 0.181 respectively. The life span estimate was 1.8 years, while the von Bertalanffy growth parameter calculated from the tmax was 1.67. These estimates could be used to cropping the fish or obtain desired length class with the highest biomass for harvest, evaluate signs of growth overharvesting, know and prevent mortality at larval or adult stages of fish, indicate poor or good food conversion efficiency, know the life span of the fish thereby informing the time of harvest and thus saving cost of production. All these could be used in the management of the species in aquaculture.

(Keywords: life history, length, weight, sexual maturity, photoperiod)

INTRODUCTION

Estimation of life history parameters such as length (L), weight (W), mortality (M), population food consumption (Q/B), gross food conversion efficiency (GE), von Bertalanffy growth factor (K), relative yield (Y/R), life span (tmax) of fish using empirical equations is a useful tool in fish biomass dynamics, modelling, conservation, exploitation and management. The estimation of the life history parameters of fish is usually done from the geometric measurements of vital dimensions and morphometry of fish. These measurements are then mathematically transformed using a set of equations to estimate the indices of life history parameters. When these life-history parameters are plotted against each other for a large number of fish species, clear patterns emerge (Froese R. & Pauly D., 1998). The estimation of life history parameters could also reveal important biological information about a fish species. Thus, life history parameters could be used to complete any mathematical model of a fish population in which limited or no general population estimates are available (Miller E. F. et al, 2011).

Estimation of life history parameters have been conducted on various wild and captured fish species (Miller E. F. et al, 2011; Stergiou K. I., 2000; Rochet M. J., 2000; Froese R. & Binohlan C., 2003; Beddington J. R. & Kirkwood G. P., 2005; Chu C. & Koops M. A., 2007; Bokhutlo T., 2011). However, there has not been very little information on the estimation of the life history parameters of fish in culture or the application of empirical equations for estimating the life history of fish species in aquaculture.

The estimation of life history parameters of fish is desirable in aquaculture in which the life history parameters could be attained even more than in the wild. According to (Myers R. A. & Worm B.,2003) and (Binohlan C. & Froese R., 2009), overfishing exerts a high mortality rate in wild fishes that there is little chance of even a few individuals to survive long enough to reach maximum size.

Photoperiodism or light manipulations have been used in to increase growth (Mustapha M. K et al., 2012) and faster gonadal development of different stages of fish species (Veras G. C., 2013). The application of photoperiodism could enable the attainment of life history parameters of cultured fish to be reached much earlier than when the fish is cultured naturally or even in the wild. Thus, photoperiodism could enable the estimation of life history parameters of fish species to be obtained faster than normal in any photoperiod where the fish species has been adjudged to grow well. The life parameter estimates obtained from such species in its optimum photoperiod could then be used for stock assessment, cropping, and general management of the species if cultured in photoperiodic manipulation. Also, the results of the estimation could be compared with that of captured fishes from the wild and naturally cultured fish species, more so, when there has not been any published information of the estimation of life history parameters of fish species cultured under photoperiodic manipulations.

The objective of this paper is to estimate the some life history parameters from length at first maturity of *Clarias gariepinus* (Burchell 1822) cultured under 0L: 24D photoperiod using empirical equations. The choice of 0L: 24D photoperiod to estimate the life history parameters of the species was due to its best performance in terms of significant increase in length, weight and gonadal maturation in that photoperiod (Mustapha M. K et al., 2012; Britz P. J. & Pienaar A. G.,1992; Hossain M. A. R. et al,1998; Appelbaum S. & Mcgeer J. C., 1998; Boeuf G. & Bail P. Y. L., 1999; Appelbaum S. & Kamler E., 2000; Adewolu M. A., 2008; Almazán-Rueda P., 2005; Mukai Y. and Lim L. S., 2011; Solomon S. G. & Okomoda V. T., 2012).

MATERIALS AND METHODS

Sixty juveniles of *Clarias gariepinus* were reared in 0L: 24D photoperiod in triplicates with 20 juveniles of the species in each replicate tank. The tank volume was 60L and measured 1x1x0.2m. The fish were acclimatized in the tanks for seven days under laboratory conditions before the commencement of the experiment. The tanks were placed in a well-ventilated dark room and the fish fed with commercial feed of coppens twice daily (8.00 am and 6.00 pm) at 3% and later 5% body weight for 180 days which was the time 50% of the fish reached maturity stage. The maturity stages of the fish species were determined macroscopically through the analysis of gonad appearance and relative size and weight of the gonads after dissection to obtain age and length at first maturity. The fish assumed sexual maturity at stage V of gonadal maturation when the fish belly became distended, pressed and eggs and milts were released. Ripe eggs were translucent and flat, while the milts were opaque and milky.

Water in the tanks were changed weekly and the water quality parameters were also measured weekly with the aid of Lamotte Aquaculture Lab Model SCL-08. Estimation of the life history parameters from length at first maturity was done using spread sheet with equations developed by (Pauly D., 1980; Palomares M. L. D. & Pauly D.,1998; Froese R. & Binohlan C., 2000).

Fish base (Froese R. & Pauly D., 2014) has created life history key facts that provide estimates with error margins of important life history parameters for all fishes. It uses data from capture as defaults for various equations for the life history tools of fish. These defaults were replaced by actual measurements of length and weight of *Clarias gariepinus* at first maturity cultured at 0L: 24D photoperiod to estimate the some of the life history parameters of the species such as optimum length (Lopt), mortality (M), population food consumption (Q/B), gross food conversion efficiency (GE), life span (tmax) and von Bertalanffy growth parameter (K).

The estimation of optimum length (Lopt) from length at first maturity (Lm) was done according to the following equation (24):

$$\text{Lopt} = 10^{(1.053 * \log10(\text{Lm}) - 0.0565)}$$

$$95\ \%\ \text{Conf. Interv.} = \text{Lopt} \pm (1.993 * 0.139 * \text{SQRT}(0.0132 + (0.0962 * (\text{LOG10}(\text{Lm}) - 1.404)^{2})))$$

The mortality estimate was done using temperature and weight growth parameters according to the following equation (22):

$$\log10\text{M} = -0.2107 - 0.0824 \log10 \text{Winf} + 0.6757 \log10 \text{K} + 0.4687 \log10\text{T}$$

Where Winf = live weight in grams
K = 1/year
T = temperature in degree Celsius

The estimate of the population food consumption (Q/B) was done using the equation below (23):

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

Where Z = total mortality 1/year
Winf = 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 (23):

GE =10^(-5.847 + 0.72 * LOG Z + 0.152 * LOG Winf + 1.36 * 1000 / (T + 273.15) - 0.062 * A - 0.51 * h - 0.39 * d)

Where Z = total mortality 1/year
Winf = live weight in grams
T = temperature in degree Celsius
A = Aspect ratio of caudal fin
h and d = food type

The life span (tmax) estimation from age at first maturity (tm) was evaluated according to this equation (24):

logtmax = 0.5496 + 0.957 * logtm

where tm = age at first maturity

The von Bertalanffy growth parameter (K) was estimated from tmax according to this equation (24):

K = 3 / tmax

Where tmax = life span

The statistical analysis of the data which was expressed as means ±SE of the results was done using One-way ANOVA and Duncan's multiple range test to test for significant differences between each replicate at P<0.05.

RESULTS

The mean length and weight at first maturity of *Clarias gariepinus* cultured under 0L: 24D photoperiod is presented in Table 1. The mean length at first maturity was 45.7 ±0.2cm, while the mean wet weight (Winf) at first maturity was 728.13 ± 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 27 °C, which is optimum for the species metabolic activities and was used in the estimation of the life history parameters. The range of dissolved oxygen concentration was between 6.0 – 6.8 mg^{-l}, carbon dioxide 0.01 – 0.03 mg^{-l} and pH between 7.5 – 8.5. There was no significant difference (P>0.05) in the means of the water quality parameters among the replicates tanks.

Table 1. Mean length-weight data at first maturity of *Clarias gariepinus* cultured under 0L: 24D photoperiod

Length-weight data at first maturity	Replicate 1	Replicate 2	Replicate 3
Initial total length (cm)	14.80 ± 0.1	14.90 ± 0.1	14.90 ± 0.1
Final total length at first maturity (cm)	45.60 ± 0.2	45.80 ± 0.2	45.70 ± 0.2
Initial live body weight (g)	32.30 ± 0.1	32.20 ± 0.1	32.20 ± 0.1
Final live body weight (g)	726.10 ± 0.5	730.20 ± 0.5	728.10 ± 0.5

Table 2. Mean range of water quality parameters of *Clarias gariepinus* cultured under 0L: 24D photoperiod

Water quality parameters	Replicate 1	Replicate 2	Replicate 3
Temperature (°C)	26 - 27	26 - 27	26 - 27
Dissolved oxygen (mg-l)	6.0 - 6.6	6.0 - 6.8	6.0 - 6.8
Carbon dioxide (mg-l)	0.01 – 0.03	0.01 – 0.03	0.01 – 0.03
pH	7.5 – 8.5	7.5 – 8.5	7.5 – 8.5

The estimates of some life history parameters from mean length and weight at first maturity of *Clarias gariepinus* cultured under 0L: 24D photoperiod is presented in Table 3. Optimum length (Lopt) was estimated at 49.1 cm from the recorded length at first maturity of 45.7cm with a 95% confidence limit of between 44.9 – 53.7 cm. Mortality (M) was estimated to be low at 2.37/year, while amount of food consumed Q/B and gross food conversion efficiency were estimated to be 8.7 and 0.181 respectively. The species is estimated to live for 1.8 years (tmax) with 95% confidence limit of between 1.2 – 2.9 years. Using the life span (tmax) estimates of 1.8 years, the von Bertalanffy growth parameter (K) was estimated at 1.67.

Table 3. Estimates of some life history parameters from mean length and weight at first maturity of *Clarias gariepinus* cultured under 0L: 24D photoperiod

Life history parameters	Estimates
Optimum length (Lopt)	Lm = 45.7 cm Lopt = 49.1cm S.E range (95%) = 44.9 – 53.7 cm Lm/Lopt = 0.93
Mortality (M)	Winf = 728.13 K = 1.67 T = 27°C M = 2.37/year M = 1.18/0.5 year
Amount of food consumed (Q/B)	Winf = 728.13 T = 27°C A = 1.26 h = 0 d = 0 Q/B = 8.7
Gross food conversion efficiency (GE)	Winf = 728.13 Z = 2 T = 27°C A = 1.26 h = 0 d = 0 GE = 0.181
Life span (tmax)	tm = 0.5 years tmax = 1.8 years S.E range = 1.2 – 2.9 years tm/tmax = 0.27 years
Von Bertalanffy growth parameter (K)	tmax = 1.8 years K = 1.67

DISCUSSION

Clarias gariepinus (Burchell, 1822) is one of the most cultured fish species in Africa due to its hardy nature, resistance to stress, good taste, fast growth and ease of culture in captivity. The growth (length and weight), gonadal maturation and spawning of the species is especially faster when cultured in 0L: 24D photoperiod (Mustapha M. K et al., 2012; Britz P. J. & Pienaar A. G.,1992; Hossain M. A. R. et al,1998; Appelbaum S. & Mcgeer J. C., 1998; Boeuf G. & Bail P. Y. L., 1999; Appelbaum S. & Kamler E., 2000; Adewolu M. A., 2008; Almazán-Rueda P., 2005; Mukai Y. and Lim L. S., 2011; Solomon S. G. & Okomoda V. T., 2012).

Using empirical equations developed by several workers and as found in FishBase developed by Froese and Pauly (Froese R. & Pauly D., 2014), could give could give estimates with standard errors of some of the life history parameters of the species in culture. This could then be used in the stock assessment, cropping and management of the species during the photoperiodic culture.

The six months photoperiodic manipulations under the 0L: 24D photoperiod aided the significant increase in length, weight and sexual maturity of the species with the attainment of advanced gonadal development of both sexes. The mean length, weight and age of the species along with the optimum temperature in the culturing tanks, the type of food consumed and the aspect ratio of the caudal fin at first maturity were used to compute and estimate the some of the life history parameters of the fish. For instance, the length of maximum possible yield (Lopt) after sexual maturation length was reached will be 49.1 cm with 95% confidence limit of between 44.9 – 53cm. This estimated value could serve as a guide to cropping of the fish from ponds or manipulated through values of the length at sexual maturity to obtain desired length class with the highest biomass for harvest according to (Beverton R. H., 1992). The Lm and Lopt could also be used to evaluate the length-frequency diagrams for signs of growth overharvesting (harvesting fish before they realized most of their growth potentials in then pond) or recruitment overharvesting (reducing the number of brood stocks to a level that is insufficient to maintain the stock and hence the aquaculture. These assumptions have already been said for captured fishes from the wild (Froese R. & Pauly D., 2014).

The estimate of the mortality (M) of the total number of species cultured was 2.37/year, thus for the 6-month cultured period the estimate would be 1.18. This translates to 1.97% mortality rate based on the total population of fish cultures. This could be considered very good value for the species in aquaculture. The estimated 3.95% mortality rate would probably come from larval deaths as mortality is usually higher during the larval stages of the species than the adults in culture (Mustapha M. K. et al, 2014). Such mortality estimate could be used in the aquacultural management of the fish species to know and prevent mortality at larval or adult stages of fish by appropriately directing welfare measures to prevent stress at these stages. (Pauly D., 1980; Vetter E. F., 1988; Djabali F. et al, 1993) have used empirical equations and life history parameters to estimate mortality in wild and captured fishes. (Okogwu O. I., 2011) gave a mortality estimate of

2.54 which included fishing mortality and M/K of 1.7 for *Clarias gariepinus* in Mid-Cross River Flood Plain Ecosystem, Nigeria, while (Abdulkarim M., et al 2009) reported an M/K ratio of 1.7 for *Clarias gariepinus* in Gubi dam, Nigeria. The estimated M/K ratio obtained in this work is within the range observed by Beverton and Holt (Beverton R. J. H. & Holt S. J., 1959).

The estimated amount of food ingested by the total population of the species (Q/B) over the culture period stood at 8.7. The Q/B estimates by Palomares and Pauly (Palomares M. L. D. & Pauly D.,1998) for *Clarias gariepinus* in Lake Malawi was 1.73. The differences in the Q/B between the captured fishes of Lake Malawi and this value for cultured fishes was due to higher weight and low temperature recorded for the captured fishes as well as lower K values recorded in the lake.

The low value of the gross food conversion efficiency (GE) is an indication that the food consumed was completely utilized. This is expected during the 0L: 24D photoperiod because the species is a nocturnal feeder. (Mustapha M. K et al., 2012; Britz P. J. & Pienaar A. G.,1992; Appelbaum S. & Kamler E., 2000; Adewolu M. A., 2008), have all reported that length and weight increase of *C. gariepinus* under the 0L: 24D photoperiod was due to high feeding activity in the dark. If the estimate of the GE values for fish is high using the empirical equations, it is an indication of poor gross food conversion efficiency. Though amount of food ingested by the total population of the species (Q/B) and gross food conversion efficiency (GE) can be calculated directly from the experiment, the use of empirical equations for the calculations of the two indices will enable amount of food to be bought and given to the fish during culture thereby saving cost and food wastage.

The life span estimate (tmax) from the age at maturity and from the von Bertalanffy growth parameter (K) was 1.8 years with 95% confidence limit of between 1.2 – 2.9 years. There is probability that the tmax estimate would increase if the K is high, because in culture, fish can survive for a very long time. The use of this type of estimate is good for the fish farmer as he will know the life span of his cultured fish and thus harvest the fish before the terminal year of the fish life, thereby saving him the cost of production. The life span record for the species in the wild ranged between 6 – 8 years (Okogwu O. I., 2011; Skelton P. H., 1993), but overfishing which exerts a high mortality rate in wild fishes will prevent the fish from surviving to such a long time (Myers R. A. & Worm B., 2003; Froese R. & Binohlan C.,2000).

The von Bertalanffy growth parameter (K) from tmax was high 1.67/0.5 years in spite of the fact that the fish was cultured for only 6 months. The reason for this was because of the culturing of the juveniles of the fish, the sexual maturity of the juvenile fish at very little age as well as the good water quality parameters especially the temperature and dissolved oxygen of the cultured tanks. This led credence to the fact that 0L: 24D photoperiod in *Clarias gariepinus* increase the K value of the fish. Abdulkarim *et al.* observed that K value is higher in young than adult fish species (Abdulkarim M., et al, 2009). Although K could be obtained directly from the experiment, the use of empirical equation to obtain estimates of von Bertalanffy growth parameter (K) in cultured fish is highly desirable as it will show how high or low the K value will be during the culture period. This would then inform appropriate management to be directed to the species in the pond to increase the K value in case of low estimates of the K value.

CONCLUSION

This is the first work of estimating life-history parameters from the morphometrics of *Clarias gariepinus* obtained under photoperiodic manipulations and culture. The use of length at first maturity as compared to maximum length for estimation of some life history-parameters for the species in this work was more desirable because the species will reach sexual maturity in less time especially under 0L: 24D photoperiodism as compared to culturing the species for a very long time to reach maximum length. Also, aqua culturists or fish farmers are more interested in their fish reaching table size than maximum length. Even in the wild, reaching the species maximum length as recorded in books, literatures and data bases is becoming a mirage because of over exploitation.

The use of empirical equations for estimating the life history-parameters of this species in culture will ensure that the species is managed adequately from the point of stocking to feed consumption and conversion as well as harvesting in 24D: 0L photoperiod. The estimate will help in reducing unnecessary incursion of costs during culture as well as ensuring high profitability for the fish farmers if the estimates were followed strictly.

The use of empirical equations to estimate life history parameters could not be said to be fool proof because of errors as even acknowledged in FishBase. In order to test the reliability of empirical equations to determine the life history of cultured fishes, actual measurements from the experiment should be compared with that of the empirical estimates.

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