



**UPM**  
UNIVERSITI PUTRA MALAYSIA  
BERILMU BERBAKTI

**GROWTH, REPRODUCTIVE PERFORMANCE, AND MORPHOMETRIC  
VARIATION OF HYBRIDIZED *Clarias gariepinus* BURCHELL, 1822 × *Clarias  
macromystax* GÜNTHER, 1864 IN NIGERIA**

By

**DADILE ABDULRAHMAN MUHAMMAD**

**Thesis Submitted to the School of Graduate Studies, University Putra Malaysia, in  
Fulfillment of the Requirement for the Degree in Doctor of philosophy**

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## **DEDICATION**

This thesis is dedicated to my late father, who has supported me financially before his demise.



Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree in Doctor of Philosophy

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**June 2022**

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This study was conducted to examine the hybrid between two African catfish *C. gariepinus* and *C. macromystax* using induction breeding. *Clarias gariepinus* is the most popular aquaculture species in Nigeria and the second most popular in Africa which is gaining attention from both the government and private sectors in Nigeria. The rapid growth rate, adaptation to adverse environmental conditions and diversity make this species an ideal candidate for aquaculture, especially in sub-Saharan Africa. The lack of sufficient quality seed stock is considered to be one of the major obstacles to the development of *Clariid* catfish farming. Morphological and meristic measurements were carried out on the parent, with F<sub>1</sub> and hybrid progeny. Fecundity and gonadosomatic indices of parent species were evaluated and calculated using standard procedures. Growth performance at different growth stages, in two rearing conditions indoors (hatchery) and outdoors (happa net), was evaluated. The results show that both species have the same gonadosomatic index. The male parent species *C. gariepinus* has significant male reproductive quality ( $P < 0.05$ ) compared to the male parent species *C. macromystax*. Fecundity was higher ( $P < 0.05$ ) in the female parent species *C. macromystax* and lower in the female parent species *C. gariepinus*. The highest fertilization rate and hatching rate were achieved in the hybrid cross ( $\text{♀}C. macromystax \times \text{♂}C. gariepinus$ ) ( $\text{♀}Cm \times \text{♂}Cg$ ). The highest rate of deformed larvae was recorded in the hybrid hybrid *C. gariepinus* × *C. macromystax* ( $\text{♀}Cg \times \text{♂}Cm$ ) and the lowest deformed larvae was achieved in the hybrid hybrid  $\text{♀}Cm \times \text{♂}Cg$ . The survival rate at the larval stage is more than 70% with the highest survival record in the  $\text{♀}Cm \times \text{♂}Cg$  hybrid compared to the reciprocal hybrid ( $\text{♀}C. gariepinus \times \text{♂}C. macromystax$ ) ( $\text{♀}Cg \times \text{♂}Cm$ ) which recorded the lowest value. However, the survival rate at the offspring level is lower than 65% with the highest rate in the  $\text{♀}Cm \times \text{♂}Cg$  hybrid followed by the  $\text{♀}Cg \times \text{♂}Cg$  F<sub>1</sub> parent and the lowest survival rate recorded in the cross parent  $\text{♀}Cm \times \text{♂}Cm$ . Gonadal cross-sections of F<sub>1</sub> progeny from parent *C. gariepinus* and *C. macromystax* showing testes with well-developed seminiferous tubules and well-developed germinal epithelium. Ovaries also have mature ovum in the ovarian tissue. However, the F<sub>1</sub> hybrid ova were detected in various stages of development and the testes

had sparse germ cells with seminiferous tubules that were not fully expanded indicating that their gonads were still immature at the end of eight (8) months of study. Observation of advanced stages of spermatogenesis and mature spermatogonia in the gonads of F<sub>1</sub> hybrid progeny indicates that, F<sub>1</sub> reciprocal hybrids are not sterile but may have the capacity to reproduce. Growth performance at the offspring stage was not significantly different in *C. gariepinus* parents (♀Cg x ♂Cg) and F<sub>1</sub> hybrid hybrids (♀*C. macromystax* x ♂*C. gariepinus*) (♀Cm x ♂Cg) compared to *C. macromystax* parent hybrids (♀Cm x ♂Cm) and a cross (♀*C. gariepinus* x ♂*C. macromystax*) (♀Cg x ♂Cm). Similar observations were recorded, at the juvenile to adult stage where final weight, weight gain and heterosis for growth were better in the ♀Cm x ♂Cg hybrid. Regardless of the cross considered, the size of heterogeneity is greater in hybrids and the condition factor (K value) is low. The length-weight relationship is significant with a coefficient of determination R<sub>2</sub> greater than 0.9. Growth is of the negative allometric type (with b less than 3). Positive heterosis was recorded for survival and growth at all growth stages. This study revealed the potential of hybrids (♀*C. macromystax* x ♂*C. gariepinus*) (♀Cm x ♂Cg), and hybridization between female *C. macromystax* x *C. gariepinus* is indeed possible and proven to have better growth and survival rates in semi-arid areas, which will contribute to the increased production of *Clarias macromystax* in captivity in the Semi-arid zone of Nigeria.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

**PERTUMBUHAN, PRESTASI PEMBIAKAN DAN MORFOMETRIK VARIASI HYBRID *Clarias gariepinus* BRUCHELL 1822 × *Clarias macromystax* GÜNTHER 1864 DI NIGERIA**

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Kajian ini dijalankan untuk mengkaji kacukan antara dua ikan keli Afrika *C. gariepinus* dan *C. macromystax* menggunakan pembiakan aruhan. *Clarias gariepinus* merupakan spesies akuakultur paling popular di Nigeria dan kedua paling popular di Afrika yang semakin mendapat perhatian daripada kedua-dua sektor kerajaan mahupun swasta di Nigeria. Kadar pertumbuhan yang cepat, penyesuaian kepada keadaan persekitaran yang buruk dan pelbagai menjadikan spesies ini sebagai calon yang sesuai untuk akuakultur, terutamanya di sub-Sahara Afrika. Kekurangan stok benih berkualiti yang mencukupi dianggap sebagai salah satu halangan yang paling utama kepada pembangunan ternakan ikan keli Clariid. Pengukuran morfologi dan meristik telah dijalankan ke atas induk, dengan progen  $F_1$  dan hibrid. Indeks fekunditi dan gonadosomatik spesies induk dinilai dan dikira menggunakan prosedur piawai. Prestasi pertumbuhan pada peringkat pertumbuhan yang berbeza, dalam dua keadaan pemeliharaan dalaman (hatcheri) dan di luar (happa bersih), telah dinilai. Keputusan menunjukkan bahawa kedua-dua spesies mempunyai indeks gonadosomatik yang sama. Spesies induk jantan *C. gariepinus* mempunyai kualiti pembiakan jantan yang ketara ( $p < 0.05$ ) berbanding induk jantan spesies *C. macromystax*. Fekunditi adalah lebih tinggi ( $P < 0.05$ ) dalam spesies induk betina *C. macromystax* dan lebih rendah dalam induk betina spesies *C. gariepinus* (86354.55 telur  $kg^{-1}$ ). Kadar pensenyawaan tertinggi dan kadar penetasan dicapai dalam kacukan hibrid ( $\text{♀}C. macromystax \times \text{♂}C. gariepinus$ ) ( $\text{♀}Cm \times \text{♂}Cg$ ). Kadar larva cacat tertinggi dicatatkan dalam kacukan hibrid *C. gariepinus*  $\times$  *C. macromystax* ( $\text{♀}Cg \times \text{♂}Cm$ ) dan larva cacat yang paling rendah dicapai dalam kacukan hibrid  $\text{♀}Cm \times \text{♂}Cg$ . Kadar kemandirian pada peringkat larva adalah lebih daripada (70%) dengan rekod kemandirian tertinggi dalam hibrid  $\text{♀}Cm \times \text{♂}Cg$  berbanding kacukan hibrid timbal balik ( $\text{♀}C. gariepinus \times \text{♂}C. macromystax$ ) ( $\text{♀}Cg \times \text{♂}Cm$ ) yang mencatatkan nilai terendah. Walau bagaimanapun, kadar kemandirian pada peringkat anak adalah lebih rendah daripada 65% dengan kadar tertinggi dalam kacukan hibrid  $\text{♀}Cm \times \text{♂}Cg$  diikuti oleh kacukan induk  $\text{♀}Cg \times \text{♂}Cg$  dan kadar kemandirian terendah dicatatkan dalam induk silang  $\text{♀}Cm \times \text{♂}Cm$ . Keratan rentas gonad progeni  $F_1$  dari induk *C. gariepinus* dan *C. macromystax* menunjukkan testis dengan tubul seminiferus yang berkembang dengan baik dan epitelium germinal yang berkembang. Ovari juga mempunyai ovum yang matang di dalam tisu ovari. Walau bagaimanapun, ovas hibrid  $F_1$  dikesan dalam pelbagai peringkat

perkembangan dan testis mempunyai sel germinal yang jarang dengan tubul seminiferus yang tidak mengembang sepenuhnya yang menunjukkan bahawa gonad mereka masih belum matang pada akhir lapan (8) bulan kajian. Pemerhatian peringkat lanjut spermatogenesis dan spermatogonia matang dalam gonad progeni kacukan F<sub>1</sub> menunjukkan bahawa, kacukan timbal balik F<sub>1</sub> tidak steril tetapi mungkin mempunyai kapasiti untuk membiak. Prestasi pertumbuhan pada peringkat anak tidak berbeza dengan ketara pada induk *C. gariepinus* (♀Cg x ♂Cg) dan F<sub>1</sub> kacukan hibrid (♀*C. macromystax* x ♂*C. gariepinus*) (♀Cm x ♂Cg) berbanding dengan kacukan induk *C. macromystax* (♀Cm x ♂Cm) dan kacukan silang (♀*C. gariepinus* x ♂*C. macromystax*) (♀Cg x ♂Cm). Pemerhatian yang sama direkodkan, pada peringkat anak hingga dewasa di mana berat akhir, penambahan berat dan heterosis untuk pertumbuhan adalah lebih baik pada kacukan ♀Cm x ♂Cg. Walau apa pun persilangan yang dipertimbangkan, saiz heterogeniti adalah lebih besar dalam hibrid dan faktor keadaan (nilai K) adalah rendah. Hubungan panjang-berat adalah signifikan dengan pekali penentuan R<sub>2</sub> lebih besar daripada 0.9. Pertumbuhan adalah jenis alometrik negatif (dengan b kurang daripada 3). Heterosis positif telah direkodkan untuk kemandirian dan pertumbuhan pada semua peringkat pertumbuhan. Kajian ini mendedahkan potensi hibrid (♀*C. macromystax* x ♂*C. gariepinus*) (♀Cm x ♂Cg), dan hibridisasi antara betina *C. macromystax* x jantan *C. gariepinus* sememangnya boleh dan terbukti mempunyai kadar pertumbuhan dan kemandirian yang lebih baik di dalam kawasan separa gersang, yang akan menyumbang kepada peningkatan pengeluaran *Clarias macromystax* dalam kurungan di zon Semi-gersang Nigeria.

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## LIST OF ABBREVIATIONS

AFL	Anal fin length
DFL	Dorsal fin length
HL	Head length
IOW	Interorbital width
OPL	Occipital process length
OPW	Occipital process width
PAL	Preanal length
PDL	Predorsal length
PMW	Premaxillary toothplate width
PPEL	Prepectoral length
PPL	Prepelvic length
SL	Standard length
TL	Total length
VMW	Vomerine toothplate width

# CHAPTER 1

## INTRODUCTION

### 1.1 General Introduction

Fish is an important food source for the health of billions of people in both developed and developing countries. Due to its unique nutritional properties, It contains critical micronutrients such as vitamins A, B, and D, as well as minerals, making it especially appealing in the present fight against malnutrition in low-income and food-insecure countries (FAO, 2017a). Human nutritionists advocate fish as a rich source of protein and healthful fatty acids due to its high Omega 3: Omega 6 fatty acid ratio, as well as a cheaper supply of animal protein (FAO, 2017a)

According to the Food and Agriculture Organization (FAO) of the United Nations, 257 million of the 821 million malnourished people worldwide in 2017 lived in Africa (FAO, 2018). Hunger is a global issue. Nigeria was included in the FAO's forecast that 59 million children in Africa were stunted and undernourished in the same year (FAO & ECA, 2018). In the last 50 years, the global per capita intake of fish has doubled (FAO, 2018). Since capture fisheries have found it difficult to raise their catch rates significantly, the majority of this rise in demand has been met by the expanding aquaculture sector (FAO, 2018). The production from inland and marine capture fisheries combined totaled roughly 91 million tons in 2016, and it has subsequently plateaued at or near this amount over the past 20 years (FAO, 2019).

The production of marine fisheries overall decreased, falling from 86.4 million tons in 1996 to 79.3 million tons in 2016 (FAO, 2019). In contrast to marine fisheries, inland fisheries have had a gradual growth in worldwide productivity since 1988, reaching around 12 million tons in 2016 (FAO, 2019). As the FAO does not have a status tracking system in place like it does for marine fisheries, it is considered that the data provided to them are overestimated (FAO, 2019). Mollusc, crustacean, and fish species of marine, freshwater, euryhaline, or stenohaline origin are cultured in the aquaculture sector (FAO, 2017a). The African catfish species *Clarias macromystax* and *Clarias gariepinus* are among the significant freshwater fish species. Because of their quick growth rates, disease resistance, and tolerance to high-density culture, the freshwater species of the genus *Clarias* and their hybrids are primarily cultivated (Huisman and Richter, 1987; Haylor, 1993).

*Clariid* catfish are unique in that they can breathe atmospheric air and can survive in waters with little dissolved oxygen. They are particularly appealing to aquaculture because of this quality (Bruton, 1979). The colonial governments of Africa introduced aquaculture as a method of sustainable food production between the 1940s and 1950s, with the main objectives being to improve rural nutrition, generate additional income, diversify to lower the risk of crop failure, and create jobs in rural areas (Brummet et al., 2008; Babatunde et al., 2020).

Egypt, Nigeria, Uganda, Ghana, Tunisia, Kenya, Zambia, Madagascar, Malawi, and South Africa are the top producing nations in aquaculture in Africa (Satia, 2017a). Even so, their share of the world's aquaculture production is still negligible (about 2.7%) (Halwart, 2020). According to Satia (2016), the aquaculture industry in Africa employs about 6.2 million people, the majority of whom are women working on large-scale commercial farms. As a result, the growth of aquaculture has been recognized as a supplementary strategy for addressing the food crisis, as well as a means of enhancing nutrition and generating money for populations in various African nations, including Nigeria (FAO, 2018).

## **1.2 Statements Problem**

The populations of *Clarias macromystax* are depleting in their natural range in Nigeria, which is at the critical stage to become endangered species in the region due to variety of factors such as over-exploitation due to its good taste, climate change, excessive use of pesticides and inorganic fertilizers in agricultural farms. Furthermore the major problem faced by farmers was the difficulty in the production of fingerlings and low survival rates in captivity (in the hatchery) for that reason fish farmers in Nigeria are becoming increasingly concerned about the decreasing performance of *C. macromystax* which was characterized by a decrease in growth as well as the occurrence of abnormalities. The Study exclusively involve the production of F<sub>1</sub> progenies and reciprocal hybrid *C. gariepinus* and *C. macromystax* and selection of first filial (F<sub>1</sub>) generation that perform better than the main parent.

## **1.3 Justification of the Study**

The fast growth rate, good food conversion ratio, and illness and infection resistance of *Clarias gariepinus* make it a favorite among fish producers. Although the artificial manipulation of breeding of African catfish is a well-understood process, fingerling supply is still below fish farmers' demand. It also has the ability to withstand adverse pond conditions, such as low oxygen content and high turbidity, making it an excellent choice for aquaculture. These call for the assessment of hybridization and the requirement to accelerate the growth of this significant *Clarias* species with significant potential in the aquaculture sector in order to obtain high-quality catfish fingerlings, while taking into account the desire of the fish farmers in the area to have a new farmed African catfish that can combine the fast growth trait of *C. gariepinus* and the excellent flavor of *C. macromystax* for good produce and greater return.

## **1.4 Objectives of the study**

The general objective of the research seeks to evaluate the hybridization between *C. gariepinus* and *C. macromystax* where broodstock is obtained to be use in hatcheries by farmers. The findings of this investigation could be used to make decisions on implementation of *C. macromystax* growth improvement programs and allow hatcheries

and farmers decide and choose the best for culture. The following specific objective were undertaken in order to achieve the overall objectives of the study:

1. To perform and characterize the F<sub>1</sub> hybrid and reciprocals from hybridization between *C. gariepinus*, and *C. macromystax* from selected areas in Northern part of Nigeria using morphometric data
2. To determine fecundity, gonadosomatic index, fertilization rate, hatching rate and survival rate from the cross between *C. gariepinus* and *C. macromystax*
3. To evaluate the growth performance of the F<sub>1</sub> progenies at different developmental stages from the cross between *C. gariepinus* and *C. macromystax* with their reciprocal hybrids
4. To examine the extent of sexual maturity of the F<sub>1</sub> progenies through the histology of the gonads to understand their reproductive potentials of F<sub>1</sub> progenies and the hybrids

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