Homepage: - www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

Article DOI: 10.21474/IJAR01/11752
DOI URL: http://dx.doi.org/10.21474/IJAR01/11752

RESEARCH ARTICLE

COMPARATIVE GROWTH OF JIPE TILAPIA, OREOCHROMIS JIPE AND NILE TILAPIA, OREOCHROMIS NILOTICUS USING REGRESSION MODELING

Job Ombiro Omweno[1], Paul Sawe Orina[2], Albert Getabu[1] and Peter Maangi Ondieki[2]

1. Department of Aquatic and Fishery Sciences, Kisii University, P.O Box 408-40200, Kisii, Kenya.
2. Kenya Marine & Fisheries Research Institute (KMFRI), Kegati Aquaculture Research Station, P.O. Box 3259, 40200, Kisii, Kenya.

Manuscript Info

Manuscript History
Received: 20 July 2020
Final Accepted: 24 August 2020
Published: September 2020

Key words:-
Regression Models, Length-Weight Relationships, R-Software, Oreochromis Jipe, Oreochromis Niloticus

Abstract

Regression modeling analyses the relationship between two or more variables and can be used to predict the response variable from one or more independent variables. The present study uses linear regression analysis to evaluate the growth in the two fish species of genus *Oreochromis,* Nile tilapia and Jipe tilapia, under aquaculture conditions. The models were fitted using a collection of functions in the R-software library. The final models were selected using the goodness of fit criteria based on the coefficient of differentiation, the model p-values and Akaike information criteria. The significance of the linear relationship between predictor variables and the mean response was tested by comparing the computed standardized parameter estimates, whereas the confidence intervals were constructed to assess the uncertainty of predicting the response variable and determine outliers in the model. Generally, both species exhibited good condition during growth and all the measured water quality variables significantly afffected growth ($p<0.05$). However, only temperature and dissolved oxygen produced the most important linear relationship with fish weight. The study recommends that data from a controlled experiment should be used the determine the interactions between the two growth variables.

Introduction:-

Biological processes such as growth and production of a given fish population can be estimated by various methods which have been described by different authors (Abdel-Raheam et al., 2017; De Graaf *et al.*, 2005). One of such methods is the use of simple mathematical models described by equations which depict relationship between growth parameters (Jopp *et al.*, 2011). Growth models provide crucial information required for the management and general understanding of fisheries (Juan-Jordá *et al.*, 2015), and for predicting the adaptability of a given species to the culture environment (Okomoda *et al.*, 2018). For instance, the von Bertalanffy growth model which is widely applied in fisheries (Von Bartalanffy, 1938; Cailliet *et al.,* 2006), describes a scenario in which the fish approaches a theoretical maximum (asymptotic) size if allowed to grow indefinitely. Many authors have documented the species whose growth will be better described by this model to provide an excellent fit (Froese and Pauly , 2017; Smart *et al.*, 2016; Koch *et al.*, 2015). However, the overall maturity size of fish depends on many factors related to the

Corresponding Author:- Job Ombiro Omweno
Address:- Department of Aquatic and Fishery Sciences, Kisii University, P.O Box 408-40200, Kisii, Kenya.

culture environment, species and even strains within the same species (Duponchelle and Legendre, 2000). Most recent studies in culture fisheries have mainly focused in explaining the effect of stocking densities, crude protein levels and feeding regimes on growth and the physiological wellbeing of Tilapia which is cultured in many parts of the world (Yakubu *et al.*, 2013; Abdel-Tawwab, 2012). Nonetheless, the water quality variables also play a very important role as intervening variables which regulate the fish metabolic rates (Shackleton, 2012; Byström *et al.*, 2006), and the deviations above or below the lethal limits have been reported to be detrimental to fish growth and survival. For instance, the optimum growth and survival in Tilapia has been reported to occur at a temperature range of between 20 °C and 31°C, dissolved oxygen range and pH level of 4.20 to 5.90mg/I and 6.5-9.0 respectively (Mirea, 2013; Nehemia et al., 2012; Mjoun *et al.*, 2010). Conversely, the massive mortalities occur in the pH levels above 9.0 due to increased concentration of unionized ammonia to more than 0.2mg/L, which is detrimental to fish growth and survival (Nehemia *et al.*, 2012). The interaction between water variables and fish weight can be explained using the linear models given by the equation, $Y = \beta X + \varepsilon$, which relates independent variables to the mean of the response variable (Fox, 2016). Consequently, log-transformed weight-length regressions have been used to assess the influence of water quality variables on the condition factor of different fish species (Mansor et al., 2012; Abdel-Raheam and El-Bassir, 2017). These estimate parameters and the error term of predicting the population regression are conviniently estimated by the regression modeling functions using matrix algebra (Faraway, 2005; Rawlings et al., 1998). Therefore, more independent variables apart from body length can be included in the model to determine their effect on fish growth using single factor regression and multiple regression models. Despite the crucial importance of this method, only few studies have applied regression modeling to simulate growth of cultured fishes. Therefore the study aims at comparing the growth of Nile tilapia, *Oreochromis niloticus* and Jipe tilapia, *Oreochromis niloticus* to provide baseline information to researchers and graduate students who would like to conduct a future related study.

Modeling Procedure:

***Theoretical framework*:**

The study compared growth and the condition of Nile tilapia and Jipe tilapia under the same aquaculture conditions. Data used in the present study has been published by Omweno *et al.* (2020), in which the study design and data collection procedures have been discussed. The data was organized into two data frames, each containing six variables were considered from the growth data of both species collected over a period of three months. The interaction between selected variables used for fish growth modeling is illustrated in the figure 2 below:

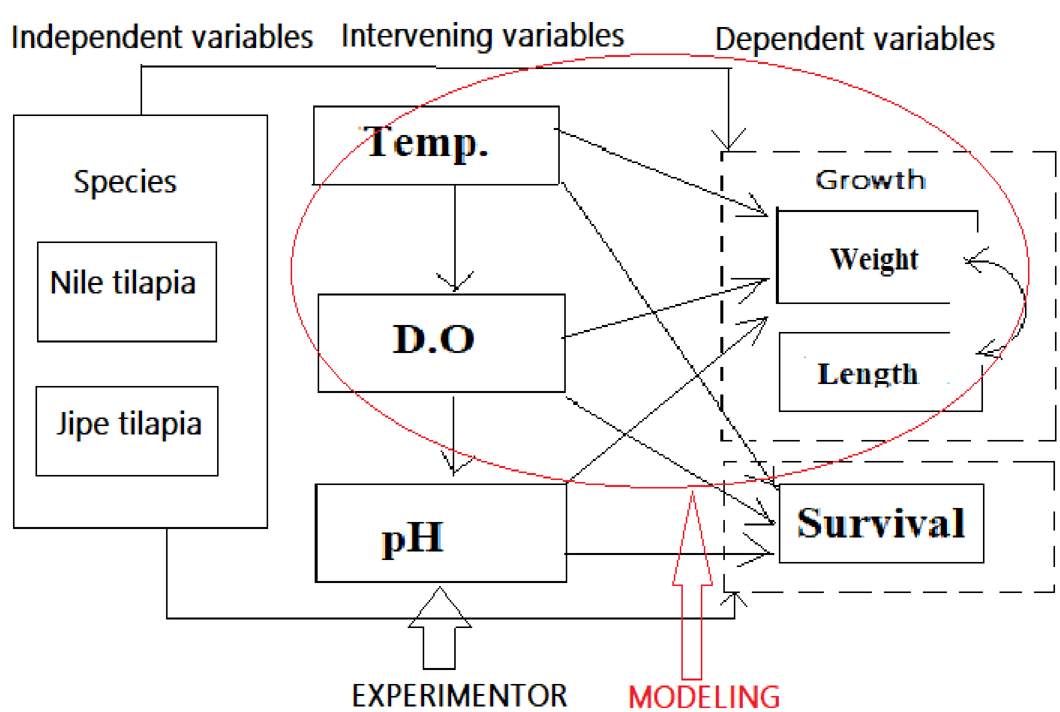

Figure 1:- Thetheoretical framework for modeling the fish growth variables.

The independent variable, species, has two levels of treatment, Nile tilapia and Jipe tilapia. The baseline comparison of growth presumed that species is the only independent variable responsible for change in fish growth and survival, whereas regression modeling compared the interactive effects among the intervening variables on the growth of both species. Each variable was initially assumed to change during the study but there was no control for the independent variable. The first, second and third intervening variables were temperature (Temp.), dissolved oxygen (D.O) and pH respectively as shown in figure 1.

Model fitting:
Modeling was done using the 64-bit R software version 3.6.2 (R-core team, 2019). The models were generated by submitting two data frames imported into the R environment to modeling arguments, which specify the predictors and response variables. In linear models, a set of operators were used to combine low order and influential terms to bring about the intended effects (Lindsey, 1997), and to nullify the interpretation of operators, allowing the use of a combination of linear parameters (Horton and Kleinman, 2015). Regression diagnostics were performed using the lmtest and car packages (Fox and Weisberg, 2019; Zeileis and Hothorn, 2002). Outliers in the models were generated according to Cook and Weisberg (1982) and residual plots were obtained by submitting the saved objects to the plot( ) and hist( ) arguments.

Linear modeling functions:
Nearly all linear modeling functions in the R software (R-core team, 2019) were provided by the inbuilt Stats package.The lm( ) function was used to perform regression and fit the regression models. Details of the model information were generated by summary function, while slope and intercept coefficients were extracted from model objects saved in R environment using coef( ) function. These coefficients were submitted to plot function which was used to graphically represent different regression models on the same plot. The residual( ) and fitted( ) functions were used to obtain residual plots which were used to check residual distributions, while confint( ) function was used to construct the 95% confidence intervals for parameter estimates in the fitted linear regression models. Finally, the predict( ) function was used to predict future observations on the response variable.

Model assessment using hypothesis:
The bivariate regression models were assessed based on the default null hypothesis which presumed that all predictors of fish weight were significantly different from zero; Ho_1: $\beta_1 = \beta_2 = \beta_3 = 0$. The second null hypothesis in multiple regressions tested a pair of predictors, Ho_2: $\beta 1 + \beta 2 \neq 1$, where the I() function was used in the argument to inhibit the interpretation of operators as being part of the model formula (Horton and Kleinman, 2015). Two nested models were generated, one having a combination of linear parameters, X_1 and X_2 using the I( ) function and the two nested models were compared using anova.

In a multiple regression, more significant predictors were selected for the final model, so that the model's prediction accuracy can be improved by minimizing the errors attributed to variance unexplained by the model. Different assessment criteria were used to arrive at the final models: adjusted R^2 which estimates the % variance explained by the model using the linear combination of predictors (Palmer and O'Connell, 2009), the Akaike information criteria (Akaike, 1974), was which was auto performed using stepAIC function in the package MASS (Venables and Ripley, 2002) and statistical significance of the linear predictors using model p-values. The relative importance of the physicochemical parameters on fish growth was assessed using the standardized parameter estimates (β-coefficients) which were computed on selected models according to Gardener (2011). The nested models were compared using analysis of variance.

Model predictions and confidence intervals:
The models' predictive capabilities were performed by assigning the differences between the predicted and actual results to the vector delta, and the distribution mean of delta estimated using the data-splitting method according to Lilja (2016). Outliers and potentially influential observations were generated using parameter estimate coefficients (dfbetas) and their standardized distance from the mean of predictors.

Results:-

Bivariate regression:
Figure 2 shows the results of the bivariate regressions between body weight and total length log-transformed data of *Oreochromis jipe* and *Oreochromis niloticus* species. The overlay of scatter in both models portrays a positive and statistically significant ($p<0.05$) relationship between the body weight and total length growth variables, which

predict an increase of 0.019g and 0.023g body weight in *O. jipe* and *O. niloticus* per every total length increase in fish during the culture period respectively.

In addition, the coefficient of determination (adjusted R^2) of the log-transformed regression models showed a strong linear relationship between total length and body weight of both species. The slope, regression intercepts and coefficients of differentiation of both models are shown in the figure below:

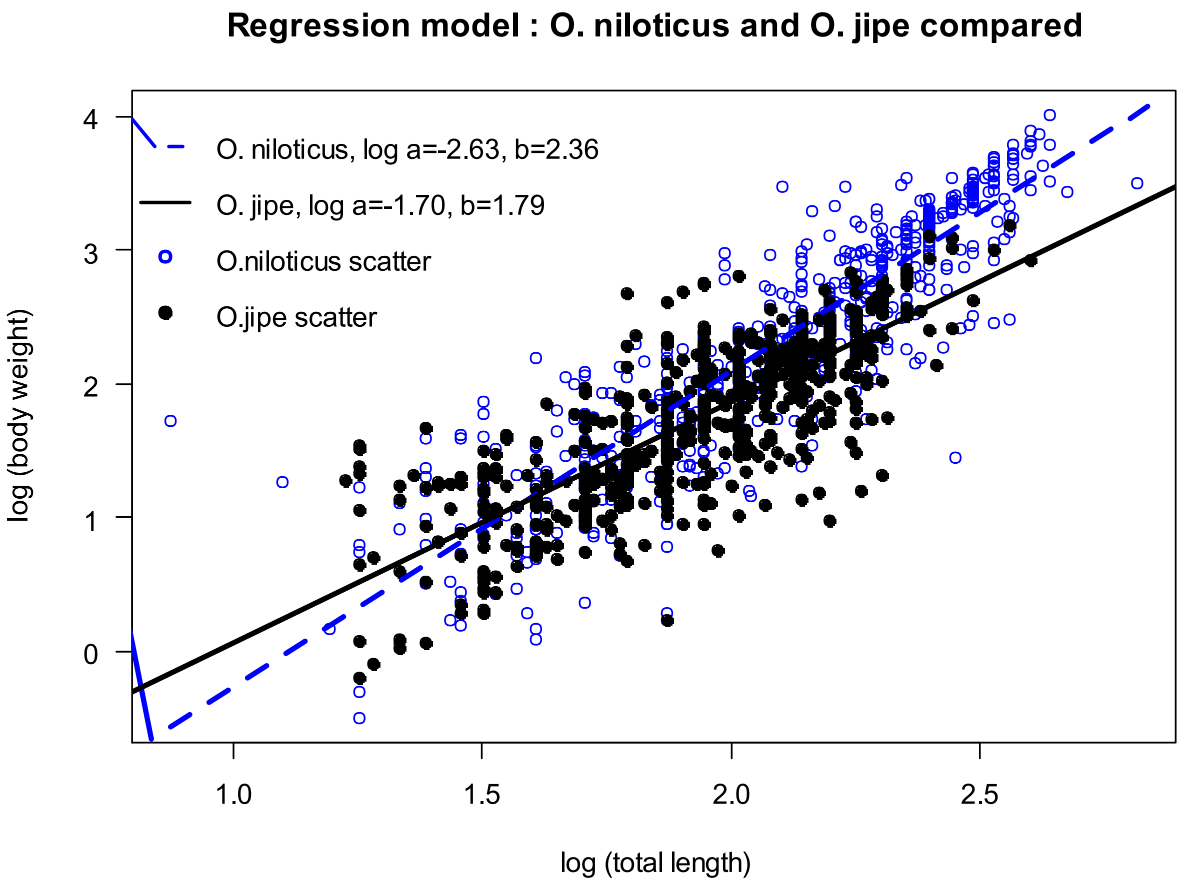

Figure 2:- Bivariate regression models of *Oreochromis jipe* and *Oreochromis niloticus* using log-transformed data.

Residual analysis:

In the bivariate regressions, the standardized residuals and studentized residuals of the response variable had a near random distribution with less than 2% of values above and below two standard deviations from the mean of zero, although ordinary residuals had a wider distribution which appeared to be non-symmetrical (figure3).

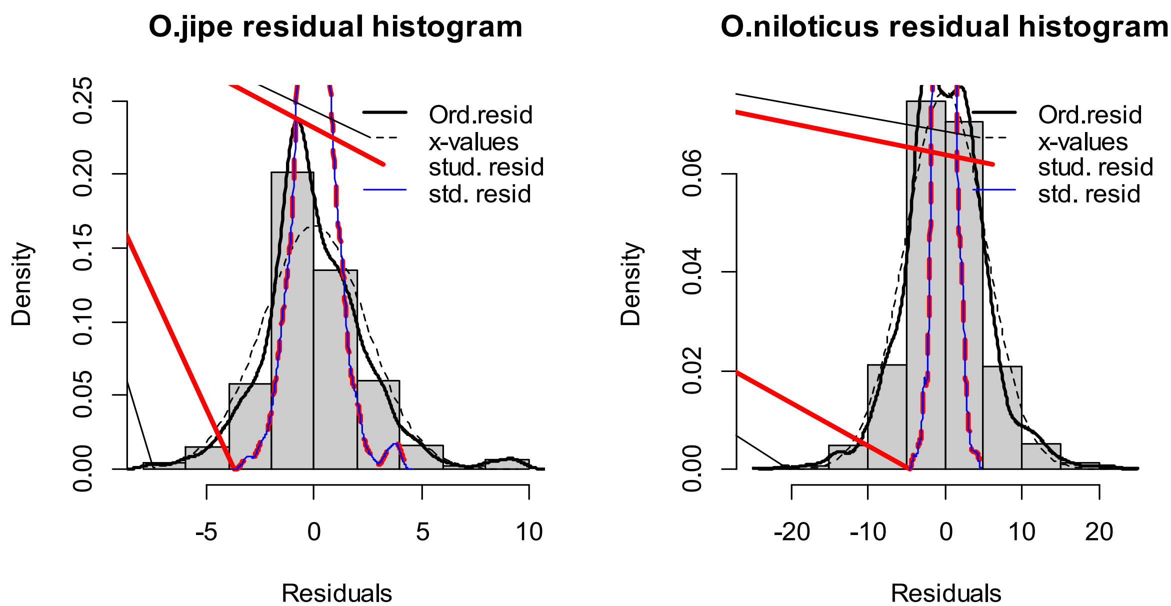

Figure 3:- Residual histograms and density distributions of body weight in *Oreochromis jipe* and *O. niloticus.*

Multiple regressions:

In the multiple regression analysis (Table 1), we evaluated the influence of five independent variables (culture period, body length, temperature, pH and dissolved oxygen) on fish body weight of the two species. All predictors of body weight in fish were statistically significant ($p<0.05$), therefore parameter estimate coefficients because are significantly different from zero at 95% significance level. In terms of model fit, the data is good to averagely well-fitted and the the six independent variables used explain 64.7% and 81.4% of the total variance in the dependent variable in *O. jipe* and *O. niloticus* respectively. The anova p-value ($p>0.05$) obtained from comparing nested models indicated that no sufficient evidence to treat dissolved oxygen and pH level separately in the model, hence the null hypothesis cannot be rejected. The regression coefficients and standardized beta coefficients of the multiple regressions are shown in table 1.

Table 1:- Comparison between parameter coefficients and standardized parameter coefficients returned by multiple regression models.

Parameter estimate	*Oreochromis jipe*			*Oreochromis niloticus*		
	β±S.E	**CIs**	**$\beta_{std.}$**	**β±S.E**	**CIs**	**$\beta_{std.}$**
Culture period	0.10±0.01	0.09-0.12	0.73	0.18±0.02	0.14-0.22	0.46
Length	0.93±0.07	0.78-1.07	0.44	2.17±0.14	1.88-2.45	0.53
Temperature	0.87±0.13	0.62-1.11	0.28	0.69±0.42	-0.12-1.51	0.07
pH	2.46±0.48	1.52-3.40	0.24	2.04±0.65	0.77-3.31	0.07
Oxygen	2.49±0.52	1.46-3.51	0.21	2.52±0.65	1.24-3.79	0.06

β=Parameter estimate coefficient, **β_{std}** = Standardized parameter estimate coefficient**, CIs=** Confidence Intervals **and S.E=** Standard Error of the estimate

The confidence intervals for the distribution of delta values obtained from predictions using one factor regressions are shown in the figure 4 below.

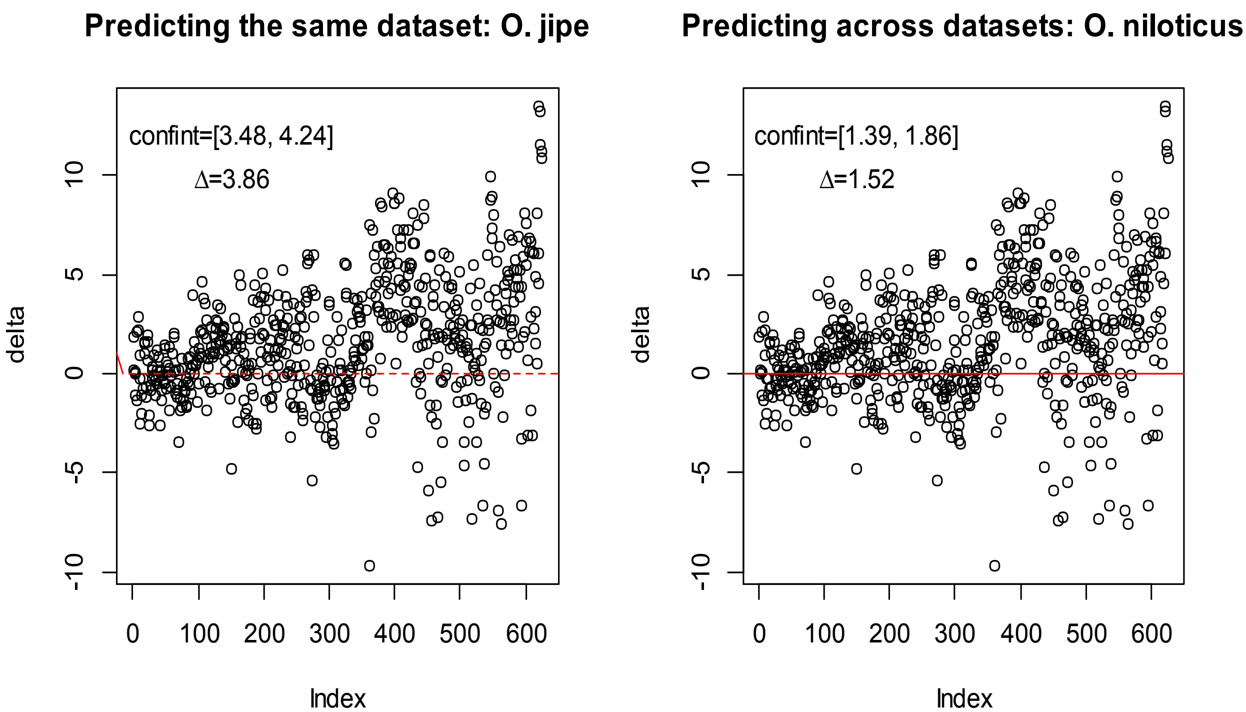

Figure 4:- Standard distribution and **c**onfidence intervals for delta values predicted using bivariate regressions.

The prediction confidence limits of [3.48, 4.24], were obtained when predicting *O. jipe* using the split dataset obtained from *O. jipe* in which several data points lie outside the mean of zero, indicating overestimation of predicted weight values. However, only few data points lie outside the mean of zero when *O. jipe* weight is predicted using using different *O. niloticus* dataset and [1.39, 1.86] confidence intervals were obtained when predicting across the datasets.

Discussion:-

Regression modeling is an inferential statistics method used to study the relationship between one or more independent variables and the response variable. Regression models can also be used to provide crucial information on interaction between primary variables which influence the growth process, by statistically determining the relationship between the growth response variable and one or more independent predictors (Palmer and O'Connell, 2009). Apart from being used for explanations, regression analysis is also useful for making predictions on future observations (Pedhazur, 1997). In fisheries research, the log-transformed length-weight regression analysis is used to determine the fish condition factor, whereby, the values of length-weight coefficient (b) indicate whether the fish is growing isometrically or allometrically (Ighwela et al., 2011). In the present study, both *O. jipe* and *O. niloticus* exhibited allometric growth, with the values of length-weight coefficient (b) of less than 3. The result corroborates with the findings of Ighwela et al. (2011) and Gupta et al. (2012), which show that most fish species at the fingerling stage exhibit negative allometric growth ($b<3$), but mature fish tend to show isometric growth and postive allometric growth (b> or equal to 3). The overall model significance ($p<0.05$), showed that there was sufficient information to conclude that all β-coefficients were significantly different from zero, hence, fish weight in both species was influenced by all the independent variables under study. This is supported by the parameter t-values which were greater than 1.96 indicating a lower probability $Pr(>|t|)$ of getting $\beta \neq 0$ by chance and confirmed by larger model F-stat values.

Residuals are the differences between the actual values and the values predicted by the regression model. The randomness in residual distributions is assumed for the predicted response variable, which in this study was was the fish body weight, whose standardized and studentized residual values exhibited a standard normal distribution with two standard devitions away from the mean of zero. In addition, the standard error of each of the parameter estimates of body weight was less than times smaller than the corresponding parameter estimate coefficient which showed that our regression models were best-fitting for the datasets (Lilija, 2016). This is because a large coefficient to standard error ratio indicates high variability in the parameter estimate, hence uncertainty in the model predictions. Graphically, the residuals in the normal probability (q-q) plots followed a straight line and were randomly scattered without homoscesdascity except for few outliers which were less than 2% of the data. These outliers might have been caused by missing or omitted values, variance heterogeneity or unconverging algorithm which failed to capture the complexity of the aquaculture system in order to make a perfect prediction on the two fish populations under study. Consequently, the raw residuals were widely scattered with 5-20 standard deviations around the mean of zero (**figure 3**). The assumption of normality in the response variable body weight was also tested using Shapiro-Wilk test (Shapiro and Wilk, 1965) and residual distributions in order to assess the model quality. Since (W=0.975, p>0.05), there was insufficient evidence to reject the null hypothesis that residuals were not normally distributed although we detected non-normality in residual histograms (**figure 3**) due to a small sample used in modeling. Despite the datasets meeting the normality assumption, it is worthy to note that the assumption of normality is only obeyed by extremely large samples which underlie the use of F- and t-tests where data is likely to be normally distributed. However, the independent variables do not necessarily have to meet this assumption because they are fixed. A wide non-symmetric distribution of raw residuals exhibited by *O. jipe* regression models may have been caused by a small number of shooters which gained weight faster than the rest of mixed-sex fingerlings. Apart from the residual standard error and distribution of the standard residuals, the adjusted coefficient of determination (adjusted R-squared), which estimates the percentage of total variance of the predicted response variable explained by the linear regression, also provides a relative measure of goodness of fit (Zar, 1984). According to Fox (2016), the higher the adjusted R^2 value, the better the model in making predictions. The bivariate regression models accounted for 64.5% and 81.2% of the variance explained in the response variable in *O. jipe* and *O. niloticus* respectively. The higher adjusted R^2 value in *O. niloticus* log-transformed model indicates that a greater proportion of weight in this species can be explained from the regression model compared to *O. jipe*.

The parameter estimate coefficients (betas) shown in **table 1** determines how much the mean of the response variable increases with each increase in the independent variable, while the sign of the coefficient shows whether the change caused by the independent variable is postive or negative. In this study, a change in each of the independent variables caused a corresponding positive change in fish weight. It is however difficult to compare the parameter estimate coefficients unless they are standardized to the same scale. The standardized parameter (beta) estimate coefficients provide a standardized way of comparing all the estimate parameters associated with the growth response variable weight, which were quantified using different metric units. These coefficients were computed using the programmed algorithm published by gardener (2011). The comparison of standardized beta coefficients found that temperature (^oC) was the most important parameter in the growth of both species of *Oreochromis*, followed by dissolved oxygen and pH respectively. However, in *O. jipe*, weight and culture period provided the strongest linear relationship with the largest standardized beta coefficient in the multiple regression. The overall dominance effect of each of the physicochemical parameters in the growth of both species corroborates with the standardized rank of beta (slope) coefficients as shown in table 1.

The parameter estimates obtained by this study are not just precise values but more often, regression models give a range of uncertainty within which the true values of prediction lie, defined by 100(1-α)% outside which any point in the model will be rejected based on the null hypothesis. This region is called confidence interval or simply confidence limits. The Confidence Intervals (CIs) provide an alternative way of testing the multiple hypothesis concerning uncertainty in prediction of the response variable. For reliable predictions , the mean delta (Δi) values at 95 percent confidence interval should close to zero and the delta values uniformly distributed on both sides of the mean zero (Lilja, 2016). However, our prediction confidence limits of [3.48, 4.24], when predicting the same dataset and [1.39, 1.86] when predicting across the datasets lie outside the mean of zero, which could be due to overestimation of predicted values. Therefore, the mean weight of *O. jipe* but can be most reliably predicted using the weight-length regression performed on the data drawn from *O. niloticus* because the confidence interval contains very small delta values distributed around the mean of zero as shown in figure 4 above. This further predicts the stability of *O. niloticus* species in the captive environment compared to *O. jipe*.

Conclusion And Recommedations:-

In conclusion, the fingerlings *O. niloticus* and *O. jipe* cultured in wooden backyard ponds were in good condition. The weight gain in *O. jipe* had high dependance on the number of culture days but showed greater uncertainity in captivity. In addition, a large number of shooters in O. jipe data could necessitate multiple cropping of cultured fish before final harvest. The study recommends further trials using mono-sex fingerlings under controlled culture conditions.

Acknowledgments:-

This project was funded by the African Development Bank (AfDB) through Kisii University, Kenya. The authors also wish to thank the Kenya Marine and Fisheries Research Institute (KMFRI-Kegati) for providing the necessary materials and technical assistance required during the study.

References:-

1. Abdel-Raheam, H A El-Bassir (2017). Length-Weight Relationship and Condition Factor of Three Commercial Fish Species of River Nile, Sudan". EC Oceanography 1(1): 01-07.
2. Abdel-Tawwab, M. (2012). Effects of dietary protein levels and rearing density on growth performance and stress response of Nile tilapia, *Oreochromis niloticus* (L.) International Aquatic Research, 4 (3):Pp 1-13
3. Akaike, H. (1974) A New Look at the Statistical Model Identification. IEEE Transactions on Automatic Control, AC- 19, 716-723. http://dx.doi.org/10.1109/TAC.1974.1100705
4. Byström, P., Anderson, J., Kiessling, A. and Eriksson, L. (2006). Size and Temperature Dependent Foraging Capacities and Metabolism: Consequences for Winter Starvation Mortality in Fish. Oikos 115: 43-52.
5. Cailliet, G. M., Smith, W. D., Mollet, H. F. and Goldman, K. J. (2006). Age and growth studies of chondrichthyan fishes: The need for consistency in terminology, verification, validation, and growth function fitting, Environmental Biology of Fish 77:211–228. http://doi.org/10.1007/978-1-4020-5570-6_2
6. Cook, R. D. and Weisberg, S. (1982) Residuals and Influence in Regression. Chapman and Hall, https://conservancy.umn.edu/handle/11299/37076.
7. De Graaf, G. J., Dekker, P. J., Huisman, B. and Verreth, J. A. J. (2005). Simulation of O. niloticus culture in pond, through individual–based modeling, using a population dynamics approach. Aquaculture Research, 36: 455-472.
8. Duponchelle, F. and M. Legendre (2000). *Oreochromis niloticus* (Cichlidae) in Lake Ayame, Côte d'Ivoire: life history traits of a strongly diminished population. Cybium, 24(2):161-172. Fishbase Ref. No.36190
9. Faraway, J. J. (2005). Linear Models with R, Chapman & Hall/CRC: Texts in Statistical Science. NewYork, USA. ISBN 0-203-59454-1
10. Fox, J. (2016). Applied Regression Analysis and Generalized Linear Models. Third Edition. Thousand Oaks CA:Sage.
11. Fox, J. and Weisberg, S. (2019). An {R} Companion to Applied Regression, Third Edition. Thousand Oaks CA: Sage. URL:https://socialsciences.mcmaster.ca/jfox/Books/Companion/
12. Froese R and Pauly D. (2017). [August 2017]. FishBase data base. http://www.fishbase.org
13. Gupta, N., Hague, M. M. and Khan, M. (2012). Growth performance of tilapia fingerling in cage in ponds managed by Adivasi households: An assessment through length-weight relationship. J. Bangladesh Agril. Univ., 10(1): 149–155, ISSN 1810-3030
14. Horton, N. J. and Kleinman, K. (2015). Using R and rstudio for data management, statistical analysis, and graphics, second edition, CRC Press, Boca Raton, 313 Pp. ISBN 978-1-4822-3736-8. DO - 10.1201/b18151. Retrieved from http://www.amherst.edu/~nhorton/r2/
15. Ighwela, K. A., Aziz Bin Ahmed, A. B., and , Abol-Munafi, A. B. (2011). Condition Factor as an Indicator of Growth and Feeding Intensity of Nile Tilapia Fingerlings (*Oreochromis niloticus*) Feed on Different Levels of Maltose. American-Eurasian J. Agric. & Environ. Sci., 11 (4): 559-563, ISSN 1818-6769
16. Jopp, F., Reuter, H. and Breckling, B. (2011). Modelling complex ecological dynamics: An introduction into ecological modelling for students, teachers & scientists. https://doi.org/10.1007/978-3-642-05029-9
17. Juan-Jorda, M. J., Mosqueira, I., Freire, J., Dulvy, N. K. (2015). Population declines of tuna and relatives depend on their speed of life. Proc. R. Soc. B 282: 20150322. http://dx.doi.org/10.1098/rspb.2015.0322
18. Koch V, Rengstorf A, Taylor M, Mazon-Suastegui JM, Sinsel F, Wolff M.(2015). Comparative growth and mortality of cultured Lion's Paw scallops (*Nodipecten subnodosus*) from Gulf of California and Pacific populations and their reciprocal transplants. Aquaculture Research, 46:185–201. doi: 10.1111/are.12175.
19. Lilja, D. J. (2016). Linear Regression Using R: An Introduction to Data Modeling Linear Regression Using R. University of Minnesota Libraries Publishing Minneapolis, Minnesota, ISBN-13: 978-1-946135-00-1. https:/doi.org/10.24926/8668/1301. Downloaded from http://z.umn.edu/lrur
20. Lindsey, K. J. (1997). Applying generalized Linear Models. Springer-Verlag New York, Inc. ISBN 0-387-98218-3

21. Mansor, M.I., Mohamad, N.A.B., Mohamad-Zafrizal, M. Z., Khairun,Y. and Siti-Azizah, M. N. (2012). Length-weight Relationships of Some Important Estuarine Fish Species from Merbok Estuary, Kedah. Journal of Natural Sciences Research, 2(2): Pp. 8-18. http://www.iiste.org .ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online).
22. Mirea, E. T. (2013). Influence of different water temperature on intensive growth performance of Nile tilapia in a recirculation aquaculture system, Lorena Dediu University of Agriculture, Science and Veterinary medicine, 60.
23. Mjoun, K., Rosentrater, K., and Broun, M. (2010). Tilapia: environmental biology and nutritional requirements. Fact sheets. 164 Pp.
24. Nehemia, A., Maganira, J. D. and Rumisha, C. (2012). Length-Weight relationship and condition factor of Tilapia species grown in marine and fresh water ponds. Agriculture Biol. J. N. Am.3 (3):117-124.
25. Okomoda V. T., Koh I. C. C., Hassan A., Amornsakun T., Shahreza S. M. (2018). Length-weight relationship and condition factor of the progenies of pure and reciprocal crosses of Pangasianodon hypophthalmus and Clarias gariepinus. AACL Bioflux 11(4):980-987.http://www.bioflux.com.ro/aacl
26. Omweno J. O., Orina P. S., Getabu, A. and Outa, N. O. (2020). Growth and aquaculture potential of Tilapia jipe, *Oreochromis jipe* and Nile tilapia, *Oreochromis niloticus*. International Journal of Fisheries and Aquatic Studies, 2020; 8(3): 395-399. http://www.fisheriesjournal.com
27. Palmer, P. B. and O'Connell, D. G. (2009). Regression Analysis for Prediction: Understanding the Process. Cardiopulmonary Physical Therapy Journal, 20(3): 23-26.
28. Pedhazur EJ. Multiple Regression in Behavioral Research. 3rd ed. Fort Worth, TX: Harcourt Brace College Publishers; 1997.
29. Rawlings, J.O, Pantula, S. G. and Dickey, D.A (1998). Applied Regression Analysis: A research tool, Second Edition. Springer-Verlag, New York, Inc. ISBN 0-387-98454-2.https://www.springer.com ›Applied Regression Analysis - A Research Tool | John O ... – Springer
30. R-Core Team (2019). R: A language and environment for statistical computing. R-Foundation for Statistical Computing, Vienna, Austria. URL:https://www.R-project.org/.
31. Shackleton, E. (2012). Effects of temperature and terrestrial carbon on fish growth and pelagic food web efficiency, Umeå University: ISBN 978-91-7459-412-6 Printed Print & Media.
32. Shapiro, S. S. and Wilk, M. B. An Analysis of Variance Test for Normality (Complete Samples). Biometrika, 1965; 52(3/4) 91-611.
33. Smart JJ, Chin A, Tobin AJ, Simpfendorfer CA. (2016). Multimodel approaches in shark and ray growth studies: strengths, weaknesses and the future. Fish and Fisheries, 17:955–971. https://doi.org/10.1111/faf.12154
34. Venables, W. N. & Ripley, B. D. (2002) Modern Applied Statistics with S. Fourth Edition. Spriger, New York. ISBN 0-387-95457-0. http://www.stats.ox.ac.uk/pub/MASS4
35. Von Bartalanffy, L. (1938). A quantitative theory of organic growth. Human Biology, 10:181-213. Retrieved from https://www.jstor.org/stable/41447359 on 25th February, 2020.
36. Yakubu, A. F., Okonji, V. A., Nwogu, N. A., Olaji, A. D., Ajiboye , O. O. and Adams, T. E. (2013). Effect of Stocking Density on Survival and Body Composition of *O. niloticus* Fed Multi Feed and Niomr Feed in Semi FlowThrough Culture System. Jour. of Natural Sciences Research, 3 (14).
37. Zar, J. H. (1984), "Biostatistical Analysis", (2nd ed.). Englewood Cliffs, New Jersey: Prentice Hall.
38. Zeileis, A. and Hothorn, T. (2002). Diagnostic Checking in Regression Relationships.R News, 2(3):7-10. URL https://CRAN.R-project.org/doc/Rnews/.