BREEDING AND SELECTION FOR FASTER GROWTH STRAINS OF THE NILE TILAPIA, *OREOCHROMIS NILOTICUS* IN GHANA.

BY

FELIX YAO KLENAM ATTIPOE

THESIS SUBMITTED TO THE DEPARTMENT OF ZOOLOGY OF THE FACULTY OF SCIENCE, UNIVERSITY OF CAPE COAST IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF DOCTOR OF PHILOSOPHY DEGREE

APRIL 2006

DECLARATION

CANDIDATE'S DECLARATION

I hereby declare that this thesis is the result of my own original research and that no part of it has been presented for another degree in this University or elsewhere.

…………………………….. Date……8/5/06……………...

Felix Yao Klenam Attipoe

SUPERVISORS' DECLARATION

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

…………………………………………… Date:…8/5/2006……

Prof. John Blay Jnr.

Principal Supervisor

…………………………………………… Date:…8/5/06……

Prof. Kobina Yankson

Co-supervisor

ABSTRACT

Three wild stocks of Nile tilapia, *Oreochromis niloticus* were collected from three different agro-ecological zones in the Volta system in Ghana. A fourth stock of the same species was obtained from a farm at Nsawam. These were used in a study aimed at generating strain(s) of *O. niloticus* with an improved growth rate or performance compared to the wild stocks. Equal aged broodstock were generated under similar environmental conditions from all four stocks and evaluated for growth and reproductive performance in monoculture and polyculture systems. Diallele crossing of the four stocks was conducted. The growth performance of progeny from the crosses were tested in three culture environments. Least square means of body weight and total body length at harvest were computed for each stock combination within the culture environments. Heterosis and breeding values (BVs) were estimated. A genetically mixed base population was established by creating a selection line and a control line. Response to selection in the performance of progenies from the selection and control line was evaluated. The additive genetic variance (6^2A), phenotypic variance (6^2 P) and heritability (h^2) were estimated for the base population. Results mainly indicated the following: (i) Reference reproductive performance, the Yeji stock (Transitional zone) produced the highest number of seed (0.17 fry /g female /day) followed by the Nawuni stock (Guinea Savana zone) and then the Kpando stock (Semi-deciduous forest zone). The Farm stock produced the least value (0.10 fry /g female /day). (ii) Growth performance assessment showed that males were significantly heavier compared to females in all stocks. The ratio of the weight of females to males ranged from 0.61 - 0.70 for Yeji and Nawuni stocks respectively. (iii) Observed sex ratio was skewed towards females, being 1:1.8 and towards females, being 1:1.8 and 1:2.2 in the extensive and semi-intensive culture environments respectively. (iv)With respect to growth performance of stocks, the Nawuni stock was superior to the other three stocks. It had the highest mean daily growth rate in almost all growth evaluation trials while the lowest growth rate occurred in the Yeji stock. (v) Expression of heterosis was negative for all crosses. (vi)The genotype-environment interaction was very low (0.1 %) suggesting that it would not be necessary to develop specialized *O. niloticus* strains for different culture environments. (vii) A positive response to selection of over 10 % in improvement in growth rate of the selection line over the control line was observed. Recommendations for further investigations and implications of selecting appropriate stocks for improving the growth rate of *O. niloticus* in Ghana are discussed.

ACKNOWLEDGEMENTS

I acknowledge with deep gratitude the favour and guidance of Almighty God Jehovah during the course of this study.

I am grateful to my supervisor Prof. John Blay Jnr. for taking the time to painstakingly read through the script, effecting all the necessary corrections and providing invaluable suggestions despite his busy schedule as the head of the Department of Fisheries and Aquatic Sciences.

I acknowledge the financial support of the Worldfish Center through the United Nations Development Program (UNDP) sponsored collaborative research Project on "Transfer of Selective Breeding (GIFT) Technology for Aquaculture Improvement from the Philippines to Sub–Saharan Africa" which partly sponsored this study and my training courses in "Application of Quantitative Genetics to Aquaculture" in Philippines, India, Egypt and Thailand. I am indebted to Dr. Raul Ponzoni, Geneticist and Project Leader of the Aquaculture and Genetic Improvement Unit of the Worldfish Center, Malaysia, for his interest, technical advice and persistent encouragement which were of immense benefit to the write-up.

My sincere thanks go to Drs. Eddie Kofi Abban, Joseph Kinston Ofori and Heddy Roosevelt Danquah for their help, thoughts, words spoken and deeds done. I particularly acknowledge the assistance offered by the entire team of dedicated staff of the CSIR-WRI, Aquaculture Research and Development Center (ARDEC) where the study was undertaken, for their hard work, commitment and co-operation which made the project a successful one.

DEDICATION

In memory of my late parents, Rev. Robert Lawyer Kwamiga Attipoe and Mrs. Janet Afiwa Abotsi Attipoe.

To my dear wife, Mrs. Cecilia Emefa Adzo Voegborlo-Attipoe and my children, Julius, Esther, Ruth, Gabriel and Deborah, for their prayers, love, patience and support throughout the program.

TABLE OF CONTENTS

page

LIST OF TABLES

Page

LIST OF FIGURES

LIST OF PLATES

CHAPTER ONE

INTRODUCTION

Background to the Study

Tilapias are widely recognized as one of the most important groups of fish for fresh water aquaculture in a wide range of fish farming systems, from simple waste-fed fish ponds with minimal management to intensively stocked and managed culture systems (Pullin, 1985; Fitzsimmons, 2000). This is mainly because they are very hardy and can thrive in water that normally would not support most other aquaculture species, with the possible exception of the catfishes (Fitzsimmons, 2000). Their ability to survive in low dissolved oxygen habitat, and a wide range of water conditions that would normally kill more sensitive fish allow them to be grown in higher densities. They are amenable to handling, have short breeding interval, show little susceptibility to diseases and most importantly, are valued by humans as a food source. More than 70 species of this fish are referred to by the common name "tilapia", but only eight or nine species feature prominently in aquaculture (Schoenen, 1982).

Since 1984, aquaculture production of tilapia has been dominated by three species namely, the Nile tilapia, *Oreochromis niloticus* (Linnaeus), the Mozambique tilapia, *Oreochromis mossambicus* (Peters), and the blue tilapia, *Oreochromis aureus* (Steindachner) (Rana, 1997). Of these, *O. niloticus* is considered the most important for aquaculture (Kocher, 1997) accounting for 44 % of global production in 1995 (Rana, 1997). It has been widely introduced due to its good growth rate (Chimits, 1957; Bardach *et al*., 1972; Shedadech, 1976).

Although Ghana is endowed with diverse natural fish resources from freshwater and marine environments which supply over 60 – 70 % of the animal protein intake (Balarin, 1988), production of fish in both marine and freshwater environments has continued to decline over the last two decades due to a number of factors including over-exploitation, destruction of fish habitats and destructive fishing practices. There is growing evidence that the fishery in these environments have been exploited beyond the sustainable limit, and this is reflected in the 25 % reduction in average fish consumption from 29.4 kg /caput/year in 1970 to 22 kg/caput/year in 1997 (Owusu *et al.*, 2001). Due to reduced capture fishery production, aquaculture, with emphasis on fish culture is gaining grounds in Ghana and for similar reasons, in Africa.

The main focus of aquaculture in most parts of the world has been on increasing productivity through the improvement of management procedures related to the rearing environment, such as intensive feeding practices, flow through water systems, aeration with air blowing devices such as paddle wheels, and control of diseases. Investment benefits can however, be enhanced by using genetically improved animals that are able to take full advantage of the culture environment (Gjerde and Rye, 1997). Unfortunately, recent estimates show that only a small proportion of the world's total aquaculture production is based on genetically improved stocks (Gjedrem, 1997).

Productivity of most farmed finfish species in the tropics has remained close to that of wild stocks and has rarely been influenced by the advances in breeding technology which have enhanced terrestrial agriculture production. For example, the average number of eggs laid per year by hens has steadily increased from approximately 120 in the 1940s to more than 320 by the mid 1980s, while the time required to produce 1.7 kg of broiler bird has been reduced from 14 weeks to 7 weeks using half the amount of feed. Similarly, 11.6 million diary cows currently produce the same amount of milk which was produced by 26.6 million cows in the 1980's (GIFT, Final Report, 1992). It is therefore necessary to accelerate research efforts on genetic enhancement of aquaculture species to allow for faster growth and more efficient use of feed in order to increase aquaculture production (Jamu and Ayinla, 2003). Approaches used to improve the performance of cultured fish species involve techniques which manipulate variations in quantitative traits. Two main genetic improvement techniques that have been applied extensively are hybridization and selective breeding.

Cross-breeding / Hybridization technique

Cross-breeding is based on the expression of favorable dominant genetic effects in each generation, the effects of which are not cumulative from one generation to another, but could be enhanced by appropriate selection. When the frequency of heterozygous genotypes are increased through crossbreeding, the chance of recessive alleles to be expressed is reduced, and so the fitness of the population can be increased. Increased heterozygosity of crossbred individuals is often observed as hybrid vigor or heterosis, a phenomenon in which the average value of the offspring for a particular trait exceeds the mean of the average values of the parental lines. Heterosis has been exploited in animal breeding programs by matings between parental lines through partial or complete diallele crosses.

Hybridization or cross-breeding has been used to improve several traits which are considered important in the production of aquaculture species, as exemplified by studies on the common carp (Moav *et al*., 1975; Suzuki and Yamaguchi, 1980), rainbow trout (Ayles and Baker, 1983), Atlantic salmon (Refstie and Gjedrem 1975; Blanc and Chevassus, 1979; Chevassus, 1979), channel catfish (Dunham and Smitherman 1983), and tilapias (Lee, 1979; Wohlfarth and Hulata 1983; Behrends and Smitherman 1984; Khater, 1985; Hulata *et al*., 1985; Uraiwan and Phanitchai, 1986; Jayaprakas *et al*., 1988; Tave *et al.*, 1990; Boliver *et al*., 1994).

Studies to assess the extent of heterosis have been conducted in a number of fin fishes such as the Nile tilapia, *Oreochromis niloticus* (Dionisio, 1995; Yapi- Gnaore, 1996; Bensen *et al*., 1998; Marengoni *et al.,* 1998; Tayamen *et al.,* 2002), rainbow trout, *Salmo gairdneri* (Klupp, 1979; Fricke *et al.,* 1984; Hortgen-schwark *et al.,* 1986; Gjerde, 1988; Neira *et al.,* 1990), Atlantic salmon (Gjerde and Refstie, 1984), lake trout, *Salvelinus namaycush* (Nelson and Kapuscinski, 1990), channel catfish, *Ictalurus punctatus* (Wolters and Johnson, 1995; Bosworth *et al.,* 1998), silver barb, *Barbodes gonionotus* (Hussain *et al.,* 2002). Heterosis has also been studied in rohu carp, *Labeo rohita* (Gjerde *et al.,* 2002), common carp, *Cyprinus carpio* (Gela and Linhart, 2000), and paradise fish, *Macropodus opercularis* (Gerlai and Crusio, 1995). These studies have demonstrated that heterosis occurs in inter and intra-strain crosses and have been exploited to improve production of some species. Hybridization has also been employed to produce all-male tilapia fry since the male fish grow faster compared to the female in mixed sex cultures (i.e. males and females reared in the same pond) (Agnese *et al.,* 1998). To achieve a significant improvement in the characteristics of aquaculture species through crossbreeding, the magnitude of heterosis should be substantial. There should also be well established genetic characterization records to facilitate monitoring of the long term purity levels of the parental lines to ensure that indigenous gene pools are not contaminated (Changadeya *et al.,* 2003).

Selective breeding techniques

Selective breeding techniques on the other hand is based on the accumulation of favorable additive genetic effects from generation to generation. It provides continuous genetic improvement over a long period of time. It entails choosing some individuals that possess majority of positive desirable genes from the population as parents for the next generation. These individuals are selected from the animals which reach sexual maturity. The frequency of alleles with favorable effects on the phenotype under selection are increased, and the frequency of less favorable genes decreased. The effect of changing the frequencies of the favorable alleles can be observed as a change of population mean for the trait under selection (Gjedrem and Thodesen, 2005). This change is referred to as response to selection or genetic gain. Individuals that possess a majority of positive genes are said to have a high breeding value.

A number of selective breeding methods have been used in fish. These include individual or mass selection, family selection, within family selection and combined selection. The efficiency of selection is partly dependent on how accurately the breeding values of individual animals are evaluated. The appropriate selection method to choose is dependent on several factors including heritability of the trait, nature of the trait, recording methods and the reproductive capacity of the species.

Individual or mass selection refers to selection solely based on the individual's own performance or phenotype. It has been used for most aquaculture species because of its simplicity. It is the least costly because it does not require individual identification or the maintenance of pedigree records. It can produce rapid improvements if the heritability of the trait under selection is high; however it may be unsuitable if there are large uncontrolled systematic environmental variations (eg. age differences) as observed in

Oreochromis niloticus which is an asynchronous spawner. It is also unsuitable for traits that require slaughter of the animals (eg. carcass or flesh quality traits or selection for salinity tolerance). Another disadvantage of individual selection is that there is no control of inbreeding and this has caused serious problems in a number of fish breeding programs (Moav and Wohlfahrt, 1976; Hulata *et al*., 1986; Teichert-coddington and Smitherman, 1988). Individual selection is not efficient on traits with low heritability. It is not possible to keep track of the relationship among individuals when individual selection is applied because they are not tagged. This could lead to reduction in overall fitness of the stock as a result of inbreeding.

The family selection approach refers to a selection method in which family groups are ranked according to the mean performance of each family and whole families are saved or discarded (Lush, 1947). The individuals saved as breeders for the next generation are either all the individuals in selected families or randomly chosen individuals taken equally from all selected families. The advantage of family selection over the other types of selection is greater when environmental deviations constitute a large part of the phenotypic variance and when the trait selected has a low heritability. With low heritability, the use of family mean give an increased accuracy when estimating the breeding value. To reduce the common environmental effect, the environment for all families should be standardized as far as possible in the period the families are kept separate and individuals from all families should be tagged as early as possible and reared together in the same tank, pond or cage (communal rearing). One major advantage of family selection is that breeding values can be estimated for traits that cannot be measured on the individuals that are to be used as parents; thus traits like carcass quality and disease resistance which cannot be measured by individual selection method could be measured by family selection method. In order to keep the rate of inbreeding low, the number of family groups bred and measured should not be smaller than fifty and the family groups should be kept separately prior to tagging. The method of family selection is very costly due to the large space required to maintain separate families till tagging. One major disadvantage of family selection is that only fifty percent of the additive genetic variation is expressed between families and intensive family selection can quickly result in rapid accumulation of inbreeding because whole families are selected.

Within family selection requires identification of the families. This may be achieved by maintaining them in separate tanks, cages, hapas or any other means of containment without necessarily tagging the fish. The criterion of selection is the deviation of each individual from the mean of the family to which it belongs. Within family selection is advantageous when there is a large component of environmental variance common to the members of a family. Selection within family eliminates this large non-genetic component from the variation operated on by selection (Uraiwan and Doyle, 1986). Breeding space is economized when the method of within family selection is used, unlike family selection, however, it has low efficiency compared to most other selection methods (Gall and Huang, 1988a, b).

Combined selection is used when more than one method of selection is employed in a breeding plan. It combines information from all available sources, that can add up to our knowledge about the breeding value of the animal (eg. full and half-sibs, progeny and pedigree). All the additive genetic variance is available for selection and the use of information from relatives increases the accuracy of the estimates of breeding values. Relative's records can be used to estimate breeding values for traits that require slaughter of the animals (eg. carcass and flesh quality traits) which is not possible for most of the other methods.

Improvement of traits of economic importance in farmed fish using selective breeding methods has been the subject of investigation by several researchers (Gall, 1969; Gjedrem, 1976; Ihssen, 1976; Moav *et al.*, 1978; Jamu and Ayinla, 2003; Changadeya *et al.*, 2003). Such traits include growth rate, age/size at first maturation, survival, frequency of spawning, skin color, body conformation, fillet yield and cold tolerance (Behrends *et al.*, 1982, 1990; Fitzsimmons, 2000). Selection of resistant strains against diseases such as furunculosis in brown trout (Ehlinger, 1977), dropsy disease in common carp (Kirpichnikov *et al.*, 1993) and infectious pancreatic necrosis in rainbow trout (Okamoto *et al.*, 1993) has resulted in significant reductions in mortality of selected lines and improvement in production. Some countries have instituted national breeding programs utilizing genetic breeding techniques to attain significant genetic improvement in cultured species. In Norway, the

Atlantic salmon and rainbow trout programs which started in 1975 have been very successful (Refstie, 1990), while the National Tilapia Breeding Program in the Philippines which started in 1988 and uses the family selection and combined selection approach has resulted in the production of a new tilapia strain which is said to grow 60 – 70 percent faster than other farmed strains (Eknath, 1995)

Eknath *et al.* (1991) examined the growth performance of 8 strains of *O. niloticus* under different culture conditions (ponds, rice fields and cages). The results indicated significant differences in growth among the strains. Even though the Ghana strain of *O. niloticus* was among the poorest in growth rate out of eight strains from Asia and Africa (Bolivar *et al.,* 1993; Eknath *et al.,* 1993a; Palada-deVera and Eknath, 1993; Bentsen *et al.,* 1998), application of selective breeding techniques could result in improvement of the local Ghanaian stock. It is important to evaluate the performance of the stocks in the environments in which the progeny would be cultured i.e. ponds, tanks, and cages. This enables identification of the appropriate stock for a particular culture environment.

The need for evaluation of the performance of different strains of tilapia for aquaculture and the importance of choosing appropriate strains to establish base populations has been emphasized (Tave, 1988; Boliver *et al.*, 1993). Differences among strains in rates of gonadal development (Oldorf *et al.,* 1989), tolerance of crowding (Basiao and Doyle, 1990 a, b), and tolerance of poor nutrition (Romana-Eguia and Doyle, 1992) have been demonstrated.

Kamel, (1999) conducted a study on the genetic evaluation of three strains of *O. niloticus* from different geographical locations in Egypt under pond culture conditions, and found significant differences in their growth performance. Identifying the best performing tilapia stock in the local culture systems in Ghana would help improve the overall production from aquaculture.

A very important question that needs to be addressed in the design of a genetic breeding and selection program is the interaction between the genotype of the test strains and the environment as the expression of both additive and heterosis effects can be influenced by the culture environment. Determination of the effect of genotype- environment interaction of the test strain is important in guiding the fish culturist to decide whether to develop different strains for different environments or one strain for all test environments. The effects of genotype by environment interactions have been investigated in a number of species. These include populations of catfish (Sneed, 1971), Atlantic salmon (Gunnes and Gjedrem, 1978), rainbow trout (Gunnes and Gjedrem, 1981; Ayles and Baker, 1983), carp (Moav *et al.,* 1975; Wohlfarth *et al.,* 1983) and tilapia (Eknath *et al.,* 1993b; Bolivar and Newkirk, 2000; Elgobashy *et al.,* 2000).

Even though tilapias are endemic to most parts of Africa (Wohlfarth and Hulata, 1983), most of the fish breeding schemes on these species have been conducted in Asia. It is only recently that selective breeding programs aimed at increasing the growth rates of local species have been initiated in national research institutions in Cote d'Ivoire, Egypt, Ghana and Malawi

(Gupta *et al.,* 2001). The work reported on here has taken advantage of the Ghana Program and its results will also benefit the program. Results of this work would also be beneficial to fish culture scientists and aquaculture extension specialists in general, who would use it to initiate breeding and selection activities in culturable fish species in Ghana and Africa to support commercial aquaculture ventures. Hatchery managers would also benefit by utilizing the improved breeders to produce fast growing fish seed which fish farmers could use. This would result in increased yields in fish production and therefore increased protein availability to Ghanaians.

Background to fish farming in Ghana

Fish farming in Ghana has undergone considerable progress over the last decade. Culture systems currently in practice are pens, earthen ponds and cages with culture in ponds being the most predominant. The levels of operation range from extensive culture where ponds are stocked at low densities of 1-2 fish / m^2 and fertilized with organic and inorganic manure to medium scale operations where stocking densities range between 3 - 4 fish / m^2 with application of supplementary feed. Over the last five years, intensive culture system of aquaculture has been practiced by a number of commercial enterprises (e.g. Tropo Farms and Crystal Lake). These commercial farmers have installed net cages in the Volta Lake. The stocking densities of fish in these cages range between 100-150 fish / m^3 and fish are fed on complete diets of 30-35 % crude protein levels. Existing cage culture operations in

Africa indicate that it is viable and has tremendous potential to produce high quality fish products for domestic and export markets (Windmar *et al*., 2000).

The tilapias, (*Oreochromis niloticus, Sarotherodon galilaeus, Tilapia zilli*) catfishes (*Clarias gariepinus, Heterobranchus longifilis*) and the bony tongue fish *Heterotis niloticus* are the main species cultured in either monoculture and/ or polyculture systems. *O. niloticus* is currently the predominant fish species grown in earthen ponds and is the sole species grown in cages. It is either cultured as mixed-sex or as all-male stocks. The growth rate of *O. niloticus* in ponds stocked with mixed- sex and all-male at a density of 1.1 - 5 fish / m^2 and reared over a period of five months ranged between 0.49 - 0.55 g/ d and 0.97 – 2.4 g/ d respectively while annual yield ranged from 1.12 - 1.20 t/ha/ yr and 1.48 – 8.33 t/ha /yr. respectively (Owusu-Frimpong *et al*., 1992). Farmed tilapia production in Ghana is shifting from mixed-sex culture to all-male culture using *O. niloticus* species due to the higher growth rate and better yield obtained in all-male culture compared to the mixed-sex culture.

A major constraint to the culture of *O. niloticus* in Ghana is the lack of good quality seed in adequate quantities to stock fish ponds. Some farmers rely on wild stocks from rivers and lakes while others obtain their stocks from hatcheries. Public and private hatcheries which produce *O. niloticus* seed for farmers are very few. The source of their fingerlings are mostly from undrainable ponds which are stocked with broodstock which have not been replaced or replenished over a period of several years. Poor quality fingerlings are therefore continually harvested with drag nets and supplied to fish farmers. This technique of harvesting has led to active selection of small early maturing fish being sold to farmers as fingerlings. This practice has resulted in decline in tilapia yield from ponds in Ghana. Comparison of tilapia yields in Ghana with that from Central Luzon State in the Philippines which was 16 t/ha/ yr. (ADB, 2005) indicate that current yields in Ghana is about half what is obtained in the Philippines under similar conditions. Tilapia production in Ghana can be improved substantially if farmers get access to high quality broodstock, which would produce fast growing strains of fingerlings to stock ponds and cages at the right time.

Objectives of the study

The aims and objectives of the present work were as follows:

(a) To identify the best of four stocks of *Oreochromis niloticus* in respect of their seed production capacity, growth and survival under different culture environments. (b) To investigate the presence or otherwise of genotype–environment interaction among the stocks. (c) To determine the magnitude of non–additive genetic effects (heterosis) in complete diallele experiments. (d) To estimate the genetic gain of the base population and (e) to generate strain(s) of the Nile tilapia which would have an improved growth rate of performance compared to wild stocks of fish in the Volta system in Ghana.

CHAPTER TWO

MATERIALS AND METHODS

Sources of experimental fish

Samples of three stocks of *Oreochromis niloticus* were collected from the Volta basin in Ghana at Nawuni (NA) in the Northern Region, Yeji (YE) in the Brong Ahafo Region and Kpando (KP) in the Volta Region (Fig. 1). These stations are located in three ecological zones in Ghana, which are the Guinea Savanna, semi-deciduous forest and the transitional zones respectively. A fourth stock of the species was obtained from a fish farm at Nsawam (FS) in the Eastern Region of the country where fingerlings had been stocked by the erstwhile Institute of Aquatic Biology in 1982, and which had not been replenished for the past twenty four years. Nsawam is also located in the semi-deciduous forest zone.

The specimens were held in a quarantine facility for three months at the Water Research Institute's Aquaculture Research and Development Center (ARDEC) at Akosombo, 100 km North-East of Accra where the study was conducted (Plate 1).

Characteristics of the sampling sites

Nawuni is located in the Guinea Savanna zone of the country. This zone is characterized by a single rainy season from May to September with an

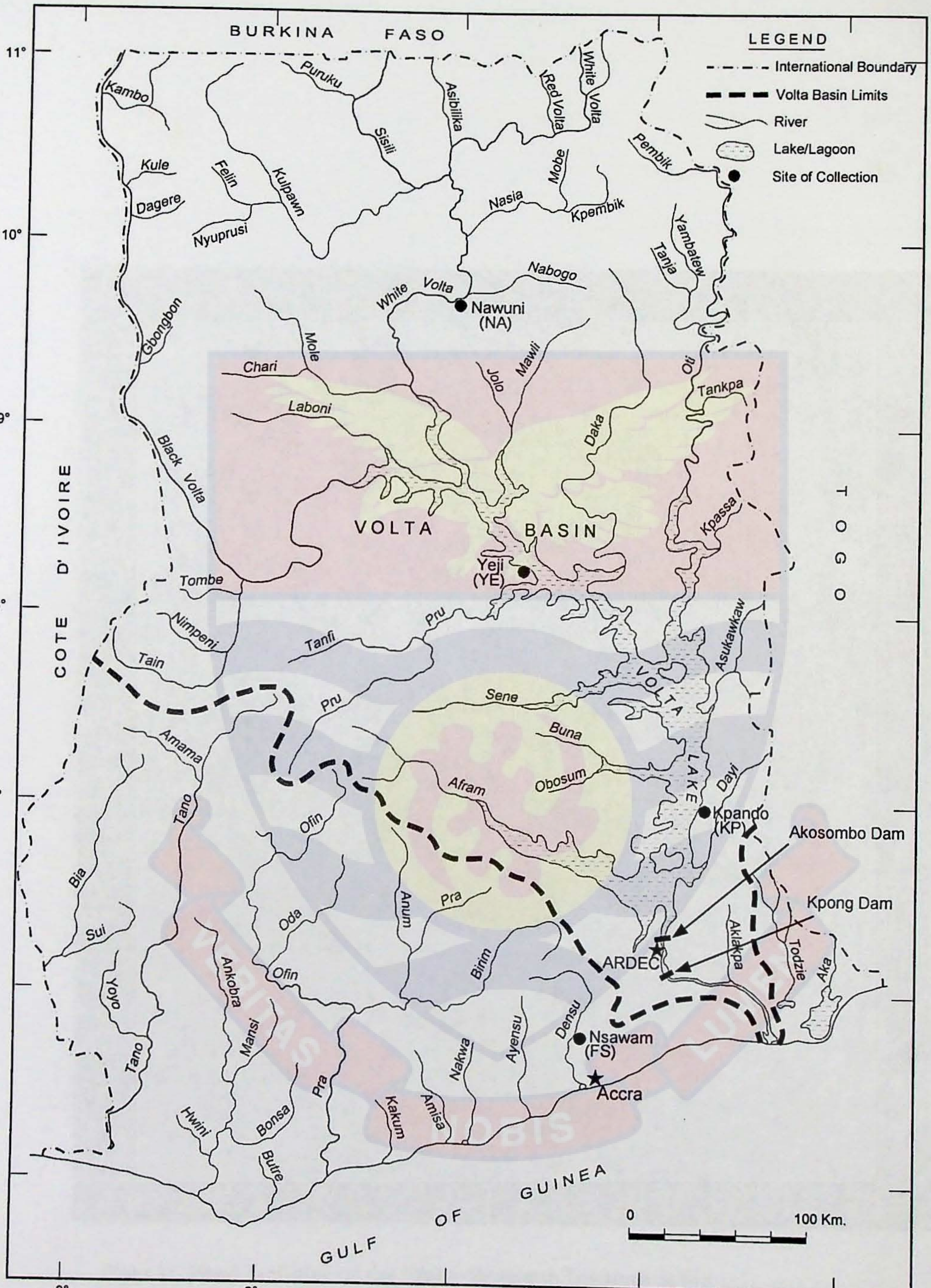

Fig.1: Map of Ghana showing sites of collection of *O. niloticus* stocks. (Source: World Bank, 1985)

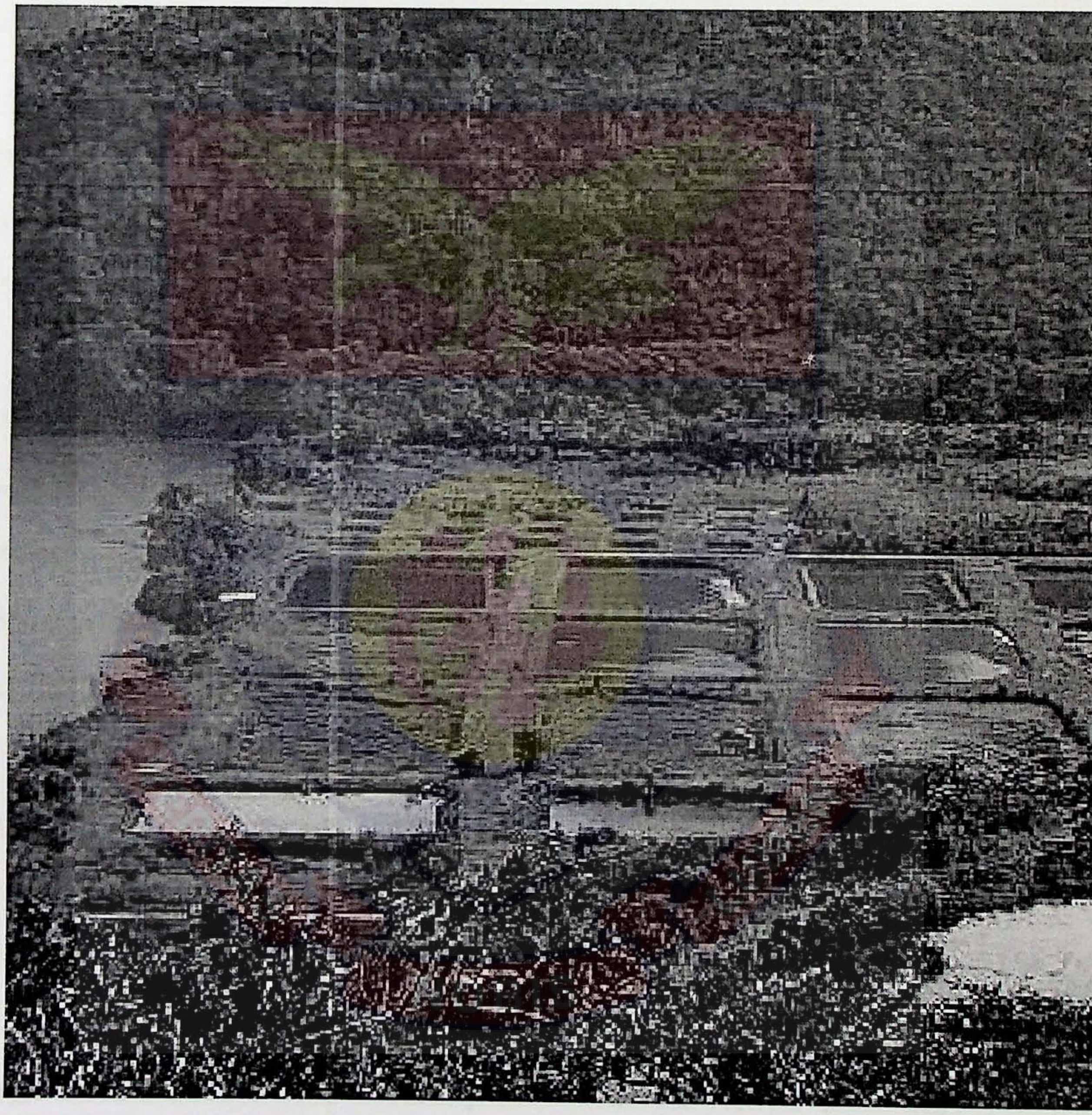

Plate 1: Pond facilities of the Water Research Institute at the

Aquaculture Research and Development Center (ARDEC) Akosombo.

annual rainfall ranging from 800 mm per annum to 1200 mm per annum spanning five months. At the peak of the dry season, the rate of evaporation increases from 1300mm to over 1700 mm per annum and the river breaks into turbid pools. Humidity during the dry period is about 30% - 50% in the morning decreasing to 20% - 30% in the afternoon (Hall and Swaine, 1981).

Kpando is located in the semi-deciduous forest zone of Ghana which experiences two rainy seasons annually with values ranging from 1250 mm /year to 1615 mm /year. Humidity in the area is about 65% - 75% in the wet season and 55% - 65% during the dry months (Balarin, 1988).

Yeji is located in the transitional zone between the Guinea Savanna and the semi-deciduous forest zones which experiences a bimodal rainfall pattern. The major season occurs between April and August while the minor season is from October to November (FAO/WHO/OAU, 1984). The annual rainfall ranges from 1300 mm /year to 1800 mm /year and humidity from 55% to 65% during the dry months (Balarin, 1988).

At Nawuni and Yeji, traps were used to capture the wild fish from the white Volta River and the Volta lake respectively, while at Kpando, the wild fish were caught from acadja enclosures with hand nets. Fish from the fish pond at Nsawam was caught with a drag net. The number, sexes and range of weight of wild fish of the four stocks is shown in Table 1. Yeji, Kpando and Nsawam (Farm stock) were caught from December 1998 – January 1999 while the Nawuni stock was collected in December 1997. Survival at the end of the quarantine period (three

Table 1: Number, sexes and range of weight of four stocks of *O. niloticus* collected from the wild in the Volta basin and a fish pond in Ghana.

Stock	Total No. of fish collected	No. of ♀	No. of ♂	Weight (g) of ♀ (Range)	Weight (g) of ♂ (Range)
NA	309	168	141	90.0 – 150.5	137.0 – 210.5
YE	360	179	189	37.5 – 85.0	50.5 – 118.0
KP	354	162	212	57.5 – 155.0	65.0 – 175.0
FS	20	11	9	78.0 – 165.5	75.5 -185.5

months) was 309, 250, 183 and 20 specimens for Nawuni, Yeji, Kpando and Farm stocks respectively. Offspring were produced from these wild stocks and used to access the reproductive performance of the stocks.

Production of parental stocks of uniform size and age

The average age of specimens from the wild stocks and the condition in their environments were not known but they were expected to be different for the various stocks. If such specimens were used in the evaluation experiments, genetic influences in the traits under investigation could be masked and thus make selection difficult. The first step in the breeding process was therefore to obtain fry of uniform size and age, and rear them to adults under similar environmental conditions. This would reduce the effects of initial size and age differences in the comparative study of genetic parameters such as breeding values, heritability and genetic gain.

Preparation of pond facilities

A pond of 0.2 ha size was drained and allowed to dry for a period of two weeks. This procedure ensured that eggs of fish and ecto-parasites such as leeches were killed. Three hundred kilograms of lime was spread on the pond bottom prior to filling with water. The pond inlet was covered with a 1 mm mesh mosquito proof netting to prevent the entry of predators and larvae of other organisms into the pond. The water depth was 0.8 m at the shallow end and 1.2 m at the deepest end. The water was fertilized with chicken manure at a rate of 1000 kg / ha to stimulate the production of plankton and hapas for conditioning the broodstocks were installed in the pond a week after application of the manure.

Conditioning and stocking of breeders

Conditioning is a process whereby potential breeders are separated by sex and reared in hapas, tanks or ponds prior to stocking in breeding hapas. The essential thing about the process of conditioning is that female and male breeders are kept separately, for at least two weeks prior to pairing. Breeders in conditioning hapas feed well because distractions due to sexual reproductive activities of the opposite sex are very minimal. Furthermore, individual breeders are exposed to the same reproduction triggering factors at the same time and this helps to synchronize spawning activities (WorldFish Center, 2004).

Prior to stocking in breeding hapas, female and male breeders from the four stocks were sorted and conditioned for three weeks (Guerrero and Guerrero, 1985) in 3 m^2 hapas mounted in the pond. Females were stocked at 6 fish / m^2 and males at 4 fish / m^2 and the fish were fed a diet of 15 % crude protein at a rate of 5 % their body weight twice daily. The stocking density of female breeders was higher than that of the male breeders because the males were heavier than the females.

Sixty four gravid females and 32 males from each of the four stocks were removed from the conditioning hapas and stocked in 3 m^2 breeding hapas. A total of 32 hapas consisting of eight replicates for Nawuni (NA), Yeji (YE), Kpando (KP) and Farm Stock (FS) were stocked at a density of 4 fish / m^2 at a ratio of 2 females to 1 male. Fry of approximately the same age were collected from each stock two weeks after the breeders were stocked. These were stocked at a density of 200 fry /m^2 in 3 m^2 outdoor concrete tanks (Plate 2) and fed a diet of 30 % crude protein for 60 days. Out of this number, 300 fingerlings from each stock were transferred into 50 m^2 earthen ponds and reared for twelve months. These were used as breeders to assess spawning capacity of the stocks and growth rates of their offspring.

Assessment of reproductive performance of the stocks

One year old *Oreochromis niloticus* broodstock were conditioned for three weeks and the weight of males and females determined. Twelve females and 6 males were stocked in 3 m^2 hapas; each stock was replicated six times. The hapas were covered with a net to prevent predatory birds from preying on the experimental fish. Breeders were fed on pelleted diet (WRI TF2) of 15 % crude protein (Appendix 1) twice daily at 8.30 h and 15.30 h at a rate of 5 % biomass except on Sundays and on days when fish seed were harvested.

The first batch of fish seed were harvested two weeks after stocking and subsequently every fortnight for a period of six months. At fish seed harvest, all broodfish were removed from the hapas, sexed and bulk weighed using a spring balance. Dead or missing broodfish were replaced with fish of similar size and sex. Broods were washed out of the mouths of incubating females (Little *et al.*, 1993), and separated into three categories namely, fertilized eggs, yolk sac fry and swim up fry. They were then counted. Fertilized eggs were hatched in continuous flow of water in conical plastic containers. The source of water to the hatchery

Plate 2 : Outdoor concrete tanks for rearing fry.

was from overhead tanks in which chlorine-free water had been stored. Yolk sac fry were stocked in plastic containers filled with chlorine-free water which was changed twice daily till they developed to the swim up stage. The percentage of yolk sac fry and fertilized eggs that developed into swim-up fry was computed. The fry were stocked in 1 m^3 nursery hapas mounted in 0.2 ha earthen ponds and their growth monitored.

Pond water temperature was measured at a depth of 0.3 m from the surface twice daily at 8.30 h and 15.30 h five days a week while pH, dissolved oxygen, nitrite, nitrate, ammonia, phosphate, total hardness and total alkalinity were monitored once every fortnight at 8.30 h.

The mean seed production per stock was estimated as:

(i) the average fecundity (Macaranas *et al.,* 1997) and

(ii) the mean number of seed produced per gram female (Lovshin and Ibrahim, 1988).

By definition

$$\text{Average fecundity} = \frac{y_1}{x_1}$$

where: y_1 = total no. of seed produced and

x_1 = no. of breeders in a breeding cycle

$$\text{Mean no. of seed per g female} = \frac{y_2}{x_2}$$

where: y_2 = average no. of seed produced per hapa and

x_2 = average weight of female breeders per hapa

Differences in seed production among the stocks were determined by the analysis of variance (ANOVA) in the INSTAT (1993) statistical package.

Comparison of growth and survival of fry in earthen ponds

Fry from the four stocks were separately collected from breeding hapas, counted, bulk weighed and stocked in 200 m^2 earthen ponds at a stocking density of 3 fish /m^2 for 55 days. Fry for the second replicate of the NA stock were fewer because inadequate numbers were produced. Fry were fed three times daily at 8.30 h, 12.00 h and 15.30 h on a powdered diet (WRI TF3) of 30 % crude protein (Appendix 1) at 20 % biomass per day. At the end of the experiment the fingerlings were counted, and weighed in bulk with a spring balance. Differences in the means of final weight of the stocks were analyzed using ANOVA in the INSTAT (1993) Statistical Package at the 5 % level of significance.

Evaluation of the growth performance and survival of mixed sex fingerlings in a monoculture system

Fry from the different stocks were reared in 1 m^2 nursery hapas at 200 fry per hapa and fed on a diet of 30 % crude protein till they attained a mean weight of 8 g. The fingerlings from NA, YE, KP and FS were tagged with red, green, blue and brown circular discs respectively, as described by Ofori *et al.* (1999). These were communally stocked (Moav and Wohlfarth, 1968; Wohlfarth and Moav, 1969) in 50 m^2 earthen ponds in triplicate at a density of 3 fish /m^2 after their initial total lengths and body weights had been taken. Communal stocking is an experimental system of culture in which different populations or strains of fish are reared in the same environment. It circumvents the need for large numbers of replicate ponds.

The fish were fed twice daily for six days in a week with pelleted diet of 15 % crude protein at 10 % body weight. Every three weeks, samplings were taken to monitor their growth performance for a period of 130 days at the end of which they were harvested and measured for total length and body weight. The final sampling was taken on the 25^{th} day instead of 21 days. Survival rate (%) was determined by dividing the total number of fish at harvest with the initial number and multiplied by 100. Differences in the means of final weight of the stocks were determined at the 5 % level of significance using ANOVA in the INSTAT (1993) statistical package.

Evaluation of the growth performance of all-male fingerlings in monoculture culture and polyculture systems

Production of all-male fingerlings

Two-week old swim up fry of total length between 9 mm – 11 mm from the four stocks were reared in 3 m^2 outdoor concrete tanks at a density of 700 fry /m^2 for the production of all-male fish. The fry were fed on a diet of wheat bran and fish meal (< 1 mm grain size) incorporated with 60 mg of 17α-methyl testosterone per kilogram of feed (Shelton *et al.*, 1978) at 20 % biomass five times daily for 28 days. The diet was administered at 2 hour intervals from 8.0 h to 16.0 h.

The treated fry were then transferred into 3 m^2 hapas installed in 0.2 ha earthen ponds and fed on 30 % crude protein diet twice daily at 10 % body weight for 75 days. Fingerlings from the stocks were tagged as described in the preceding section (Ofori *et al.,* 1999).

Grow-out in monoculture and polyculture systems

The initial standard length, total length and weight of fingerlings from the four stocks were recorded after tagging and the fish reared for 160 days to evaluate their growth performance in monoculture and polyculture systems. Each experiment was replicated three times. Experimental fish were fed on pelleted diet of 15 % crude protein twice daily at 5 % biomass. Samples were taken every four weeks and weighed to monitor growth and adjust the quantity of feed administered. The final sample was taken on the 160^{th} day of culture period. For the monoculture experiment, fingerlings were cultivated at 3 fish /m^2 in 200 m^2 ponds.

Two polyculture experiments were conducted. In the first experiment, 400 *O. niloticus* and 12 *Heterotis niloticus* (Osteoglossidae) fingerlings were stocked per 200 m^2 pond while in the second experiment, 400 *O. niloticus* and 14 *Heterobranchus longifilis* (Claridae) fingerlings were stocked per 200 m^2 pond. Sampling and harvesting regimes were the same as adopted for the monoculture system. The standard length, total length and body weight of each fish were recorded at harvest. The mean daily growth rate (MDGR) and condition factor (K) were estimated for each stock. The mean daily growth rate was calculated as:

$$MDGR = \frac{W_2 - W_1}{t_2 - t_1}$$

where: W_1 and W_2 = the mean initial and final weights of fish

t_1 and t_2 = the time at stocking and at harvest

and the condition factor was calculated using the following formula (Tesch, 1971):

$$K = \frac{W \times 100}{L^3}$$

where:

W = live weight of fish in g and

L = standard length of fish in cm

Differences in the means of the final body weight of the stocks were analyzed using ANOVA.

Evaluation of culture performance of the progeny of diallele crosses (generation 2)

Diallele crossing is an experimental design used for crossing inbred lines or different strains or populations in which each line, strain or population is crossed with every other line. A diallele cross could be used to establish a base population prior to starting a breeding program.

Preparation of breeding facilities

A 0.2 ha earthen pond was drained, allowed to dry for two weeks and filled with water to a depth of 0.8 m at the deepest point near the monk. Poultry manure was applied at a rate of 1000 kg / ha to induce the production of natural food.

Eighty 1 m^2 breeding hapas (Plate 3) were installed in the pond at 1.5 m intervals to facilitate water circulation.

Production and rearing of fry from diallele crosses

Breeders from each of the four stocks were conditioned for three weeks in 1 m^2 hapas. The pre-maxilla of male breeders was clipped to avoid female mortality due to male aggression (Lee, 1979).

Diallele crossing of the four stocks was carried out following the Genetic Improvement of Farmed Tilapias (GIFT) Project procedure (De Vera, 1988). Twenty gravid females and twenty ripe males from each stock were mated with corresponding numbers of males and females from the other three stocks in 1 m^2 hapas. This resulted in sixteen (i.e. four by four) diallele crosses. Each cross was replicated five times. The mating procedure was single pair-wise (i.e. one female: one male) (Eknath *et al.*, 1993 a) to produce full-sib family groups i.e. progeny from the same parents. The breeders were fed twice daily with a pelleted diet of 15 % crude protein at 3 % biomass. Breeding hapas were inspected for fry fortnightly. At the same time the mouth of females was examined for fertilized eggs and if present, they were collected and hatched in incubators. Yolk sac fry were kept in plastic bowls till they developed to swim up fry. The progeny of each pair was counted, weighed and 200 fry transferred into 1 m^2 nursing hapas of 1.0 mm mesh size. Fry from each full-sib family was maintained separately and fed three times daily at a rate of 30 % biomass for the first 30 days on a 30 % crude protein diet. The feeding rate was thereafter reduced to 20 % of body weight. A total of 150 of these fry from each progeny were then transferred into 1 m^2 B-net cages with 6 mm mesh size 42 days after stocking and reared till they attained a weight of 3.0 g – 8.0 g before harvesting. The B-net cages were installed in a 0.2 ha earthen pond. Eighty fingerlings from each group were tagged for family and individual identification.

Grow-out of progeny of diallele crosses in culture environments

Tagged fish were communally stocked in three grow-out environments representing extensive, semi-intensive and intensive cultures. The following data were recorded for each fish: family identity, individual identity, total body length (mm) and body weight (g).

The extensive culture environment consisted of two replicates of 0.2 ha earthen ponds which did not receive any supplementary feed but were fertilized with poultry manure at a rate of 2000 kg /ha every fortnight. The fish were stocked at a density of 1fish /m^2 in this culture environment. Forty tagged fingerlings per full-sib family were stocked in this pond. A total of 1087 tagged fish from 58 family groups were stocked per replicate pond. The number of fish was made up to the required density of 1 fish /m^2 with 913 untagged fish.

The semi-intensive culture environment consisted of two 200 m^2 earthen ponds which were fertilized with 2000 kg /ha of poultry manure every fortnight and stocked at a density of 3 fish /m^2. Twenty tagged fingerlings per full-sib family were stocked in this pond. Five hundred and fifty seven tagged fish from

Plate 3: 1 m^2 breeding hapas installed in a 0.2 ha pond

58 families were stocked per pond instead of 580 due to mortality of tagged fish prior to stocking. The number of fish was made up to the required density of 600 with 43 untagged fish. Fish in this environment were fed on a pelleted diet of 15 % crude protein at 5 % biomass twice daily.

The intensive culture environment consisted of two 8 m^3 cages (2 x 2 x 2) m installed in a 0.2 ha earthen pond. Water was pumped from the River Volta to maintain a continuous flow of water through the pond for six hours once every other day. Fish were stocked at a density of 100 /m^3. Five hundred and seventy nine tagged fish from 58 families were stocked per cage instead of 580 due to mortality of tagged fish prior to stocking. The total number was made up to 800 per cage with 221 untagged fish. Fish in this environment were fed on pelleted diet of 30 % crude protein at 5 % biomass. The ration was administered at two hour intervals from 8.0 h to 16.0 h.

The temperature was measured daily while pH, dissolved oxygen, nitrite, nitrate, ammonia, total alkalinity and total hardness of the ponds were recorded every fortnight at 8.30 h for all three environments.

All tagged fish in the three environments were harvested after a grow-out period of 120 days. Fish were harvested early in the morning before sunrise or late in the afternoon when temperatures were low using a seine net initially, and any remaining fish harvested after draining the pond completely. After harvesting, the fish were held in 3 m^2 hapas without feeding for 24 hours before data were taken.

The following data were recorded for each tagged fish at harvest: family number, individual fish number, standard body length, total body length (mm), body weight (g) and sex. The age at stocking and harvest were also determined from spawning and harvest dates.

Analysis of data on progeny of diallele crosses

Determination of Least square Means

Body weights and total lengths at harvest were analyzed for Least Square Means across all test environments according to the following Generalized Linear Model (GLM) using the SAS (1990) computer software:

$$Y_{ijklm} = a + E_i + S_j + B_k + G_l + S_j*E_i + S_j*G_l + G_l*E_i + e_{ijklm}$$

Where:

Y_{ijklm} = the body weight or total length at harvest of the m^{th} individual

a = the mean body weight or body length

E_i = the effect of the i^{th} environment (i = 1, 2, 3)

S_j = the effect of the j^{th} sex (j = male or female)

B_k = the effect of the fish age at harvest

G_l = the effect of the l^{th} stock combination (l = 1, 2, 3… 15)

e_{ijklm} = the random error

The model was used to estimate the marginal contribution of the model effects, type III mean squares and the percentage contribution of the independent variables included in the model, and to test the significance of the effects on the least mean squares of body weight and total length. Type III mean squares method consists essentially of computing the mean squares by the method of fitting Yates constants (Yates, 1934), and equating the values to their expectations. It gives an unbiased estimate of the variance component for any classification, irrespective of the balance of the data or the nature of the other classification in the model. Its main disadvantage has been the difficulty in computing the mean squares and their expectations since the method of fitting constants or least squares analysis of variance requires the solution of the least square equations. This difficulty has been greatly reduced in recent years since computers and more powerful programs make it feasible to solve very large sets of least squares equations (Cunningham, 1995).

The Least Square Means of body weight and total length at harvest were computed across and within the test environments. In order to maintain a common coefficient of variation, the data for replicated treatments were pooled after applying a multiplicative correction factor generated by dividing the mean body weight and total length at harvest respectively for a given test environment by the respective mean value of their replicates (Eknath *et al.,* 1993 a). Because of unequal variances in the sex by test environment subcells, the observations were weighted by the reciprocal of the within–cell variances during the analysis using the Generalized Linear Model (Bentsen *et al.,* 1998). The interaction term between the cross combinations and the test environment was used to test for the magnitude of the interactions between the genotype and environment.

The chi-square test for a fixed-ratio hypothesis was used to determine whether the observed sex ratio differed significantly from the expected 1:1.

Estimation of heterosis in progeny of the crosses

Heterosis is the mean value of the crossbred population minus the mean value of the parental populations. It is almost exclusively the aggregate of all single locus dominance effects. It was estimated from the Least Square Means of the body weight and total length of the progeny at harvest by computing the difference in the Least Square Means between each cross and the mean values for the parent stocks within each environment. The general reciprocal effect of the test stocks, which is the difference in the performance of the progeny when the stock is used as the female or male parent was also computed.

The following formulae were used to estimate the average heterosis, the average individual effect and the average maternal effect of the test stocks on the LSM of body weight and total length of the progeny at harvest (Bovenhuis *et al.*, 1995; Ponzoni, 2002).

(i) Average heterosis for all crosses $h!... = \Sigma h_{ij} = X_{n(n-1)} - P_n$

(ii) General heterosis (general combining ability of the stock concerned) $h\% = (X_i - P_n) / P_n \times 100$

(iii) Average heterosis for reciprocal cross $h!_{ij} = (X_{ij} + X_{ji} - P_i - P_j) /2$

(iv) Average stock heterosis $= \Sigma h!_{ij} / (n-1)$

(v) Average maternal genetic effect $g^m = \Sigma (X_{ij} - X_{ji}) / n$

(vi) Average individual effect $g^i = P_j - P_n - g_m$

where:

P_n = mean phenotype of all pure stocks

$P_i = P_j$ = mean phenotype of one purebred

X_j = female stock mean

X_i = male stock mean

n = number of purebreds and crossbreds

X_{ij} = mean phenotype of a two way cross (male line)

X_{ji} = mean phenotype of a two way cross (female line)

$X_{n(n-i)}$ = mean phenotype for all crossbreds for i = j

h = heterosis

g^m = maternal genetic effect

g^i = individual genetic effect

Estimation of breeding values for progeny of diallele crosses

The breeding value (BV) refers to the value of genes transmitted to the progeny. It is additive and depends on the value of the individual allelic effects. It is generally expressed as a general mean, and is twice the mean deviation of an animal's progeny from the population mean. The deviation is doubled because a particular parent provides only half of its gene to the progeny. It was computed using the SAS (1990) program after pre-adjusting grow-out data on fish harvested from the three test environments for the following fixed effects: culture environment, replicate, age at harvest and sex (Eknath *et al.,* 1993 a; Bentsen *et al.,* 1998). Fixed effects are a group of identifiable effects that can be assigned a class variable. The breeding value was based on information on the growth performance of the individual fish and those of its full-sibs (brother-sister). Each individual fish was ranked by sex and family according to their breeding values (Appendix 2a, 2b).

Evaluation of response to selection in the base population (generation 3)

Establishment of the base population

Two breeding lines were created during the 2003/2004 spawning season (June 2003 – March 2004) with progeny from the diallele crosses (generation 2) to form a base population (generation 3). A selection line was created based on male and female fish with high breeding values while a control line was developed based on male and female fish with average breeding values.

Mating of pairs of broodstock from the same family was avoided. Selected breeders were conditioned for a period of two weeks. A hierarchical or nested mating system was used to produce progeny from the selection line where one male was mated with one female in a $1m^2$ hapa. In a nested or hierarchical design, each sire (paternal fish) is mated with several dams (maternal fish) to produce several progenies. This mode of breeding produces a population of full-sib (brother-sister) and half-sib (half brother-half sister) families. The design allows for testing of sire effect, dam effect, dam within sire effect. A male which successfully bred with a female was removed and paired with a second female to produce half-sib families, i.e. progeny with one parent in common. A total of 45 full-sib and 25 half-sib families from the selected line were produced in four batches in June – September 2003 and reared to taggable sizes of 3.0 g to 8.0 g. The date of spawning was recorded. Rearing of fry followed the same procedure described for the diallele cross experiment. For the control line, fifteen males and fifteen females of average breeding values were randomly paired to produce fry which were then reared to taggable sizes.

Grow-out of progeny of base population in different culture environments

Eighty fish from the full-sib and half-sib groups of the selected line were tagged and divided into three groups, two of twenty and one of forty individuals and stocked in duplicate in three culture environments. The individual tag number, standard length (mm), total length (mm), body weight (g) body width (mm) and sex of the fish were recorded at stocking in extensive, semi-intensive and intensive environments respectively. Three hundred fish from the control line were also tagged and 100 of these were stocked in the same culture environments as fish from the selected line.

The characteristics and management procedures of the grow-out culture environments were as used for the diallele cross experiment. All tagged fish were harvested after a rearing period of 120 days. The standard length (mm), total length (mm) width (mm) and body weight (g) of the fish were recorded at harvest. The age of individual fish was also derived from the spawning and harvest dates.

Analysis of data on the base population (Generation 3)

The data collected on the growth of the progeny of the base population (generation 3) in the three culture environments, was first analyzed using the SAS

(1990) computer software to calculate the means and standard errors of the selection and control lines. This was followed by fitting the fixed effects (generation, culture environment, sex, age at harvest) and random effects (sire, dam, dam nested within sire and sire by environment interaction) using the PROC MIXED routine in the SAS (1990) computer software to compute the variable components of mixed models which have fixed and random effects.

A third set of analysis was conducted using the ASReml (Gilmour *et al.*, 2002) computer software package to estimate the additive genetic variance and the phenotypic variance. Pedigree information on the diallele crosses (generation 2) was used with information from the base population (generation 3). The variance components were estimated using an animal model. An animal model is a linear mixed model developed by Mao and Shaeffer (1993). 'Animal' refers to the random effects associated with genetic individuals or animal groups e.g. sire effect of half-sib groups in fish. It also refers to animals such as cattle, individual cows, their sires, dams, maternal grandsires and other relatives or any combination. The 'animal model' defines additive genetic effects for all individual animals and accounts for all variances and co-variances among them (Meyer and Hill, 1991). All the animals involved in the selection decisions, regardless of whether they contributed offspring or not are included in the analysis. A major strength of the animal model approach is that pedigree information, performance and genetic relationships for all individuals in all generations are utilized simultaneously (Gall *et al.*, 1993).

The animal variance component was used to estimate the additive genetic component ($б^2_A$), while the phenotypic variance ($б^2_P$) was estimated from the sum of all the variance components. Heritability (h^2) i.e. the degree of resemblance between relatives was computed as the ratio between the additive genetic variance and the phenotypic variance while the maternal and common environmental effect was calculated as the ratio between the dam variance component and the phenotypic variance.

Breeding values were computed for experimental fish harvested from all the three culture environments and these were used to estimate the response to selection. The response to selection was estimated by two methods:

(a) by comparing the estimated breeding values for body weight at harvest of the progeny of the diallele crosses (generation 2) and the progeny of the selection line of the base population (generation 3), and

(b) by comparing the least square means of the selected and control lines in each culture environment using the following equation (Ponzoni, 2002)

$$\text{Response } (\%) = \left(\frac{s_1}{c_1} - 1 \right) \times 100$$

where: s_1 = mean weight of selected line and

c_1 = mean weight of control line

CHAPTER THREE

RESULTS

Production of seed by the four stocks

A summary of the environmental conditions in the breeding pond during the production period is shown in Table 2. The water temperature and pH of the pond ranged from 28.0 °C to 36.5 °C and 6.2 to 7.5 respectively while dissolved oxygen values ranged from 5.4 mg/l to 6.6 mg/l. Nitrate-nitrogen, nitrite-nitrogen and phosphate concentrations varied between 0.008 mg/l and 0.070 mg/l while alkalinity and total hardness was within the range of 32 mg/l – 38 mg/l, indicating that the water quality was within the normal range for *O. niloticus* (Hussain, 2004)

The results of the mean number of seed comprising either fertilized eggs, yolk sac fry, swim up fry or combinations of these stages produced from April 2000 to September 2000 are shown in Table 3. Brood fish from all four stocks produced seed continuously throughout the period, but the pattern of seed production was irregular (Fig. 2). Seed output was generally high during the first three months (April – June) and low in the last three months (July – September). Peak seed production for all the stocks occurred during the first week of June 2000. Specimens from Yeji (YE) produced the highest mean seed in four of the six months of seed production. Fish seed produced by YE in April, May and June 2000 was significantly higher ($P < 0.05$) than that of NA, KP and FS (Table 3)

Table 2 : Physico-chemical characteristics of breeding pond of *O. niloticus* (April – September 2000).

Parameter	Range
Temperature (˚C)	28.0 – 36.5
pH	6.2 - 7.5
Dissolved oxygen (mg/l)	5.4 - 6.6
Nitrite (NO_2-N) (mg/l)	0.008 – 0.023
Nitrate (NO_3-N) (mg/l)	0.010 – 0.070
Ammonia (NH_3-) (mg/l)	0.100 – 0.140
Phosphate (PO_4-P) (mg/l)	0.010 – 0.040
Total alkalinity as $CaCO_3$ (mg/l)	35.0 – 38.0
Total hardness as $CaCO_3$ (mg/l)l)	32.0 – 38.0

Table 3 : Mean seed production ± S.E. per hapa by the four stocks of *O. niloticus* (April to September 2000)

Stock	Month					
	April	May	June	July	August	September
NA	1279.2 ± 65.2^{b*}	1246.0 ± 58.5^{b}	1885.5 ± 78.4^{b}	1387.5 ± 127.6^{a}	323.3 ± 36.4^{a}	182.7 ± 19.7^{b}
YE	2210.0 ± 87.8^{a}	1946.9 ± 96.3^{a}	2793.0 ± 184.9^{a}	1290.0 ± 84.9^{a}	293.2 ± 44.1^{a}	659.7 ± 66.7^{a}
KP	944.8 ± 50.7^{b}	1272.3 ± 47.7^{b}	1852.0 ± 128.7^{b}	1137.0 ± 104.8^{a}	387.8 ± 46.1^{a}	448.3 ± 42.2^{c}
FS	1071.6 ± 149.1^{b}	987.9 ± 914.0^{b}	1447.0 ± 121.7^{b}	618.0 ± 121.7^{b}	1004.7 ± 151.8^{b}	643.3 ± 50.3^{a}

ANOVA in INSTAT (1993) statistical package used to determine differences in seed production.
*Mean values within the same column with different superscript are significantly different.

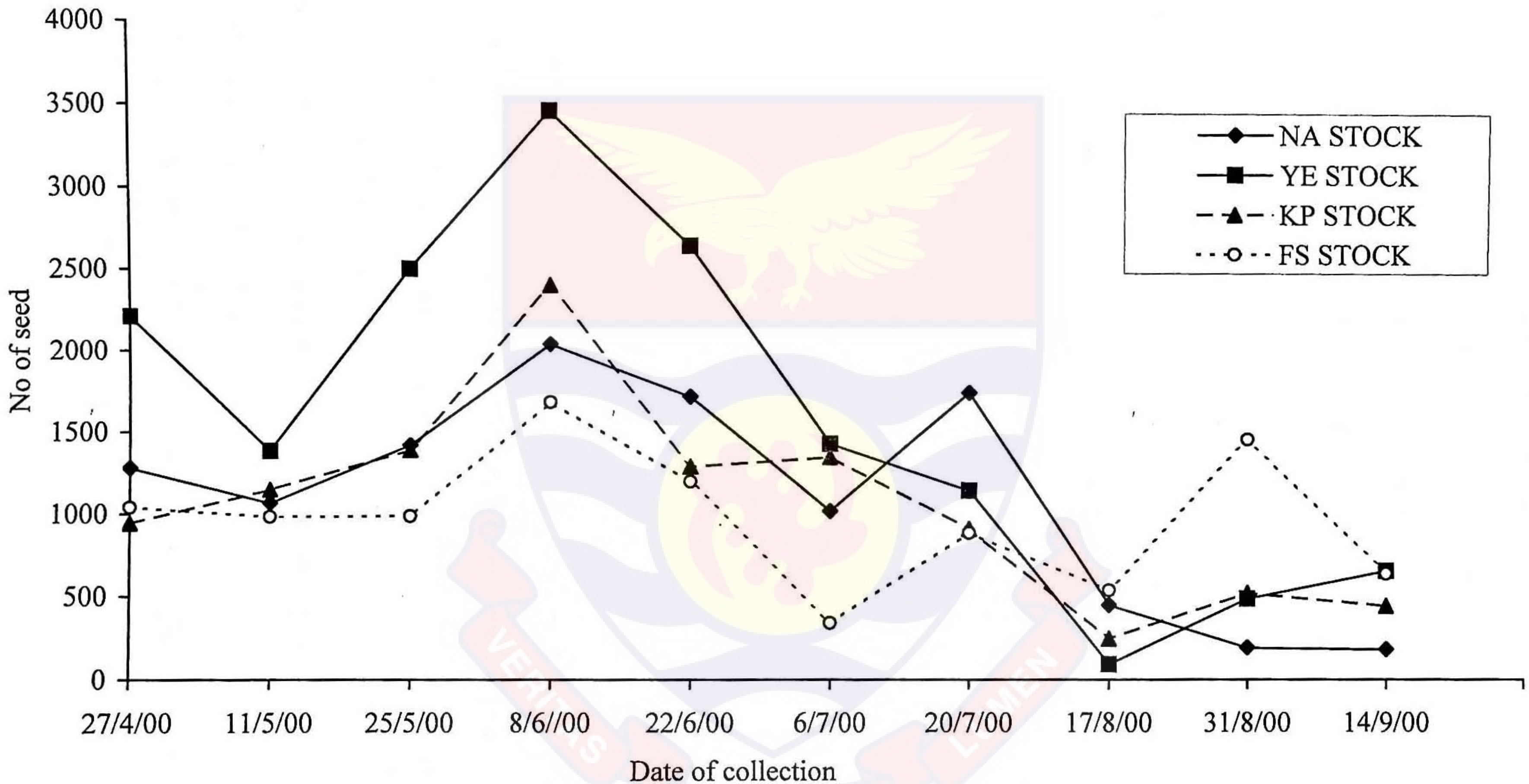

Fig. 2 : Mean number of seed produced by four stocks of *O. niloticus* from April to September 2000.

(Appendix 3a - 3f). The range in the mean number of seed produced per gram female during the production period was 0.02 – 0.23, 0.03 – 0.32, 0.04 – 0.20 and 0.06 – 0.15 for NA, YE, KP and FS respectively (Table 4).

The proportion of swim-up fry encountered was higher than that of yolk sac fry and fertilized eggs for all stocks throughout the production period except in May 2000 when the percentage of fertilized eggs produced by YE and FS were higher. The proportion of yolk-sac fry under incubation was the lowest, and was between 0 % and 42.7 % for all the stocks. Swim-up fry compositions were 40.4 % - 100 % for NA, 38.7 % - 84.5 % for YE, 59.0 % - 94.6 % for KP and 37.0 % - 78.1 % for FS (Table 5). The proportion of fertilized eggs and yolk-sac fry that developed into swim-up fry under artificial incubation ranged from 0 - 65.0 % and 0 - 100 % respectively (Table 6). Generally, the proportion of yolk-sac fry that developed into swim-up fry was higher than that of fertilized eggs under artificial incubation.

Growth performance and survival of offspring of the four stocks

Growth and survival of fry and fingerlings in monoculture system

The growth performance of fry of the four stocks of *Oreochromis niloticus* reared over a period of 55 days is shown in Table 7. Results of the trial showed that progeny from NA attained the highest average weight (22.64 g) at harvest while KP had the least (17.50 g). The average daily weight gain was between 0.32 g/d and 0.40 g/d. The mean survival rate (± s. e.) was high for fingerlings of the stocks, and ranged from 85.6 ± 4.7 % for NA to 93.9 ± 1.5 % for KP.

Table 4 : Mean seed production per female of the four stocks of *O. niloticus* from April to September 2000.

Month	Stock	Mean weight/ Hapa of females (g) ± S.E.	Mean no. of seed / g female	Mean no. of seed / g female / day
	NA	439.8 ± 6.8	2.91	0.21
April	YE	593.7 ± 10.7	3.72	0.27
	KP	582.3 ± 8.8	1.62	0.12
	FS	614.0 ± 13.7	1.75	0.13
	NA	574.8 ± 8.2	2.17	0.16
May	YE	631.2 ± 4.5	3.08	0.22
	KP	622.4 ± 8.7	2.04	0.15
	FS	652.7 ± 8.9	1.51	0.11
	NA	575.0 ± 10.1	3.28	0.23
June	YE	676.0 ± 5.3	4.52	0.32
	KP	659.2 ± 8.1	2.81	0.20
	FS	692.1 ± 0.5	2.09	0.15
	NA	577.3 ± 9.5	2.40	0.17
July	YE	683.1 ± 3.0	1.89	0.14
	KP	665.8 ± 10.3	1.71	0.12
	FS	698.9 ± 16.9	0.88	0.06
	NA	586.3 ± 9.8	0.55	0.04
August	YE	687.0 ± 4.3	0.43	0.03
	KP	642.6 ± 12.0	0.60	0.04
	FS	732.8 ± 17.2	1.37	0.10
	NA	852.4 ± 11.7	0.21	0.02
September	YE	828.1 ± 4.7	0.80	0.06
	KP	751.1 ± 13.2	0.60	0.04
	FS	948.2 ± 18.6	0.68	0.05

ANOVA in INSTAT (1993) statistical package used to determine differences in seed production.

Table 5 : Proportions of the three categories of seed produced monthly by Four stocks of *O. niloticus* (April to September 2000).

Month	Stock	Percentage		
		Fertilized Eggs	Yolk-sac Fry	Swim-up Fry
April	NA	17.7	6.1	76.2
	YE	35.5	5.3	59.2
	KP	6.7	33.8	59.5
	FS	51.7	5.2	43.1
May	NA	34.3	26.3	40.4
	YE	40.0	21.3	38.7
	KP	17.4	13.8	68.8
	FS	48.1	14.9	37.0
June	NA	7.7	34.1	58.2
	YE	25.9	18.8	55.3
	KP	16.5	12.2	71.3
	FS	17.2	23.5	59.3
July	NA	8.8	7.5	83.7
	YE	33.5	3.9	62.6
	KP	33.7	7.3	59.0
	FS	8.5	13.4	78.1
August	NA	0.0	0.0	100.0
	YE	24.8	0.0	75.2
	KP	1.3	4.1	94.6
	FS	25.6	1.2	73.2
September	NA	18.1	0.0	81.9
	YE	0.0	15.5	84.5
	KP	0.0	22.3	77.7
	FS	0.0	42.7	57.3

Table 6 : Proportions of fertilized eggs and yolk-sac fry that developed into swim-up fry under artificial incubation.

Month	Stock	Fertilized eggs	Yolk-sac fry
		Percentage	Percentage
April	NA	*	78.5
	YE	*	100.0
	KP	*	100.0
	FS	*	100.0
May	NA	13.2	89.5
	YE	0.0	80.3
	KP	0.0	78.2
	FS	8.3	91.3
June	NA	18.5	60.7
	YE	23.2	73.2
	KP	13.0	81.3
	FS	8.9	60.0
July	NA	32.0	100.0
	YE	38.5	100.0
	KP	26.5	100.0
	FS	42.3	100.0
August	NA	0.0	0.0
	YE	55.3	0.0
	KP	65.0	100.0
	FS	52.0	100.0
September	NA	*	0.0
	YE	0.0	97.0
	KP	0.0	100.0
	FS	0.0	87.0

*Fertilized eggs not incubated due to problems with water flow system.

Table 7 : Growth and survival of fry of the four stocks of *O. niloticus* reared for 55 days.

Stock	Average Number Stocked	Initial Average Weight (g)	Final average weight (g)	Average Daily Weight Gain(g/d)	Survival (%) Mean ± S.E.
NA	580	0.51	22.64	0.40	85.6 ± 3.3
YE	600	0.17	18.71	0.34	88.5 ± 1.5
KP	600	0.48	17.50	0.32	93.9 ± 1.1
FS	600	0.24	20.13	0.36	88.3 ± 1.8

ANOVA in INSTAT (1993) statistical package used to determine differences in growth and survival of fry.

The growth performance of male and female fingerlings reared together in earthen ponds for 130 days is presented in Table 8. There was a clear difference in the growth performance of male and female fingerlings as the former attained heavier weights than the latter ($p < 0.05$) in all the stocks. In terms of the relative weight of males to females, YE had the lowest value while NA had the highest (Table 9). Fingerlings of NA grew fastest and had the highest final mean weight and highest mean daily weight gain for both males (56.00 g; 0.36 g/d) and females (41.79 g; 0.25 g/d) although the initial mean weight was the lowest. In contrast, KP fingerlings with the highest mean weight at stocking, recorded the lowest mean daily weight gain for males (0.34 g/d) while YE had the least final mean weight for females (0.25 g/d). The mean survival rate was similar for all stocks and ranged from 62.7 ± 4.8 % for FS to 68.0 ± 5.8 % for YE (Table 8), with no significant differences between the stocks ($p \geq 0.05$) for mean daily weight gain and survival rate.

Growth and survival of all-male fingerlings in monoculture system

Table 10 shows the mean daily weight gain, condition factor and survival of the four stocks of *O. niloticus* reared in a monoculture system. FS had the highest mean daily weight gain while NA had the least. The condition factor ranged from 3.52 for KP to 3.66 for FS while survival rate was similar and showed values between 54.9 ± 2.3 % for KP and 68.6 ± 5.3 % for NA. Differences among the different stocks with respect to the mean daily weight gain, condition factor and fish survival were however not statistically different ($p \geq 0.05$). Fig 3 illustrates the growth pattern of the stocks. The growth of YE was the lowest throughout the

Table 8 : Growth and survival of mixed-sex fingerlings of four stocks of *O. niloticus* reared in earthen ponds for 130 days.

Stock	Mean initial weight (g) ± S.E.	Mean final weight (g) ± S.E.			Mean daily weight gain (g/d)			Survival (%)
		Male	Female	Mixed	Male	Female	Mixed	Mean ± S.E.
NA	9.32 ± 0.45	56.00 ± 1.97	41.79 ± 1.74	47.60 ± 1.51	0.36	0.25	0.29	65.3 ± 1.1
YE	9.82 ± 0.35	54.71 ± 1.88	36.19 ± 1.36	41.81 ± 1.45	0.35	0.20	0.25	68.0 ± 5.8
KP	12.42 ± 0.78	56.66 ± 1.51	40.27 ± 1.82	47.80 ± 1.82	0.34	0.21	0.27	66.7 ± 5.9
FS	9.75 ± 0.50	56.86 ± 1.79	37.77 ± 2.98	49.55 ± 1.68	0.35	0.22	0.31	62.7 ± 4.8

ANOVA in INSTAT (1993) statistical package used to determine differences in growth performance.

Table 9 : Relative weight of female to male of four stocks of *O. niloticus* reared in monoculture system for 130 days.

Stock	Mean weight gain (g)		Ratio of mean weight of females to males
	Females	Males	
NA	32.47	46.68	0.70
YE	26.37	44.89	0.59
KP	27.80	44.19	0.63
FS	28.02	46.11	0.61

Table 10 : Growth performance of four stocks of all-male *O. niloticus* reared in earthen ponds for 160 days.

Stock	Mean Initial Weight (g) ± S.E.	Mean final weight (g) ± S.E.	Mean daily weight gain (g/d)	Condition Factor (K) ± S.E.	Survival (%) ± S.E.
NA	18.5 ± 0.4	53.8 ± 0.7	0.22	3.58 ± 0.02	68.6 ± 5.3
YE	12.7 ± 0.2	51.0 ± 0.9	0.24	3.54 ± 0.02	59.7 ± 4.3
KP	15.2 ± 0.3	54.8 ± 1.0	0.25	3.56 ± 0.02	54.9 ± 2.3
FS	14.2 ± 0.3	58.8 ± 1.0	0.29	3.62 ± 0.02	59.2 ± 3.6

ANOVA in INSTAT (1993) statistical package used to determine differences in growth performance.

was the lowest throughout the culture period while that of FS was slow during the first month, picked up in subsequent months and was the fastest during the last two months.

Growth and survival of all-male fingerlings in polyculture systems

Results of growth performance of all-male *O. niloticus* from the four stocks reared with the catfish *Heterobranchus longifilis* is presented in Table 11 and the growth patterns are shown in Fig. 4. Mortality was very high in all the stocks with survival rate ranging from 0.7 ± 0.4 % for FS to 28.0 ± 2.0 % for NA. The survival rate of NA was significantly higher ($p \leq 0.05$) than YE and FS (Appendix 3g). Values for the mean final weight and mean daily weight gain of FS should be interpreted with caution as only two specimens were recovered from the three replicate ponds. If the values for FS are ignored, NA becomes the stock that shows the highest values for all growth parameters assessed although there were no significant differences ($p \geq 0.05$) among them.

The growth pattern of the four stocks reared with *Heterotis niloticus* is presented in Fig. 5 while data on growth characteristics is shown in Table 12. The data on survival rate followed the same trend as observed for the *O. niloticus* - *H. longifilis* polyculture system. While NA had a survival rate of 60.0 ± 2.0 %, values for KP, FS and YE were significantly lower ($p \leq 0.05$) (Appendix 3h). The mean final weight, mean daily weight gain and condition factor of FS were higher than those of the other three stocks, with values for YE being the least; however the differences were not significant ($p \geq 0.05$).

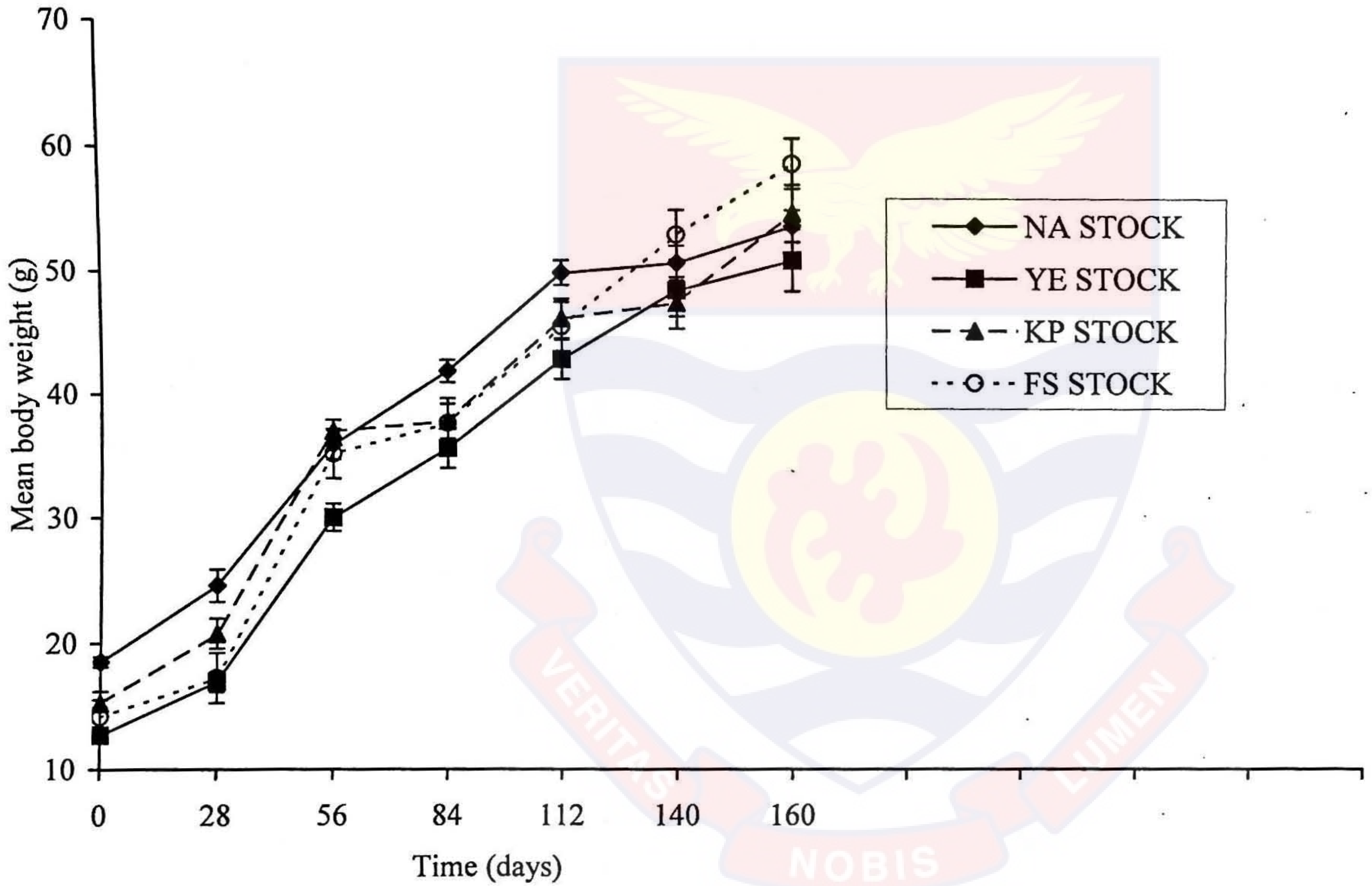

Fig. 3 : Growth performance of four stocks of all-male *O. niloticus* reared in earthen ponds. (Vertical bars represent standard errors).

Table 11 : Growth performance of four stocks of all-male *O. niloticus* in polyculture with *Heterobranchus longifilis* for 160 days.

Stock	Mean Initial Weight (g) ± S.E.	Mean Final Weight (g) ± S.E.	Mean Daily Weight Gain (g/d)	Mean Condition Factor (K) ± S.E.	Survival (%) ± S. E.
NA	15.9 ± 0.3	108.4 ± 2.3	0.58	3.50 ± 0.04	28.0 ± 4.0[a]
YE	17.2 ± 0.4	97.2 ± 4.3	0.50	3.40 ± 0.05	11.0 ± 3.8[bd]
KP	14.3 ± 0.2	97.3 ± 3.1	0.52	3.49 ± 0.03	19.0 ± 3.0[ab]
FS**	18.2 ± 0.3	151.7 ± 34.3	0.83	3.73 ± 0.34	0.7 ± 0.4[cd]
H. longifilis	133.9 ± 86.19	238.06 ± 77.68	0.65	1.47 ± 0.02	52.9 ± 21.3

**only 2 specimens
Mean values with different superscript are significantly different

ANOVA in INSTAT(1993) statistical package used to determine differences in growth performance.

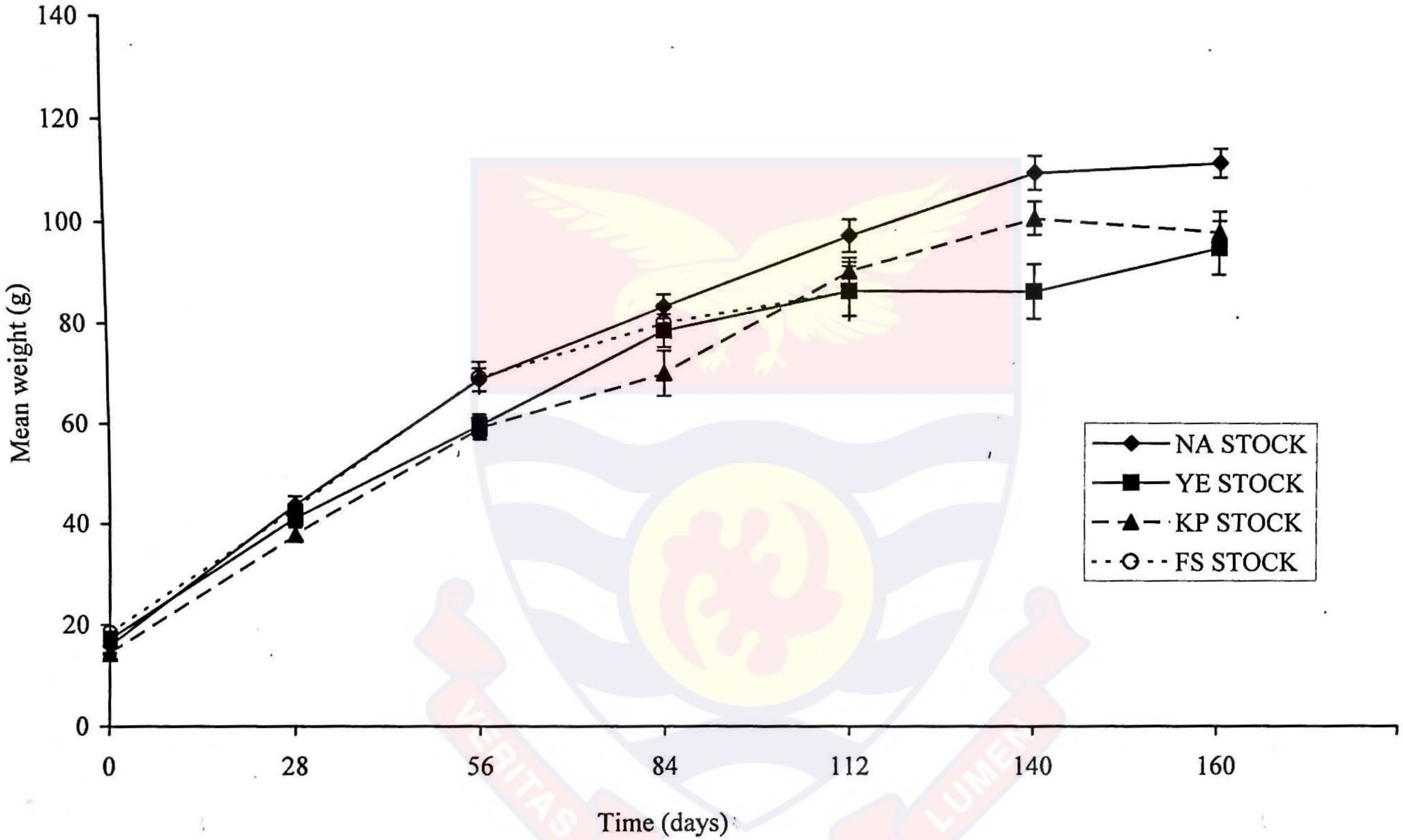

Fig. 4 : Growth performance of four stocks of *O. niloticus* reared in an all-male polyculture system with *Heterobranchus longifilis*. (Vertical bars represent standard errors).

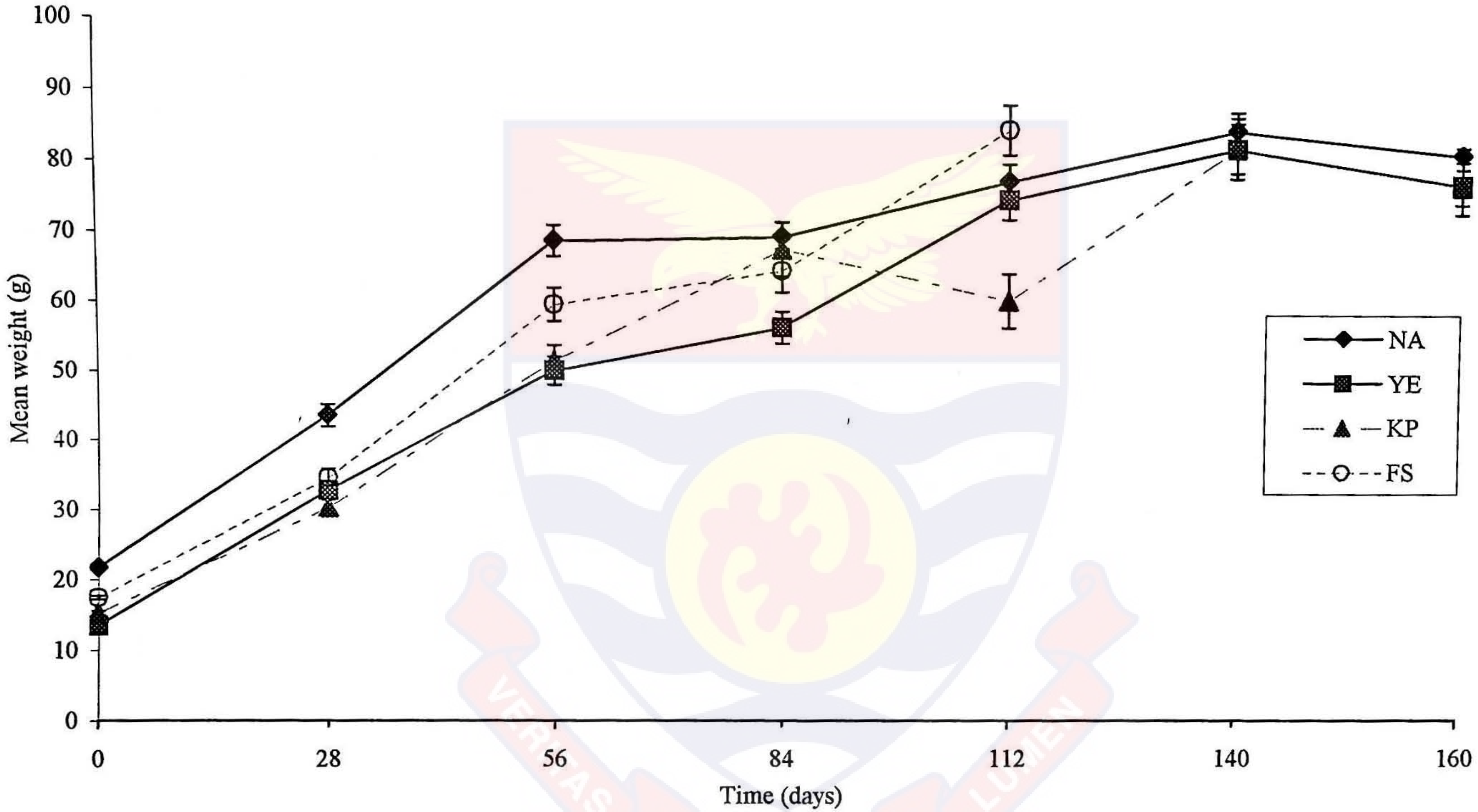

Fig. 5: Growth performance of four stocks of *O. niloticus* reared in an all-male polyculture system with *Heterotis niloticus*. (Vertical bars represent standard errors).

Table 12 : Growth performance of four stocks of all-male *O.niloticus* in polyculture with *Heterotis niloticus* for 160 days.

Stock	Mean Initial Weight (g) ± S.E.	Mean Final Weight (g) ± S.E.	Mean Daily weight gain (g/d)	Condition Factor (K) ± S.E.	Survival (%) ± S.E.
NA	21.6 ± 0.2	82.9 ± 1.0	0.38	3.42 ± 0.01	60.0 ± 2.0[c]
YE	13.6 ± 0.4	74.9 ± 3.0	0.38	3.38 ± 0.06	3.7 ± 0.7[a]
KP	15.2 ± 0.2	80.4 ± 2.5	0.40	3.44 ± 0.02	20.5 ± 1.8[b]
FS	17.6 ± 0.4	85.8 ± 2.5	0.43	3.46 ± 0.03	15.8 ± 2.1[b]
Heterotis niloticus	339.0 ± 11.9	643.0 ± 217.0	1.90	1.17 ± 0.02	72.0 ± 19.0

Means with different superscript differ significantly ($p < 0.05$)
ANOVA in INSTAT (1993) statistical package used to determine differences in growth performance.

Performance of progeny of diallele crosses

Growth, survival and sex ratios within the three culture environments

Table 13 shows the initial number of experimental fish stocked, initial and final mean body weight and total body length, and the survival rate within the three culture environments. The mean body weight at harvest was lowest for the extensive culture environment and highest for the intensive culture environment. Survival rate was similar for the three culture environments and ranged from 48 % for the semi – intensive to 57 % for the intensive culture environment. There were no significant differences in mean survival rates among the three culture environments.

The estimates of mean squares for the main effects in the model and their interactions derived from the generalized linear model procedure are given in Tables 14a and 14b. The results are the analysis of variance in body weight and total length at harvest. The mean squares for all effects in the model were significant ($p < 0.0001$), except the effect of age class which was non-significant ($p > 0.05$). The culture environment and sex effects accounted for most of the variations (67.5 % and 29.5 % with respect to variation in body weight, and 65.6 % and 33.7 % % with respect to body length). The variation explained by the interaction between culture environment and cross was very small and accounted for only 0.1 percent of the total variance ($P \leq 0.05$). The significant genotype – environment interaction was a magnitude effect as the rankings of

Table 13 : Mean weight and body length at stocking, harvest and survival rate of *O. niloticus* fingerlings reared in three culture environments for 120 days.

Culture Environment	No. stocked per replicate Pond	Mean weight at stocking (g) ± S.E.	Mean weight at harvest (g) ± S.E.	Body length at stocking (mm) ± S.E.	Body length At harvest (mm) ± S.E.	Survival (%) ± S.E.
Extensive	1087	6.6 ± 0.1	27.3 ± 0.3	71.6 ± 0.3	117.6 ± 0.4	51.0 ± 0.02
Semi-intensive	557	8.0 ± 0.1	34.8 ± 0.4	76.1 ± 0.4	112.5 ± 0.8	48.0 ± 0.02
Intensive	579	8.5 ± 0.1	69.7 ± 0.8	77.8 ± 0.4	154.3 ± 0.6	57.0 ± 0.02

ANOVA in SAS (1990) statistical package used to determine differences in body length and weight at harvest.

Table 14a : Analysis of variance of body weight of *O. niloticus* at harvest from the generalized linear model (GLM) procedure.

Effects	Degrees of Freedom	Mean squares[a]	Percent (%)[b]
Culture environment	2	256,658.2	67.5
Sex	1	112,361.9	29.5
Age class	1	569.6[ns]	0.2
Cross	14	360.2	0.1
Culture environment x sex	2	9,403.8	2.5
Culture environment x cross	28	361.7	0.1
Sex x cross	14	501.2	0.1
Error	2,091	121.4	-

a Type III mean squares; all significant ($p<0.0001$) except age class ($p>0.05$).
b Based on total marginal mean squares for all independent variables.

Table 14b: Analysis of variance of total body length of *O. niloticus* at harvest from the generalized linear model (GLM) procedure.

Effects	Degrees of freedom	Mean squares [a]	Percent (%) [b]
Culture environment	2	248,893.0	65.6
Sex	1	127,796.2	33.7
Age class	1	-	-
Cross	14	554.9	0.2
Culture environment x sex	2	991.0	0.3
Culture environment x cross	28	484.6	0.1
Sex x cross	14	484.3	0.1
Error	2,091	151.0	-

a Type III mean squares; all significant (p<0.0001).

b Based on total marginal mean squares for all independent variables.

the crosses were not significantly altered. The magnitude of the interactive effect between culture environment and sex of the fish, and sex of fish andcross wereminimal and varied between 0.1 % and 0.3 %. All effects in the model explained 78 % of the variance in body weight and total body length at harvest.

The least square means (LSM) of body weight and total body length at harvest within the three culture environments according to the model are presented in Table 15. The LSM of body weight at harvest was lowest in the extensive culture environment and highest in the intensive culture environment, while the LSM for total body length was lowest in the semi-intensive environment and highest in the intensive environment. The LSM values for males were significantly higher than those females ($p \leq 0.05$) in all three culture environments. Females outnumbered males and the sex ratios differed significantly ($p \leq 0.05$) from the expected 50: 50 ratio.

Effects of stock crosses on progeny across the three culture environments

Fifteen out of the sixteen cross combinations produced progeny which were tested in the three culture environments. The cross between the male KP and female FS failed to breed in spite of replacing breeders which died or those that did not spawn during the period when fry were collected from the other crosses. Progeny of the male KP x female FS were therefore not available for the diallele cross experiment.

Table 15 : Least square means (LSM) of body weight, total body length and sex ratios of O. niloticus reared in three culture environments for 120 days.

Culture environment / Sex	LSM of body weight at harvest (g) ± S.E.	LSM of total body length at harvest (mm) ± S.E.	Male : Female sex ratio
Extensive	29.6 ± 1.0^{a}	120.6 ± 1.2^{a}	1:1.8
Semi-intensive	26.8 ± 1.0^{b}	115.3 ± 1.2^{b}	1:2.2
Intensive	74.2 ± 0.9^{c}	158.0 ± 1.1^{c}	1:2.2
Males	55.7 ± 0.9	140.9 ± 0.9	-
Females	37.8 ± 0.6	121.6 ± 0.8	-

Means with different superscript differ significantly ($p<0.05$)
ANOVA in SAS (1990) used to determine differences in total body weight and total body length at harvest.

Tables 16a and 16b present the data on LSM of body weight and total body length respectively at harvest across the three culture environments for the 15 stock combinations of *O. niloticus.* Results of the trial showed that among the purebreds, NA progeny were slightly heavier in body weight thanthose of FS, KP, and YE, but the differences were not significant ($p \geq 0.05$). A similar trend was evident when total body length of pure breeds was compared. Among the progeny of all the crosses reared in the three culture environments, total body length of the NA x FS hybrid was the greatest followed by the NA purebred, while the progeny that attained the least size was KP x NA. With respect to body weight, FS x NA was second to NA purebred while YE x FS attained the least size.

Effects of stock crosses and ranking of progeny of diallele crosses within the three culture environments

Rankings of the progeny of crosses based on the least square means of body weight and total body length at harvest are presented in Tables 17a and 17b respectively. Among the progeny of the different cross combinations reared in the extensive culture environment, FS x KP attained the highest body weight at harvest, followed by NA x FS. The least ranked cross was YE x NA. In the semi-intensive culture environment, NA x FS attained the highest body weight at harvest while YE x KP was the least. The highest ranked cross by weight in the intensive culture environment was FS x NA with 81.48 g mean body weight followed by NA x YE and NA x NA with mean body weights of 80.98 g and

Table 16a : Least square means of body weight ± S.E. at harvest of progeny of 15 crosses of *O. niloticus* across three culture environments after 120 days of culture.

Male stock	Female stock			
	NA	YE	KP	FS
NA	50.8 ± 1.5	47.8 ± 1.2	47.4 ± 0.9	47.3 ± 1.4
YE	46.1 ± 1.6	45.4 ± 1.3	45.1 ± 1.0	42.9 ± 1.5
KP	44.1 ± 0.9	47.2 ± 0.8	47.6 ± 1.1	*
FS	49.5 ± 1.3	44.3 ± 0.9	45.9 ± 1.1	48.2 ± 1.5

*male and female stock failed to breed
ANOVA in SAS (1990) used to determine differences in total body weight at harvest.

Table 16b: Least square means of total body length ± S.E. at harvest (mm) of progeny of 15 crosses of *O. niloticus* across three culture environments after 120 days of culture.

Male stock	Female stock			
	NA	YE	KP	FS
NA	134.7 ± 1.7	132.8 ± 1.3	132.0 ± 1.3	135.4 ± 1.5
YE	128.3 ± 1.8	128.9 ± 1.4	128.7 ± 1.4	132.2 ± 1.5
KP	127.8 ± 1.0	131.6 ± 0.9	132.5 ± 0.9	*
FS	134.3 ± 1.4	128.6 ± 1.0	132.4 ± 1.0	133.0 ± 1.6

* male and female stock failed to breed
ANOVA in SAS (1990) used to determine differences in total body weight at harvest.

Table 17a: Ranks of least square means (LSM) of body weight at harvest of the progeny of crosses of *O. niloticus* reared in three culture environments for 120 days.

Cross Male Female	LSM of body weight (g) ± S.E. Extensive	Semi-intensive	Intensive
NA x NA	32.04 ± 1.62 (4)	39.79 ± 2.42*(3)	80.44 ± 2.70 (3)
NA x YE	26.46 ± 1.47 (14)	35.82 ± 2.12 (11)	38.03 ± 1.88 (4)
NA X KP	30.04 ± 1.23 (7)	38.03 ± 1.88 (4)	74.03 ± 1.24 (8)
NA X FS	33.56 ± 3.09 (2)	41.26 ± 2.01 (1)	74.57 ± 1.63 (6)
YE X NA	25.64 ± 2.10 (15)	36.60 ± 2.76 (8)	76.03 ± 2.70 (4)
YE X YE	29.59 ± 1.58 (9)	33.96 ± 2.50 (12)	72.65 ± 2.06 (11)
YE X KP	29.36 ± 1.16 (10)	32.92 ± 2.05 (15)	73.05 ± 1.72 (10)
YE X FS	32.83 ± 2.69 (3)	36.52 ± 2.28 (9)	72.48 ± 1.93 (12)
KP X NA	28.12 ± 1.08 (13)	33.51 ± 1.69 (13)	70.61 ± 1.82 (13)
KP X YE	29.25 ± 1.21 (11)	37.29 ± 1.46 (6)	74.98 ± 1.44 (5)
KP X KP	31.36 ± 1.85 (5)	36.97 ± 2.03 (7)	74.54 ± 1.68 (7)
KP X FS*	-	-	-
FS X NA	29.06 ± 1.40 (12)	37.87 ± 1.81 (5)	81.48 ± 1.95 (1)
FSX YE	29.70 ± 1.33 (8)	36.37 ± 1.86 (10)	66.72 ± 1.63 (15)
FS X KP	35.26 ± 2.34 (1)	33.10 ± 1.80 (14)	69.36 ± 1.68 (14)
FS X FS	31.05 ± 2.17 (6)	39.85 ± 2.48 (2)	73.57 ± 2.47 (9)

* male and female cross failed to breed

Numbers in brackets indicate rankings.

ANOVA in SAS (1990) used to determine differences in total body weight at harvest.

Table 17b: Ranks of least square means (LSM) of total body length at harvest of the progeny of crosses of *O. niloticus* reared in three culture environments for 120 days.

Cross	LSM of total body length (mm) ± S.E.		
Male Female	Extensive	Semi-intensive	Intensive
NA x NA	123.67 ± 1.80 (3)	118.09 ± 2.70 (4)	162.443 ± 2.53 (2)
NA x YE	116.35 ± 1.64 (14)	118.01 ± 2.37 (5)	164.11 ± 2.41 (1)
NA X KP	121.79 ± 1.37 (7)	115.56 ± 2.10 (9)	158.73 ± 1.82 (7)
NA X FS	125.45 ± 3.45 (2)	122.58 ± 2.25 (1)	158.06 ± 1.82 (8)
YE X NA	108.23 ± 2.34 (15)	115.92 ± 3.08 (7)	160.72 ± 3.01 (4)
YE X YE	120.64 ± 1.76 (9)	109.63 ± 2.79 (14)	156.32 ± 2.29 (10)
YE X KP	120.11 ± 1.30 (10)	108.54 ± 2.29 (15)	157.50 ± 1.91 (9)
YE X FS	123.03 ± 3.00 (4)	117.76 ± 2.54 (6)	155.94 ± 2.16 (11)
KP X NA	117.78 ± 1.21 (13)	110.02 ± 1.88 (13)	155.70 ± 2.03 (12)
KP X YE	119.40 ± 1.35 (12)	115.39 ± 1.63 (10)	160.09 ± 1.60 (5)
KP X KP	121.98 ± 2.07 (6)	115.57 ± 2.27 (8)	160.02 ± 1.87 (6)
KP X FS*	-	-	-
FS X NA	121.05 ± 1.56 (8)	119.41 ± 2.02 (3)	162.29 ± 2.18 (3)
FSX YE	119.94 ± 1.48 (11)	112.99 ± 2.08 (12)	152.73 ± 1.80 (15)
FS X KP	128.33 ± 2.61 (1)	113.54 ± 2.01 (11)	155.30 ± 1.87 (14)
FS X FS	122.99 ± 2.42 (5)	120.54 ± 2.72 (2)	155.34 ± 2.76 (13)

* male and female cross failed to breed

Numbers in bracket indicate rankings

ANOVA in SAS (1990) used to determine differences in total body length at harvest.

80.44 g respectively FS x YE was the least ranked cross in the intensive environment.

Progeny of the top four ranked crosses, with respect to body weight at harvest in all the three culture environments involved either NA or FS genotypes as the male or female parent. A similar observation was made with respect to the ranking of body length at harvest.

Heterosis, maternal and individual genetic effects in the progeny of the diallele crosses

The Least square means computed for percent heterosis of body weight at harvest and total body length at harvest are presented in Table 18. Percent heterosis measures the non-additive genetic effects relative to the additive genetic and reciprocal effects. All the hybrid crosses showed negative mean percent heterosis for all the test environments for body weight at harvest, with values ranging from -7.23 % in crosses between the NA x KP to – 0.79 % in the YE x KP. The values for total body length at harvest ranged from -2.79 % in the Na x KP to 0.41 % in YE x FS, with the latter being the only hybrid cross that exhibited a positive percent heterosis.

The average heterosis for reciprocal crosses, and maternal and genetic effects of each stock for the different culture environments are presented for body weight at harvest in Table 19. NA showed the highest individual genetic effect with 2.68 g followed by FS while YE was the least with -1.73 g. The average maternal genetic effects of FS and NA were positive (1.01 ± 0.15 and

Table 18 : Least square means of average heterosis (H) and mean percent heterosis (H %) for body weight and total body length at harvest of *O. niloticus* across culture environments.

Cross	Body weight (g)		Total body length (mm)	
	H	H %	H	H %
NA X YE	-1.16	-2.41	-1.24	-0.94
NA X KP	-3.47	-7.23	-3.69	-2.79
NA X FS	-1.08	-2.25	-0.97	-0.73
YE X KP	-0.38	-0.79	-0.52	-0.39
YE X FS	-3.22	-6.71	-0.51	-0.39
KP X FS	-3.19	-6.45	0.54	-0.41

Table 19 : Individual, maternal and average heterosis for reciprocal crosses of four stocks of *O. niloticus* from the LSM for body weight at harvest (g).

Stock	Average stock Heterosis for reciprocal crosses ± S.E.	Average maternal genetic effect (g^m) ± S.E.	Average individual genetic effect (g^i)
NA	-1.98 ± 0.79	0.09 ± 1.17	2.68
YE	-1.59 ± 0.85	-0.86 ± 0.09	-1.73
KP	-2.35 ± 0.99	-0.61 ± 0.83	0.25
FS	-2.50 ± 0.71	1.01 ± 0.15	0.85

0.09 ± 1.17 respectively) while YE and KP showed negative effects (- 0.86 ± 0.09 and - 0.61 ± 0.83 respectively). The average stock heterosis for the reciprocal crosses was negative for all the four stocks (Table 19), indicating that the pure breeds performed better than most of the crossbreeds.

Response to selection in the base population

Genetic and phenotypic parameters

The Restricted Maximum Likelihood (REML) estimates of variance components, heritability and genetic correlations between body weight and total body length are provided in Table 20. Estimated heritability (h^2) was intermediate with reference to the heritability scale (Dalton, 1981) and similar for body weight and total body length (0.17 ± 0.06). The estimates for additive genetic variance (σ^2_A) and phenotypic variance (σ^2_P) were slightly higher for the total body length than for body weight. There was also a high positive genetic correlation (r_g) which was greater than the phenotypic correlation (r_P).

Genetic gain and sex ratios

The least square means for genetic gain of progeny from the selected and control lines of the base population in the three culture environments are presented in Table 21. The data showed higher mean weight at harvest for progeny of the selection line compared to the control line in the extensive and semi-intensive culture environments. It was not possible to estimate the least square means of the control line in the intensive culture system because the fish were lost when a storm damaged the cages.

At harvest, sex ratios in the extensive and semi-intensive culture environments did not show any significant differences from 1:1 ($p \geq 0.05$). As observed in the diallele crosses, the least square mean of the males (65.1 ± 0.7) was significantly higher ($p \leq 0.05$) than that of the females (39.8 ± 0.6).The genetic gain, estimated by comparing the LSM of body weight for the selection and control lines was higher for the extensive tem system (17.50 %) than for the semi-intensive culture system (12.84 %) (Table 21). These to response to selection per generation based on estimated breeding values of body weight at at at harvest for the diallele crosses and the base population was 5.0 % (Table 22).

Table 20 : Variance components and heritability ± S.E., of body weight and total body length of *O. niloticus* in the base population.

Parameter	REML estimates	
	Body weight (g)	Total body length (mm)
Additive genetic variance ($\sigma^2 A$)	19.8	20.0
Phenotypic variance ($\sigma^2 p$)	115.4	116.1
Heritability (h^2)	0.17 ± 0.06	0.17 ± 0.06

Table 21 : Genetic gain for body weight and sex ratios of the base population of *O. niloticus.*

Culture Environment	LSM Selection line in g ± S.E.	LSM Control line in g ± S.E.	Genetic gain (%)	Sex ratios (male:female)
Extensive	40.44 ± 0.6	34.42 ± 1.2	17.5	1:0.9
Semi-intensive	34.74 ± 0.6	30.79 ± 1.2	12.84	1:1.1
Intensive	81.60 ± 1.0	*	*	*

* all fish in the control line lost due to a storm
Chi-squares test for fixed ratio hypothesis used to determine differences in sex ratio.

Table 22 : Selection response per generation based on breeding values (BVs) of diallele crosses and the base population of *O. niloticus*.

Generation	Estimated BV	Response per generation (%)
Diallele crosses	0.099	-
Base population	1.445	5.0

CHAPTER 4

DISCUSSION

Seed production of the four stocks

All the four stocks of *Oreochromis niloticus* used in this study (Nawuni, Yeji, Kpando and the Farm stock) spawned continuously throughout the six months with peak reproductive activity in mid-June. The initial production was high, followed by a decrease during the second harvest; however, it increased during the third and fourth harvests before declining again. Seed harvests during the last two months were exceptionally low compared to the initial production.

The seed production pattern of the four *Oreochromis niloticus* stocks investigated in this study, is similar to that reported for the species in previous studies. For example, Hughes and Behrends (1983) recorded a very high production during the first harvest of eggs and fry, followed by decreasing seed numbers and Guerrerro and Guerrero (1985) observed an initial fry production peak after stocking the breeders, but this declined in latter spawnings. Lovshin and Ibrahim (1988) working on the same species, noted a high seed production during the first harvest which subsequently decreased during the second and third harvests, but harvests increased during the fourth and fifth harvests.

Fluctuations in seed production appear to be influenced by a number of factors which include broodstock segregation and conditioning. Prior to stocking in breeding hapas, brooders were separated by sex and conditioned for two weeks before pairing. It has been reported that during the conditioning process, social stimuli are exchanged between neighboring females and these enhance the process of synchronization of spawning, enabling a high number of females to spawn at the same time (WorldFish Center, 2004). Segregation of females from the males would allow oocyte development to proceed at a faster rate and enable the eggs to develop properly through the utilization of nutritious feed which is available to the females, which are not distracted by the activities of males. This would improve the production of eggs by the females and consequently the spawn size. Since after spawning, incubating females do not feed, this could affect subsequent development of eggs resulting in reduced seed production. When swim-up fry leave the buccal cavity of the breeders, they resume feeding and this impacts positively on subsequent fry production.

The exceptionally low numbers of seed produced by the stocks during the fifth and sixth months of spawning could be attributed to "spawning fatigue" and possibly fungal infection of the eyes of some brood fish. It was observed that a number of broodfish especially the females had their eyes covered with white patches which was suspected to be caused by fungal infection. Lovshion and Ibrahim (1988) have suggested that to maintain a high seed production level in *O.niloticus* brooders throughout a production cycle, it would be more efficient to terminate breeding after three weeks, and restock with fresh brood fish. Results from the current work have confirmed this observation. It would therefore not be advisable to use the same brood stock of *O. niloticus* continuously for more than three consecutive months of breeding before conditioning. It would be more beneficial to replace them with new breeders while the older ones are culled and replenished through the conditioning process.

From the present results, the Yeji stock had the highest daily mean number of seed per gram female (i.e. 0.17/ g female) while the Farm stock had the least value of 0.10 / g female. Seed production by the Yeji stock was higher than those reported in earlier studies on *O. niloticus*. For example the stock investigated by Hughes and Behrends (1983) yielded 0.03-0.16 eggs and fry per gram female daily while that studied by Lovshion and Ibrahim (1988) produced an average of 0.15 eggs and fry / g female daily. Furthermore, Chang *et al.* (1988) reported mean seed production of 0.06 – 0.12 seed/g female daily for the red variety of *Oreochromis niloticus*

The type of species and strains have been identified as some of the main factors that determine differences in seed production in tilapias (Ridha and Cruz, 1999). Reports of the present study indicate that, there were significant variations in seed production among the four stocks. Lee (1979), Mires (1982), Chang *et al.* (1988) and Smitherman *et al.* (1988) attributed variations in seed production in *O. niloticus* to differences in fecundity and spawning frequency of individual females. The Ghanaian strain has also been reported as the most fecund compared with strains of *O. niloticus* from Auburn University, Egypt and Ivory Coast (Kharter, 1985; Kharter and Smitherman 1988; Jayaprakas *et al.*, 1988). The low seed production of the Farm stock could be due to inbreeding depression leading to a reduction in reproductive performance as the same stock has been used for breeding for over twenty years without replenishment (Farm manager, background information). An increase in inbreeding is expected to maintain fixed genes and thus reduce genetic variance of the reproductive trait in a closed population.

The poor reproductive performance of the Farm stock brings into sharp focus hatchery practices followed by tilapia farmers in Ghana. Private hatcheries are very few in the country while most ponds used for the production of fingerlings are undrainable. Thus a greater proportion of fish farmers continuously harvest fingerlings from the same pond without any conscious effort to replenish the brood stock with improved genetic material. The outcome is that a large proportion of the fast growing fingerlings are systematically removed from ponds leaving genetically inferior and stunted fish which are sold to other farmers.

In the present study, male breeders from Kpando crossed with the Farm stock females did not produce fry even though individuals which failed to reproduce or died were replaced. Progeny from that cross was therefore not available for evaluation of growth performance. This might be due to incompatibility among the phenotypes as most of the females were found dead a day or two after pairing. Boliver *et al.* (1993) observed variation in the age at first spawning and lack of spawning in 25 % of the female population in groups of *O. niloticus*. Apart from differences in the genetic background of the fish, Boliver *et al.* (1993) cited differences in the environment as some of the factors that could cause discrepancies in reproduction. In any selection program, it is therefore necessary to identify and cull out non-spawners and replace them with good spawners in order to enhance productivity. If this is not done such individuals occupy space, consume feed and make use of labor, thus wasting resources.

Growth performance and sex ratios of the progeny

Males of the *O. niloticus* stocks investigated grew faster and attained significantly heavier weights than the females in the experiments on mixed sexes conducted in this study. This is similar to what has been reported elsewhere (see Stone, 1980; Behrends, 1983; Eknath *et al.*, 1993b; and Bentsen *et al.*, 1998) Similar observations were also made in *O. mossambicus* by Guerrero (1973) and Guerrero and Guerrero (1975). Stone (1980) observed that the expression of disparity in growth in both sexes of *O. niloticus* was so pronounced that prevention of reproduction still resulted in the males growing faster than the females. The difference in growth of the sexes observed in the present study could be attributed to genetic differences between the males and females as suggested by Pagan (1970) and Tave (1988) who also suggested that selection for better growth in this species should be carried out independently for males and females. Correction for sex should therefore be made in genetic programs otherwise selection for rapid growth may result in undesirable skewing of the sex ratio (Brzeski and Doyle, 1988).

The range of weight ratios of females to males from 0.61 to 0.70 in the Ghanaian stock is similar to the report of Bentsen *et al.*, (1998) who observed a range of 0.61 to 0.75 for overall female to male body weight ratio of the species.

The observed male: female sex ratios of 1:1.80 in the extensive culture system and 1:2.2 in the semi-intensive culture environment were markedly different from the expected 1:1. Deviations from the 1:1 ratio in intra specific mating could either be skewed towards females as observed in this study or towards males as observed by Shelton *et al.* (1983) and Marengoni *et al.* (1998). Sex ratios observed in this study were similar to the results of Boliver and Eknath (1994) who recorded ratios of 1:1.85 and 1:2.25 in two treatments while Dionisio (1995) noted a significantly lower proportion of males compared to females in crosses of *O. niloticus*. However, Wedekind *et al.* (1990) crossed five populations of *O. niloticus* and noted that 3 out of 8 male broodstock mated with females from the base population consistently produced a significant excess of males (> 90 %) in their progeny regardless of their mating partners. These workers attributed the occurrence of unbalanced sex ratios to the influence of genetic factors while Barioller *et al.* (1995) attributed it to environmental influences such as temperature. In the current study, a possible cause of the skewed sex ratio apart from genetic factors may be the higher mortality among the males due to tag loss during sampling.

Interest in sex determination and male to female ratios in tilapia is motivated by the practical and commercial implications of the production of monosex progeny for use in commercial aquaculture. Consequently, various methods such as hormonal sex reversal and species hybridization have been used for monosex brood production. It might also be possible to produce monosex populations by selective breeding if the factors influencing the sex ratios are known. Sex ratio which is skewed towards females would be advantageous in *O. niloticus* broodstock selection for mixed sex fingerling production as the proportion of female breeders used in seed production is about two to three times that of male breeders; conversely, sex ratio which is skewed towards males would favor all-male fingerling production.

Survival of progeny

Survival rates of the *O. niloticus* progeny in the polyculture systems were generally low except that involving the Nawuni stock which had high rate of survival. Fish mortality in this study could be attributed to such factors as initial handling stress and activities of predatory birds and monitor lizards. Dead fish were usually recovered a few days after stocking and these were observed to have lesions on the skin with some of the scales removed, while a few had bacteria and fungal infections at the point of insertion of the tagging thread. Some predatory birds were found around ponds during the experimental period, however their activities were reduced by use of scare crows. Presumably fish tagged with white thread were more conspicuous initially so that they were easily spotted by predatory birds.

The high mortalities recorded in the *Oreochromis niloticus-Heterobranchus longifilis* polyculture could partly be ascribed to the predatory activities of *Heterobranchus longifilis* which has the capacity of feeding on other smaller fish when they are in the same environment. High survival rates observed for the Nawuni stock in the *Oreochromis niloticus-Heterotis niloticus* polyculture system could be attributed to high tolerance of the Nawuni stock to very turbid pond water conditions. *Heterotis niloticus* is a bottom feeder and has the habit of stirring the bottom of ponds during its feeding activities. This behaviour makes the pond water very turbid as silt particles are released into the water. This is harmful to the gills of fish especially during the first few days after stocking when they were fragile and could result in mortalities. The Nawuni stock was collected from an environment where during the dry season, the rivers reduce in size and break into turbid pools where they survive till the next rainy season. It is likely that the genotype frequency of the Nawuni stock had been altered through the process of natural selection over the years to favor those which are capable of withstanding the adverse turbid conditions. This has enabled it to perform better than the other three stocks which lacked such genotypes and therefore performed poorly.

Heterosis

Expression of heterosis in the progeny of *O. niloticus* crosses in this study was negligible as most of the hybrids exhibited negative values for body weight and total body length at harvest. The computed heterosis effect value of -28.3 % for body weight was similarly reported by Uraiwan and Phanitchai (1986) when two strains of *O. niloticus* were hybridized in Thailand. Furthermore, Eknath *et al*. (1993 b) estimated heterosis for growth and survival of -5 % to 10 % while Yapi-Gnaore (1996) reported negative mean heterosis values for all growth traits involving three strains of *Oreochromis.*

In the present study the Nawuni stock showed superior growth rates in comparison with the other three stocks, and none of the hybrids showed a better growth rate than the purebred Nawuni stock. The inferior growth performance of the hybrids and non-expression of heterosis in the current study is an indication of low genetic distance between the original parent populations and raises the possibility of the four groups belonging to a single stock. Investigations by previous workers have shown that positive heterosis is particularly expressed for strains that are geographically distinct. Khater (1985) produced F1 hybrids among the Auburn University, Egypt, Ivory Coast and Ghana strains of *O. niloticus* and compared their growth rates in a 47 day yield trial in plastic pools. Heterosis for the Egypt-Ghana, Egypt-Ivory Coast and Ghana-Ivory Coast F1 hybrids were all positive, with values of 11.6 %, 3.0 % and 5.8 % respectively; however, none of these showed a better growth rate than the Egyptian strain. Jayaprakas *et al.* (1988) in hybridizing the Auburn University, Egypt and Ivory Coast strains of *O. niloticus* recorded heterosis values of 9.5 % and 28.3 % for length and body weight, respectively, for F1 hybrids while Tave *et al.* (1990) obtained significant heterosis values in both F-1 and F-2 generations for *O. niloticus* hybrid crosses using Auburn University-Egypt and Auburn University -Ivory Coast strains.

The negative heterosis values recorded in this study indicated poor growth rates in most of the hybrids compared to the purebreds. It would therefore appear that growth of the Ghanaian Nile tilapia cannot be enhanced solely through intra-specific crossing among the local stocks. Other breeding strategies such as selective breeding should be applied to develop genetically improved *O. niloticus* strains to increase production.

Genotype – environment interaction

For a selective breeding program, especially those involving the choice of stock or strain based on their performance in a number of culture systems, the genotype–environment interaction is of major importance as it reflects the level of expressions of the genotypes in the different environments in which the fish is reared. Observations on the effect of the interaction between genotype and environment on growth have been quite variable. Earlier results suggested that genotype- environment interactions are probably minor among strains and selected lines but more important in comparisons among species and hybrids (Smitherman and Dunham, 1985).

The genotype–culture environment interaction observed for growth of fifteen crosses of *O. niloticus* in this study was very low (0.1 %), but significant ($p < 0.0001$). This result is similar to what was reported by Eknath *et al.* (1993

a) who observed a significant strain-environment interaction when they tested eight strains of *O. niloticus* for two generations in eleven different environments which accounted for only 0.3 % of the total phenotypic variation. Reddy *et al.*, (2002) also noted that the interaction in body weight between two strains of *Labeo rohita* in mono and polyculture systems was highly significant but accounted for only 0.1 % of the total variation in body weight. Gunnes and Gjedrem (1981) also observed a highly significant sire-farm interaction for rainbow trout, but the interaction explained only between 1.1 % and 5.5 % of the total phenotypic variance for weight and between 0.7 % and 4.5 % of the total phenotypic variance for length. In all the above cases, the investigators concluded that the genotype–environment interaction could be neglected as it was of minor importance. The same conclusion could be drawn in the current study as the magnitude of the interaction was very low. Gjedrem (2005) indicated that the fact that an interaction is statistically significant does not mean that it is important. He further stated that the importance of an interaction is assessed from its proportion to the total phenotypic variance. If the variation due to the genotype- environment interaction account for only a small part of the total phenotypic variation, it will have little influence on the breeding value. In the light of the above, it is expected that selection based on results from the extensive culture environment would lead to improved growth in the other two culture environments. It would therefore not be necessary to develop specific strains for different culture environments.

Phenotypic and genetic correlations among traits

Correlation estimates between two traits assess the degree to which common factors influence variations in each of two traits under investigation. Genetic correlation is of great importance in breeding programs because it enables predictions of the breeding values to be made and provides an understanding of the genetic background of each trait. It is very useful in indirect selection of traits which are difficult or very expensive to measure (Kolstad, 2005). Furthermore, it is important to know if the improvement in one trait will cause simultaneous changes in the other trait and by how much. With correlations close to -1 or 1, one can expect that selection for only one of the traits gives high correlated response for the other.

The magnitude of the phenotypic and genetic correlation between the weight and total body length in this study estimated the degree to which these genes are expressed in the ponds and cages. Estimates of the phenotypic correlation between body weight and total body length of the base population was 0.76 ± 0.01 while the genetic correlation was 0.96 ± 0.02. The genetic correlation was very high indicating that if selection were conducted in any of the test environments based on body weight but progeny were to be selected based on total length, the selection would capture 96 % of the gain that could be achieved if it were carried out based on body weight. This is in good agreement with the findings of Tave and Smitherman (1980) who concluded that growth in *O. niloticus* can be improved by selecting for either body weight or body length because there was 100 % genetic correlation between these phenotypes. The magnitude of the correlation will also depend on the heritability of the traits. Interestingly equal estimates of heritability were obtained for both traits in this study, which reinforces the fact that a positive selection response for length or weight could be obtained by selecting for either trait.

Choice of the best stock

Results of evaluation of the four stocks of *O. niloticus* showed differences in their reproductive performance with the Yeji stock showing the highest fry production which is an indication of its potential to produce fish seed to meet the seed requirements of hatchery managers. If selection is based solely on reproductive capacity, the Yeji stock would be the first choice, followed by the Nawuni stock; however, a closer look at the results on growth performance indicated that the Yeji stock had the lowest mean daily growth rate in virtually all the growth evaluations in the diallele cross experiments while the Nawuni stock was the best stock with respect to growth traits. It would therefore appear that selection for high seed production may be negatively correlated and incompatible with high growth traits, and selection for one trait might mask the importance of the other trait if caution is not exercised. If females are selected solely on the basis of high seed production without due consideration of their slow growth rates, genes for slow growth would be inherited and transmitted to the offspring which would be detrimental to the aquaculture industry. On the other hand, if selection should be based mainly on fast growth trait without due regard to the level of seed production, fast growing fish would be expected to be produced to the detriment of seed production.

Bhujel *et al.* (2000) have suggested that in order to achieve both high fecundity and faster growth traits within the same species, it might be necessary to develop separate lines within the species for each trait. If a similar strategy is to be adopted for the present stocks, it should involve a separate selection line for high fecundity using the Yeji stock while separate male and female lines of Nawuni stock could be used for the best growth. A final cross which is a merger between all the three lines should produce offspring with high growth rate and high fecundity. A similar practice is adopted in animal genetics with respect to selective breeding in the poultry industry (Boa-Amponsem, personal communication).

Another strategy is the simultaneous selection of the two traits through a selection index in which appropriate economic weights are assigned to each trait (growth rate, fecundity, survival etc.) (Gjedrem, 1983) In the present circumstance, it is suggested that growth rate be assigned the highest rating as it is almost always the most important trait assessed in any fish breeding program to be followed by fecundity and survival in order of decreasing importance.

The Genetic Improvement of Farmed Tilapias project (GIFT) (GIFT Final Report, 1998) used a combined family selection approach in which individuals were selected on the basis of a selection index appropriately weighing the deviation of the full sib (brother-sister) family mean from the population mean and the deviation of individual performance from the mean of the individual's family.

A third alternative strategy is to build a genetically mixed base population by selecting the best growing individuals from the best performing purebred and crossbred groups based on the breeding values of the males and females.

Based on the findings from this study, it would be prudent to form a synthetic base population using the proposed third strategy above. This takes advantage of increase in genetic variability through recombination of alleles among the four stocks. It would provide increased additive and non-additive genetic variance and a broad genetic pool for selection in subsequent generations.

Response to selection

The estimated genetic gains from comparison of the Least Square Means of the selection and control lines of the base population were 17.50 % for the extensive culture system and 12.84 % for the semi-intensive culture system. The results showed the effectiveness of the selection technique used in this study as the selected lines exhibited superior growth performance compared with the control line. The estimates in the current study are in agreement with those reported by Rye and Eknath (1999), who conducted a large scale selection project for the Genetic Improvement of Farmed Tilapias (GIFT) in the Philippines, to improve growth rate. They observed an accumulated response of 85 % in the first 5 generations with annual variations between 12 % and 17 %. The genetic gains reported in the present study were higher than those reported by Bolivar *et al.* (1994), who after 8 generations of selection found that the improved Nile tilapia were 8-37 % heavier than the control group, and this was equivalent to 3.6 % improvement per generation. Bolivar and Newkirk (2000) also reported an improvement of 1.05 - 9.7% per generation.

Overall, the present results of growth evaluation suggest an improved growth performance of the selection line and thus a positive selection response in the base population. It is however, important to ensure that the positive response achieved continues for many generations without reduction in genetic gain. This can be achieved through such practices as using a large number of brood stock (at least 50 pairs per generation) (Bentsen and Olesen, 2002) to keep the build up of inbreeding at a low level, and also keeping an equal number of selected animals per each family that contributes parents for the next generation.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The following conclusions were drawn from the results obtained from the study:

i. On seed production of *O. niloticus* stock from the Volta system in Ghana, the Yeji stock was the best (0.17 fry/ g female/ day) while the Farm stock was the least (0.10 fry/ g female/ day). The poor performance of the Farm stock was attributed to inbreeding depression as the same stock of broodstock were used for over twenty years without replacement.

ii. On sex ratios of progeny of stocks studied, it was concluded that the sex ratios ~~was~~ were skewed towards females and this could be advantageous in *O. niloticus* broodstock selection and management as the proportion of female breeders used in fry production is two to three times that of males.

iii On growth performance of the purebred stocks and hybrid crosses, results led to the conclusion that the Nawuni stock was the most outstanding while the Yeji stock was the poorest. The performance of the hybrid crosses was inferior to that of the purebreds.

iv. The genotype-environment interaction was very low (0.1 %). It was therefore concluded that it would not be necessary to develop specialized *O. niloticus* stocks for the different culture systems tested since a selected strain for one culture environment is likely to perform equally well in the other culture environments.

v. It appears that the technique of selective breeding may be the most appropriate and beneficial strategy to adopt for the improvement of *O. niloticus* in Ghana. This was demonstrated by over 10 % improvement in growth rate of the selection line over the control line in the base population.

Recommendations

The following recommendations are made for further investigations and also to significantly increase the production of *O. niloticus* in Ghana.

i. Research is required to continuously improve the base population of *O. niloticus*. This would ensure that the initial gain in improved growth rate is not stalled or eroded.

ii. Research is also needed to evolve more efficient methods for improving existing breeding practices and consequently, increase the rate of genetic improvement of important aquaculture species.

iii. Further research is also required in the area of molecular genetics in order to identify genetic markers for improved strains of *O. niloticus*. This would make it possible to track their dissemination and performance.

iv. Passive integrated transponder (PIT) tags should be used to tag experimental fish in future experiments in order to reduce tag losses to the barest minimum. The PIT tags even though more expensive are far more superior in terms of retention rate.

v. There is no reliable data on estimates of genetic variance, heritability, phenotypic and genetic correlation among traits which are vital information required for successful establishment of breeding programs. There is therefore a great need to run a lot more breeding experiments in order to get reliable estimates of genetic parameters for economically important traits for *O. niloticus*.

vi. A national fish breeding program should be established to improve the performance of tilapia broodstock and farm strains; promote dissemination channels and enhance market intermediary mechanisms to ensure that farmers have wide access to improved seed at affordable prices.

vii. More private and state owned hatcheries should be set up to propagate and distribute certified fish seed to fish farmers while hatchery operators and managers should be trained in breeding, genetic management and modern methods of seed production using improved aquaculture strains.

viii. Broodstock management practices should be improved and sustained in order to reduce inbreeding in hatcheries to the barest minimum. These practices include: (a) giving identity to parent stock as groups or individuals to generate offspring devoid of brother-sister mating; (b) periodic introductions of broodstock from improved stock to replace deteriorated ones; (c) use of large number of parents (> 50 pairs of parents) to produce fry and (d) to rotate male and female parents for fry production.

ix. Deteriorated broodstock in both private and public hatcheries should be replaced with genetically superior breeds to ensure good quality seed production. This should be pursued under a vigorous breeding programme.

REFERENCES

Agnese, J. F., Adepo–Gourene, B. and Pouyoud, L. 1998. Natural hybridization of tilapias, p. 97–103. **In:** *Genetics and Aquaculture in Africa.* (J. F. Agnese, editor) ORSTOM Editions.

Asian Development Bank. 2005. *An impact Evaluation of the Development of Genetically Improved Farmed Tilapia and their Dissemination in selected Countries.* 124p.

Ayles, G. B. and Baker, R. F. 1983. Genetic differences in growth and survival between strains and hybrids of rainbow trout (*Salmo gairdneri*) stocked in aquaculture lakes in the Canadian prairies. *Aquaculture,* **33**: 269 – 280.

Balarin, J. D. 1988. *National reviews for aquaculture development in Africa.* FAO Fish Circ., (770.18): 121 pp.

Bardach, J. E., Rythner J. H. and McLarney, W. O. 1972. *Aquaculture: the farming and husbandry of freshwater and marine organisms.* Wiley-Interscience, New York, USA. 868 pp.

Barioller, J. F., Chourrout, D., Fostier, A. and Jalabert., B. 1995. Temperature and sex chromosomes govern sex ratios of the mouth brooding ciclid fish *Oreochromis niloticus. Journal of Experimental Zoology,* **271**: 1 – 8.

Basiao, Z.U. and Doyle, R.W. 1990a. Interaction between test and reference populations when tilapia strains are compared by the "internal control" technique. *Aquaculture,* **85**: 200 – 214.

Basiao, Z.U. and Doyle, R.W. 1990b. Use of internal reference population for growth rate comparison of tilapia strains in a crowded environment. **In:** *Proceedings of the Second Asian Fish Forum.* (R. Hirano and I. Hanyu, editors) pp 503 – 505.

Behrends, L. L., Nelson, R. Smitherman, R. O. and Stone, N. 1982. Breeding and culture of the red– gold color phase of tilapia. *Journal of World Mariculture Society,* **13** : 210 – 220.

Behrends, L. L. 1983. Evaluation of hatchery techniques for intraspecific and interspecific seed production in four species of tilapia. Doctoral dissertation, Auburn University, Alabama, USA.

Behrends, L. L. and Smitherman., R. O. 1984. Development of a cold-tolerant population of red tilapia through introgressive hybridization. *Journal of World Mariculture Society,* **15** : 172 – 178.

Bentsen, H. B., Eknath, A. E., Palada – de Vera, M. S., Danting, J. C., Bolivar, H. L., Reyes, R. A., Dionisio, E. E., Longalong, F. M., Circa, A. V., Tayamen, M. M. and Gjerde, B. 1998. Genetic improvement of farmed tilapias: growth performance in a diallel cross experiment with eight strains of *Oreochromis niloticus. Aquaculture,* **160**: 145 – 173.

Bentsen, H. B. and Olesen, I. 2002. Designing aquaculture mass selection programs to avoid high inbreeding rates. *Aquaculture,* **204**: 349 – 359.

Bhujel, R. C., Turner, W. A., Yukupitiyage, A. and Little, D. C. 2000. Broodfish Selection and Its Effect on Seed Output of Nile tilapia (*Oreochromis niloticus*) in Large-Scale Commercial Seed Production System. **In**: *Tilapia Aquaculture in the 21st Century.* (K. Fitzsimmons and J. C. Filho, editors) *Proceedings of the Fifth International Symposium on Tilapia in aquaculture,* Vol. 2, 682p.

Blanc, J. M. and Chevasus, B. 1979. Interspecific hybridization of salmonid fish. I. Hatching and survival up to the 15th day after hatching in F1 generation hybrids. *Aquaculture,* **18**: 21 – 24.

Boa-Amponsem, K. 2004. Personal communication.

Bolivar, R.B., Eknath, A. E., Bolivar, H. L. and Abella, T.A. 1993. Growth and reproduction of individually tagged Nile Tilapia (*Oreochromis niloticus*) of different strains. *Aquaculture,* **111**: 159 - 169.

Bolivar, H. L., de Vera, M. P., Reyes, R. A., Bolivar, R. B., Bentsen, H. B. and Eknath A. E. 1994. Early growth and survival of eight strains of Nile tilapia (*Oreochromis niloticus*) and their crosses. **In**: *The Third Asian Fisheries Forum.* (Chou, L. M., Munro, A. D., Lam, T. J., Chen, T. W., Cheong, L. K. K., Ding, J. K., Hooi, K. K., Khoo, N. W., Phang, V. P. E., Shim, K. F. and Tan, C. H., editors) Asian Fisheries Society, Manila, Philippines. ICLARM contribution No. 895.

Bolivar, R. B. and Eknath, A. E. 1994. Effect of Sampling Frequency on the Growth and Survival of Nile Tilapia *Oreochromis niloticus* in hapas. *Asian Fisheries Science,* **7**: 129–133. Asian Fisheries Society, Manila, Philippines.

Bolivar, R. B., Bartolome, Z. P. and Newkirk, G. F. 1994. " Response to within – Family Selection for Growth in Nile Tilapia (*Oreochromis niloticus*)" **In:** *The Third Asian Fisheries Forum.* (Chou, L. M., Munro, A. D., Lam, T. J., Chen, T. W., Cheong, L. K. K., Ding, J. K., Hooi, K. K., Khoo, N. W., Phang, V. P. E., Shim, K. F. and Tan, C. H., editors) Asian Fisheries Society, Manila, Philippines. 1135p.

Bolivar, R. B. and Newkirk,. G. F. 2000. Response to selection for body weight of Nile tilapia (*Oreochromis niloticus*) in different culture environments. P. 12–23. **In:** *Tilapia Aquaculture in the 21st Century.* (K. Fitzsimmons and J. C. Filho, editors) Proceedings of the Fifth International Symposium on Tilapia in Aquaculture, Panorama da Aquicultura – Magazine, Rio de Janeiro, Brazil. Vol. 1. 320p.

Bosworth, B. G., Wolters, W. R., Klesius, P. H. and Wise, D. J. 1998. Estimation of genetic parameters for juvenile growth and resistance to the bacterium *Edwardsiella ictaluri* from a diallele cross among channel catfish, blue catfish and their F1 hybrid. *World Aquaculture Society,* **143**: 57.

Bovenhuis, H., Brascamp, P. and Van der Werf, J. 1995. *Variation and selection.* Lecture Notes. Animal genetics. Wageningen University. Animal Sciences. 144p.

Brzeski, V. J. and Doyle, R. W. 1988. A morphometric criterion fodetermination in tilapia. Pp. 439– 444. **In:** *The Second International Symposium on Tilapia in Aquaculture.* (R. S V. Pullin, T. Bhukaswan, K. Tonguthai and J. L. Maclean, editors) ICLARM Conference Proceedings 15, 623 p. Department of Fisheries, Bangkok, Thailand, and International Center for Living Aquatic Resources Management, Manila. Philippines.

Chang, S. L., Huang, C. M. and Liao, I. C. 1988. The effect of various feed on seed production by Taiwanese red tilapia. Pp. 319 – 322. **In:** *The Second International Symposium on Tilapia in Aquaculture.* (R. S. V. Pullin, T. Bhukaswan, K. Tonguthai and J. L. Maclean, editors) ICLARM Conference Proceedings 15, 623 p. Department of Fisheries, Bangkok, Thailand, and International Center for Living Aquatic Resources Management, Manila. Philippines.

Changadeya, W., Malekano, L. B. and Ambali, A. J. D. 2003. Potential of genetics for aquaculture development in Africa. *Naga, WorldFish Center Quarterly,* **26** (3) : 31 - 35.

Chevassus, B. 1979. Hybridization in salmonids: Results and perspectives. *Aquaculture,* **17** : 113 – 128.

Chimits, P. 1957. *The tilapia and their culture*. FAO Fish Bull. **10**: 1-24.

Cunningham, E. P. 1995. Analysis of variance methods for Animal Breeding Data. P12-4. *Lecture Notes. Intensive Training Program on the Application of Quantitative Genetics to Aquaculture*. IIRR, Silang, Cavite, Philippines.

Dalton, D. C. 1981. *An introduction to practical animal breeding*. Pp. 52. Mackays of Cartham Ltd. Publishers, Kent.

De Vera, M. P. 1988. Breeding strategies. Module 4a. **In** : *Manual on Genetic Improvement of Farmed Tilapia (GIFT) Research Methodologies*. (B. O. Acosta and A. E. Eknath, editors) Vol. 1. ICLARM. Manila. (Mimeo) United Nations Development Programme–Sustainable Energy and environment Division GLO/90/016.

Dionisio, E. E. 1995. Progeny sex ratio in a complete diallel cross with eight diverse strains of Nile tilapia (*Oreochromis niloticus* L.) MS. Thesis submitted to the Central Luzon State University Munoz, Nueva Ecija, Philippines. 64 pp.

Dunham, R. A. and Smitherman,.R. O. 1983. Response to selection and realized heritability for body weight in three strains of channel catfish *Ictalurus punctatus*, grown in earthen ponds. *Aquaculture*, **33** : 89– 96.

Ehlinger, N. F. 1977. Selective breeding of trout for resistance to furunculosis. *New York Fish and Game Journal*, **24**: 25 – 36.

Eknath, A. E., Tayamen, M. M., Palda – de Vera, M. S., Danting, J. C., Reyes, R., Dionisio, E. E., Capili, J. B., Bolivar, H. L., Abella, T. A., Circa, A. V., Bensen,,H. B., Gjerde, B., Gjedrem, T. and Pullin, R S. V. 1991. Genetic improvement of farmed tilapias: the growth performance of eight strains of *Oreochromis niloticus* tested in different environments. Paper presented at *the*

Fourth International Symposium on Genetics in Aquaculture, Wuhan, China, April 29 to May 3, 1991.

Eknath, A.E., Tayamen, M. M., Palada-de Vera, M. S., Danting, J. C., Reyes, R. A., Dionisio, E. E., Capili, J. B., Bolivar, H L., Abela, T. A., Circa, A.V., Bentsen, H. B., Gjerde, B., Gjedrem, T. and Pullin, R.S.V. 1993a Genetic improvement of farmed tilapia: The growth performance of eight strains of *Oreochromis niloticus* tested in different farm environments. *Aquaculture,* **111**: 171 - 188.

Eknath, A. E., Tayamen, M. M., Palada-de Vera, M., Casayuran- Danting, J., Reyes, R. A., Dionisio, E., Bolivar, H., Bentsen, H. B., Gjerde, B., Gjedrem, T. and Pullin, R. S. V. 1993b. Genetic improvement of farmed tilapias: a complete diallele cross between four African and Asian strains of Nile tilapia (*Oreochromis niloticus*) **In** *Genetic Improvement of farmed Tilapias (GIFT)* Project Final Report (March 1988 to December 1997). Part 2. August 1998. International Center for Living Aquatic Resources Management, Manila, Philippines.

Eknath, A. E. 1995. *The Nile Tilapia in conservation of fish and shellfish Resources*: Managing Diversity. (J. E. Thorpe, G. A. E. Gall, J. E. Lannan and C. E. Nash, editors) Published by Academic Press, Harcourt Brace and Company, New York.

Elgobashy, H. A., Rahman, A., El Gamal, A. and Khater, A. M. 2000. Growth evaluation of four local strains of Nile tilapia (*Oreochromis niloticus*) under different farming conditions in Egypt. p. 346 – 351. **In:** *Tilapia Aquaculture in the 21st Century.* (K. Fitzsimmons and J. C. Filho, editors) Proceedings of the Fifth International Symposium on Tilapia in Aquaculture, Panorama da Aquicultura – Magazine, Rio de Janeiro, Brazil. Vol. 2. 682 pp.

FAO/WHO/OAU. 1984. National food and nutrition policies and programs 1985 – 1989. Accra. Joint FAO/WHO/OAU Regional Food and Nutrition Commission : 106 pp.

Fitzsimmons, K. 2000. Tilapia. the most important aquaculture species of the 21st century, p. 3 – 8. **In**: *Tilapia Aquaculture in the 21st Century.* (K. Fitzsimmons and J. C. Filho, editors) Proceedings of the Fifth International Symposium on Tilapia in aquaculture, Vol. 1, 320p.

Fricke, H., Horstgen-Schwark, G., Langholz, H. J. and Meyer, J. N. 1984. The effect of strain crossing on the production performance in trout. 35th Annual meeting of the EAAP. The Hague, Netherlands, 6 – 9 August 1984. Vol. 1. Summaries. Study commissions. Genetics, nutrition, management. Paper No. G 6.2 p. 2.

Gall, G. A. 1969. Quantitative inheritance and environmental response of rainbow trout. **In** : *Fish in Research.* (O. W. Neuhaus and J. Halver, editors) Academic Press, New York. Pp. 177 – 185.

Gall, G. A. E. and Huang, N. 1988 a. Heritability and selection schemes for rainbow trout: body weight. *Aquaculture,* **73**: 43-56.

Gall, G. A. E. and Huang, N. 1988 b. Heritability and selection schemes for rainbow trout : female reproductive performance. *Aquaculture,* **73**: 57-66.

Gall, G. A. E., Bakar, Y. and Famula, T. 1993. Estimating genetic change from selection. **In:** *Genetics in Aquaculture.* (G. A. E. Gall and H. Chen, editors) IV Proceedings of the Fourth International Symposium, 29 April – 3 May 1991, Wuhan, China. Aquaculture, Vol. **111.** pp. 75 – 88, Amsterdam.

Gela, D. and Linhart, O. 2000. Evaluation of slaughter value of common carp from diallele crossings. *Czech Journal of Animal Science,* **45** (2) : 53 – 58.

Gerlai, R. and Crusio, W. E. 1995. Organization of motor and posture patterns in paradise fish (*Macropodus opercularis*): environmental and genetic components of phenotypical correlation structures. *Behaviour Genetics,* **25** (4): 385 – 396.

Genetic Improvement of Farmed Tilapias (GIFT) Project – Final Report. 1992. International Center For Living Aquatic Resources Management (ICLARM). Project No. GLO/90/016.

Gilmour, A.R., Gogel, J. B., Cullis, B. R., Welham, S. J. and Thompson, R. 2002. ASReml User Guide Release 1.0 VSN International Ltd, Hemel Hempstead, HP1 1ES, UK.

Gjedrem, T. 1976. Possibilities for genetic improvements in salmonids. *Journal of Fish Research Board Canada* **33** : 1094 – 1099.

Gjedrem, T. 1983. Genetic variation in quantitative traits and selective breeding in fish and shellfish. *Aquaculture,* **33**, 51 – 72.

Gjedrem, T. 1997. Selective breeding to improve aquaculture production. *World Aquaculture,* March 1997, pp. 33 - 45.

Gjedrem, T. and Thodesen, J. 2005. Selection, **In**: *Selection and Breeding Programs in Aquaculture,* (T. Gjedrem, editor). Springer Publishing, Dordrecht, The Netherlands, pp. 89 – 111.

Gjedrem, T. 2005. Breeding plans, **In**: *Selection and Breeding Programs in Aquaculture,* (T. Gjedrem, editor). Springer Publishing, Dordrecht, The Netherlands, pp. 251 – 277.

Gjerde, B. 1988. Complete diallele cross between six inbred groups of rainbow trout. *Journal of Animal Science* **40**: 19 – 28.

Gjerde, B. and Refstie, T. 1984. Complete diallele cross between five strains of Atlantic salmon. *Livestock Production Science* **11**: 207 – 266.

Gjerde, B. and Rye, M. 1997. Design of breeding programs in Aquaculture species - possibilities and constraints. "Genetics and Breeding of Mediterranean Aquaculture species" Zaragoza, Spain, April 28- 30 1997.

Gjerde, B., Reddy, P. V. G. K., Mahapatra, K. D., Saha, J. N., Jana, R. K., Meher, P. K., Sahoo, M., Lenka, S., Govindassamy, P. and Rye M. 2002. Growth and survival in two complete diallele crosses with five stocks of Rohu carp (Labeo rohita). *Aquaculture,* **209** (1) : 103– 105.

Guerrero, R. D. 1973. Cage culture of male and female *Tilapia mossambicus* with and without supplementary feeding in a fertilized pond.*Central Luzon Stata University Science Journal,* **9**: 18 – 20.

Guerrero, R. D. III. and Guerrero, L. A.. 1975. Monosex culture of male and female Tilapia mossambica in ponds at three stocking rates, Kalikasan, *Philippines Journal of Biology,* **4**: 129 – 134.

Guerrero, R. D. and Guerrero, L. A. 1985. Further observations on the fry production of *Oreochromis niloticus* in concrete tanks. *Aquaculture,* **47**: 257 – 261.

Gunnes, K. and Gjedrem, T. 1978. Selection experiments with salmon : IV. Growth of Atlantic salmon. *Livestock Prod. Sci.,* **11**: 207 – 226.

Gunnes K., and Gjedrem, T. 1981. A genetic analysis of body weight and length in rainbow trout reared in seawater for 18 months. *Aquaculture,* **24**: 161 – 174.

Gupta, M. V., Acosta, B. O., Dunham, R. and Gardiner, P. R. 2001. Fish Genetics Research at the International Center for Living Aquatic Resources Management, P. 97 – 102. **In** *Fish genetics research in member countries and Institutions in the International Network on Genetics in Aquaculture.* (M. V. Gupta and B. O. Acosta, editors) ICLARM Conf. Proc., 64, 279 pp.

Hall, J. B. and Swaine, M. D. 1981. *Distribution and ecology of vascular plants in a tropical rain forest vegetation in Ghana*. W. Junk, The Hague. 383 pp.

Horstgen-schwark, G., Fricke, G. H. and Langhole, H. T. 1986. The effect of strain crossing on the production performance in rainbow trout. *Aquaculture,* **57** (4): 141 – 152.

Hughes, D. G. and Behrends, L. L. 1983. Mass production of *Tilapia nilotica* seed in suspended net enclosures. **In :** *Proceedings of the International symposium on Tilapia Aquaculture* P. 394 – 401. (L. Fishelson and Z. Yaron, editors). Israel, Tel Aviv University. Nazareth.

Hulata, G., Rothbard, S., Itzkorich, J., Wohlfarth, G. and Halevy, A. 1985. Differences in hybrid fry production between two strains of the Nile tilapia. *Progressive Fish – Culture,* **47**: 42 - 49.

Hulata, G., Wohlfarth, G. W. and Halevy, A. 1986. Mass selection for growth rate in the Nile tilapia (*Oreochromis niloticus*) *Aquaculture,* **57**: 177-184.

Hussain, M. G., Islam, M. S., Hussain, M. A., Wahid, I. M., Kohinoor, A. H. M., Dey, M. M. and Mazid, A. M. 2002. Stock improvement of silver barb (*Barbodes gonionotus* Bleeker) through several generations of genetic selection. *Aquaculture,* **204** (3/4) 469 – 480.

Hussain, M. G. 2004. *Farming of tilapia: Breeding plans, mass seed production and aquaculture techniques*. Habiba Akter Hussain, 55 Kristawpur, Mymensingh 2200, Bangladesh. pp 97.

INSTAT. 1993. Graphpad Software, V 2.02. 10855 Sorrento valley Road No.203. San Diego C. A. 92121 USA.

Ihssen, P. 1976. Selective breeding and hybridization in fisheries management. *J. Fish Res. Board Can.,* **33**: 316 – 321.

Jamu, D. M. and Ayinla, O. A. 2003. Potential for the development of aquaculture in Africa. *Naga, Worldfish Center Quarterly,* **26** (3): 9 -13.

Jayaprakas, V., Tave, D. and Smitherman, R. O. 1988. Growth of two strains of *Oreochromis niloticus* and their F-1, F-2 and backcross hybrids. **In:** *The Second International Symposium on Tilapia in Aquaculture*. (R.S.V. Pullin, T. Bhukaswan, K. Tonguthai and J.L. Maclean, editors) Department of Fisheries, Bangkok, Thailand, and International Center for Living Aquatic Resources Management, Manila. Philippines. pp. 197 – 201.

Kamel, E. A. 1999. Genetic Studies on Nile tilapia *Oreochromis niloticus* in Egypt. PhD. Dissertation, Department of Zoology, Girls College for Arts, Science and Education, Ain Shams University, Cairo, Egypt.

Khater, A.A.E. 1985. Identification and comparison of three *Tilapia nilotica* strains for selected aquaculture traits. Doctoral dissertation. Auburn University, Alabama, USA.

Khater, A. A. and Smitherman, R. O. 1988. Cold tolerance and growth of three strains of Oreochromis niloticus. **In:** *The Second International Symposium on Tilapia in Aquaculture.* (R. S. V. Pullin, T. Bhukaswan, K. Tonguthai and J. L. Maclean, editors) ICLARM Conference Proceedings 15, 623 p. Department of Fisheries, Bangkok, Thailand, and International Center for Living Aquatic Resources Management, Manila. Philippines. pp. 215 – 218.

Kirpichnicov, V. S., Ilyassov,Y. I., Shart, L. A., Vikhman, A. A., Ganchenko, M. V., Ostashevsky, L. A., Simonov, V. M., Tikhonov, G. F. and Tjurin, V. V. 1993. Selection of Krasnodar common Carp (*Cyprinus carpio* L.) for resistance to dropsy : principal results and prospects. *Aquaculture,* **111**: 7 – 20.

Klupp, R. 1979. Genetic variance for growth in rainbow trout (*Salmo gairdneri*) *Aquaculture,* **18** (2): 123 – 134.

Kocher, T. D. 1997. Introduction to the genetics of tilapia, pp. 61 – 64. **In :** *Tilapia Aquaculture.* (K. Fitzsimmons, editors) *Proceedings from the Fourth International Symposium on Tilapia in Aquaculture,* Northeast Regional Agricultural Engineering Extension, Ithaca, New York, Vol. 1, 433 pp.

Kolstad, K. 2005. Estimating phenotypic and genetic parameters. P. 135-136. **In :** *Selection and Breeding Programs in Aquaculture.* (T. Gjedrem, editor) Springer Publishing, Dordrecht, The Netherlands.

Lee, J. C. 1979. Reproduction and hybridization of three ciclid fishes, *Tilapia aurea, T. hornorum* and *T. nilotica* in aquaria and in plastic pools. PhD. Dissertation, Auburn University, AL. 84 pp.

Little, D. C., Macintosh, D. J. and Edwards, P. 1993. Improving spawning synchrony in the Nile tilapia, *Oreochromis niloticus* (L.) *Aquaculture and Fisheries Management,* **24**: 399 – 405.

Lovshin, L. L. and Ibrahim, H. H. 1988. Effects of broodstock exchange on *Oreochromis niloticus* egg and fry production in net enclosures. **In:** *The Second International Symposium on Tilapia in Aquaculture.* (R. S. V. Pullin, T. Bhukaswan, K. Tonguthai and J. L. Maclean, editors) ICLARM Conference Proceedings 15, 623 p. Department of Fisheries, Bangkok, Thailand, and International Center for Living Aquatic Resources Management, Manila. Philippines, pp 231 – 236.

Lush, J. L. 1947. Family merit and individual merit as basis for selection. Part I *American Nature,* **81**: 241-261 Part II *American Nature* **81**: 362-379.

Macaranas, M. J., Mather, P. B., Satya, N. L., Vereivalu, T., Lagibalavu, M. and Capra, M. F. 1997. Genotype and environment : A comparative evaluation of four tilapia stocks in Fiji. *Aquaculture,* **150**: 11 – 24.

Mao, I. L., and Shaeffer, L. 1993. Techniques for analyzing unbalanced data (with emphasis on applications to breeding and genetics research) – a note for linear models and estimation of breeding values. An Inter nordic Post-Graduate Course2 – 13, 1993, Honne, Norway.

Marengoni, N. G., Onoue, Y. and Oyama, T. 1998. Offspring growth in a diallel crossbreeding with three strains of Nile tilapia *Oreochromis niloticus*. *Journal of the World Aquaculture Society,* **29**-(1) 114 – 119.

Meyer, K. and Hill, W. G. 1991. Mixed model analysis of a selection experiment for food intake in mice. *Genetic Research,* **57**: 71 – 81.

Mires, D. 1982. A study of the problems of the mass production of hybrid tilapia fry. **In:** *The Biology and Culture of Tilapias*. (Pullin, R. S. V., Low- McConnel, R. H., editors) ICLARM Conference Proceedings 7, International Center for Living Aquatic Resources Management, Manila, Philippines. P. 317 – 329. 432p.

Moav, R. and Wohlfarth, G. W. 1968. Genetic Improvement of yield in carp. Proceedings of the World Symposium on Warm Water pond Fish Culture. FAO Fish Report No. 44 (4) : 12 – 29.

Moav, R., Hulata, G. and Wohlfarth, G. 1975. Genetic differences between the Chinese and European races of the common carp. Analysis of genotype - environment interactions. *Heredity,* **34**: 323 - 340.

Moav, R. and Wohlfarth, G. W. 1976. Two way selection for growth rate in common carp (*Cyprinus carpio* L.). *Genetics*, **82**: 83-101.

Moav, R., Brody, T. and Hulata, G. 1978. Genetic improvement of wild fish populations. *Science,* **201**: 1090 – 1094.

Neira, R.R., Diaz, P. F., Estay, C. and Garcia, F. X. 1990. Results from crossing wild and hatchery rainbow trouts *Oncorhynchus mykiss*. *Av. Prod. Anim.,* **15** (1 – 2) 115 – 121.

Nelson, D. M. and Kapuscinski, A. R. 1990. Application of diallele crosses to lake trout (*Salvelinus namaycush*) stock evaluation. *Aquaculture,* **85** (1 – 4) 322 – 323.

Ofori, J. K., Attipoe, F. Y. K. and Abban, E. K. 1999. A simple and inexpensive fish tagging method. *Naga*, **22** (2) 32 – 34.

Okamoto, N., Tayama, T., Kawanobe, M., Kawanobe, N., Yasuda, Y., and Sano, T. 1993. Resistance of a rainbow trout strain to infectious pancreatic necrosis. *Aquaculture,* **117**: 71 – 76.

Oldorf, W., Kronet, U., Balarin, J., Haller, R., Horstgen – Schwark, G. and Langhoiz, H. J. 1989. Prospects for selecting for late maturity in tilapia (*O. niloticus*). Strain comparison under laboratory and field conditions. *Aquaculture,* **77**: 123 - 133.

Owusu, B. S., Kuwornu, L. and Lomo, A. 2001. Integrated irrigation – aquaculture research in Ghana. **In** *Proposal for an African Network on Integrated Irrigation and Aquaculture,* 75 p. (J. F. Moehl, I. Beernaerts, A. G. Coche, M. Halnart and V. O. Sagua, editors).

Owusu-Frimpong, M., Attipoe, F. Y. K. and Padi, J. N. 1992. Development of Improved Cultural Systems for Increased Pond Production. Year Four Report 1st August 1992 – 31st July 1993. Pond Culture (Ghana): 3-P 88-0261. IAB/IDRC-4.

Pagan, F. A. 1970. Cage culture of the cichlid fish Tilapia aurea (Steindachner). Doctoral dissertation, Auburn University, Alabama, USA.

Palada – de Vera, M. S. and Eknath, A. E. 1993. Predictability of individual growth rates in tilapia. *Aquaculture,* **111** : 147 – 158.

Ponzoni, R. W. 2002. Genetic analysis of dialleles. *Lecture Notes. Third Training Course on Quantitative Genetics and its Application to Aquaculture.* Pathumthani, Thailand.

Pullin, R.S.V. 1985. Tilapias: 'everyman's fish' *Biologist* **32** (2): 84 - 88.

Rana, K.J. 1997. *Status of global production and trends.* FAO Fish Circ. No. 886. FAO. Rome.

Reddy, P. V. G. K., Gjerde, B., Tripathi, S. D., Jana, R. K., Mahapatra, K. D., Gupta, S. D., Saha, J. N., Lenka, S., Sahu, M., Govindassamy, P., Rye, M. and Gjedrem, T. 2002. Growth and survival of six stocks of rohu (*Labeo rohita*) in mono- and polyculture production systems. *Aquaculture,* **203**: 239 – 250.

Refstie, T. and Gjedrem, T. 1975. Hybrids between salmonidae species. III. Genetic and environmental sources of variation in length and weight of Atlantic Salmon in the fresh water phase. *Aquaculture,* **14**: 221 – 234.

Refstie, T. 1990. Application of breeding schemes. *Aquaculture,* **85**: 163 - 169.

Ridha, M. T. and Cruz, E. M. 1999. Effect of different broodstock densities on the reproductive performance of Nile Tilapia, *Oreochromis niloticus* (L.) in a recycling system. *Aquaculture Research,* **30**: 203 – 210.

Rye, M. and Eknath, A. E. 1999. Genetic improvement of tilapia through selective breeding- Experience from Asia. European Aquaculture Society, Special Publication. No. 27; June 1999: 207 – 208.

Romana - Eguia, M. R. R. and Doyle, R. W. 1992. Genotype - environment interaction in the response of three Nile tilapia strains to poor nutrition. *Aquaculture,* **108**: 1 - 12.

SAS Institute Inc., 1990. SAS/STAT® User's Guide, Version 6, Fourth Edition, Vols. 1 and 2 Cary, NC, USA.

Schoenen, P. 1982. A Bibliography of Important Tilapias (Pisces: Ciclidae) for Aquaculture. ICLARM Bibliographies 3. International Center for Living Aquatic Resources Management, Manila.

Shehadeh, Z.H. (editor) 1976. *Report of the symposium on aquaculture in Africa .Accra. Ghana*. FAO/CIFA Technical Paper 4 : 36.``

Shelton, W. L., Hopkins K. D. and Jensen, G. L. 1978. Use of hormones to produce monosex tilapia for aquaculture. **In:** *Proceedings of Symposium on Culture of Exotic Fishes.* (R. O. Smitherman, W. L. Shelton and J. H. Grover, editors) Fish Culture Section, American Fish Society, Auburn University, Auburn, USA, pp. 10 – 33.

Shelton, W. L., Meriwether, F. H., Semmens, K. D. and Calhoun, W. E. 1983. Progeny sex ratios from intraspecific pair spawnings of *Tilapia aurea* and *Tilapia nilotic.* **In**: *Proceedings of the International Symposium on Tilapia in Aquaculture*, 8-13 May 1983. (L. Fishelson and Z. Yaron, editors) Nazareth, Israel. Tel Aviv University, Israel, pp. 270-280.

Smitherman, R. O. and Dunham, R. A. 1985. Genetics and breeding, pp 283– 316. **In :** *Channel catfish culture* (C. S. Tucker, editor) Elsevier Scientific Publishing, Amsterdam, The Netherlands.

Smitherman, R. O., Khater, A. A., Cassel, N. I. and Dunham, R. A. 1988. Reproductive performance of three strains of *Oreochromis niloticus*. *Aquaculture,* **70**: 29– 37.

Sneed, K. E. 1971. Some current North American work in hybridization and selection of cultured fishes. **In**: *FAO Seminar / Study tour in the USSR on genetic selection and hybridization of cultivated fishes.*Rep. FAO / UNDP – (TA) 2926, pp 143 – 150.

Stone, N. M. 1980. Growth of male and female *Tilapia nilotica* in ponds and cages. Master's thesis. Auburn University, Alabama, USA.

Suzuki, R. and Yamaguchi, M. 1980. Improvement of quality in the common carp. *Aquaculture,* **113**: 31 – 46.

Tave, D. 1988. Genetics and breeding of tilapia: a review, pp 285-293. **In**: *The Second International Symposium on Tilapia in Aquaculture*. (R.S.V. Pullin, T. Bhukaswan, K. Tonguthai and J.L. Maclean, editors) ICLARM Conference Proceedings 15, 623 p. Department of Fisheries, Bangkok, Thailand, and International Center for Living Aquatic Resources Management, Manila. Philippines.

Tave, D. and Smitherman, R. O. 1980. Predicted response to selection for early growth in *Tilapia nilotica. Transactions of the American Fisheries Society,* **109**: 439 – 445.

Tave, D., Smitherman, R.O., Jayaprakas, V. and Kuhlers,D.L. 1990. Estimates of additive genetic effects, maternal genetic effects, individual heterosis, maternal heterosis and egg cytoplasmic effects for growth in *Tilapia nilotica. Journal of the World Aquaculture Society,* **21**: 263 - 270.

Tayamen, M. M., Reyes, R. A., Danting, Ma. D., Mendoza, A. M., Marquez, E. B., Salguet, A. C., Gonzales, R. C., Abella, T. A. and Vera-Cruz, E. M. 2002. Tilapia broodstock development for saline waters in the Philippines. Naga, The ICLARM Quarterly, **25** (1): 32-36.

Teichert-Coddington, D. R. and Smitterman, R. O. 1988. Lack of response by T*ilapia niloticus* to mass selection for rapid early growth. *Trans American Fish Society*, **117:** 297-300.

Tesch, F. W. 1971. Age and growth. **In:** *Methods for assessment of fish production in fresh waters* (W. E. Ricker, editor) 2nd edition. Blackwell, Oxford. P. 98–130.

Uraiwan, S. and Doyle, R. W. 1986. Replicate variance and the choice of selection procedures for tilapia (*Oreochromis niloticus*) stock improvement in Thailand. *Aquaculture,* **57**: 93-98.

Uraiwan, S. and Phanitchai, V. 1986. A study of strain selection of *Tilapia nilotica. Aquaculture,* **57**: 376 - 377.

Wedekind, H., G. HÖrstgen-schwark and Langholz, H. J. 1990. Investigations on sex ratio in *Oreochromis niloticus*. *Aquaculture,* **85**: 321 – 322.

Windmar, L., S. Jarding and Paterson, R. 2000. Current status of tilapia aquaculture and processing in Zimbabwe. P. 595 – 597 **In** : *Tilapia Aquaculture* (K. Fitzsimmons and J. C. Carvalho Filho, editors) Proceedings of the Fifth International Symposium on Tilapia in Aquaculture, Panorama da Aquicultura – Magazine, Rio de Janeiro, Brazil.

Wohlfarth, G. W. and Moav, R. 1969. The genetic correlation of growth rate with and without competition in carp. *International Association of Theoretical Applications in Limnology Procedures,* **17**: 702 – 704.

Wohlfarth, G.W., Moav, R. and Hulata, G. 1983. A genotype- environment interaction for growth rate in the common carp, growing in intensive manured ponds. *Aquaculture,* **33**: 187 - 195.

Wolters, W. R. and Johnson, M. R. 1995. Analysis of a diallel cross to estimate effects of crossing channel catfish, *Ictalurus punctatus. Aquaculture,* **137** (1 – 4) 263 – 269.

World Bank. 1985. Ghana Agricultural sector rewiew. Washington, World Bank Report (5366-GH): 32p.

WorldFish Center 2004. *GIFT Technology Manual. An aid to Tilapia Selective Breeding.* WorldFish Center, Penang, Malaysia. 50 p.

Yapi -Gnaore, C. V. 1996. Estimation of additive and non - additive genetic parameters in the growth of fry of three strains of *Oreochromis spp.* **In** : *The Third International Symposium on Tilapia in Aquaculture* (R. S. V. Pullin, J. Lazard, M. Legendre, Amon Kottias, Pauly, J. B. and D. editors) ICLARM Conf. Proc. No. 41, pp. 426 – 423.

Yates, F. 1934. The Analysis of Multiple Classifications with Unequal Numbers in the Different Subclasses. *Journal of American Statistics Ann.,* **29**: 51 – 66.

APPENDICES

Appendix 1

Composition of formulated diets used to feed fry, fingerlings and breeders of *O. niloticus*.

Ingredients	Percentage composition	
	WRI TF2	WRI TF3
Wheat bran	66.7	70.0
Groundnut bran	33.3	-
Fish meal	-	30.0
Vitamin premix	trace	trace

Appendix 2a

Breeding values and ranking of female *Oreochromis niloticus (generation 2)* reared in three culture environments.
(fish_ID = fish identification; env= culture environment, 1 = extensive, 2 = semi-intensive, 3 = intensive; bv = breeding value of individual fish; wt = final weight; rank_bv = ranks based on breeding values; m_bv = breeding value of family).

m_bv=10.5447

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
1	2005078	1001050	F	2	16.550	70.22	1.0
2	2005046	1001050	F	3	16.100	126.37	2.0
3	2005041	1001050	F	3	14.910	112.45	3.0
4	2005060	1001050	F	3	13.400	102.51	5.0
5	2005057	1001050	F	2	13.340	45.44	6.0
6	2005067	1001050	F	3	13.270	97.11	7.0
7	2005038	1001050	F	1	12.990	44.60	9.0
8	2005076	1001050	F	2	12.940	44.78	10.0
9	2005063	1001050	F	3	12.810	95.61	11.0
10	2005042	1001050	F	3	12.400	91.86	12.0
11	2005058	1001050	F	3	12.120	85.48	13.0
12	2005025	1001050	F	1	11.960	38.20	15.5
13	2005006	1001050	F	1	11.320	31.90	19.0
14	2005019	1001050	F	1	10.960	33.70	20.0
15	2005008	1001050	F	1	10.870	32.07	21.0
16	2005039	1001050	F	1	10.820	31.30	22.5
17	2005026	1001050	F	1	10.730	29.80	24.0
18	2005015	1001050	F	1	10.650	31.60	26.5
19	2005001	1001050	F	1	10.410	27.50	29.0
20	2005055	1001050	F	2	10.350	46.24	30.0
21	2005018	1001050	F	1	10.300	28.76	31.0
22	2005056	1001050	F	3	10.170	72.73	34.0
23	2005014	1001050	F	1	10.090	28.22	35.0
24	2005011	1001050	F	1	9.979	26.40	36.0
25	2005059	1001050	F	3	9.722	69.80	39.0
26	2005007	1001050	F	1	9.666	24.21	42.0
27	2005043	1001050	F	2	9.616	40.01	44.5
28	2005077	1001050	F	2	9.616	40.01	44.5
29	2005027	1001050	F	1	9.452	23.70	47.0
30	2005035	1001050	F	1	9.449	23.65	48.0
31	2005028	1001050	F	1	9.238	23.19	50.0
32	2005073	1001050	F	3	9.218	65.93	51.0
33	2005044	1001050	F	3	9.119	64.25	55.0
34	2005021	1001050	F	1	8.891	22.00	61.0
35	2005040	1001050	F	1	8.886	21.91	62.0
36	2005005	1001050	F	1	8.827	20.91	63.0
37	2005022	1001050	F	1	8.823	19.29	64.0
38	2005009	1001050	F	1	8.805	20.54	66.0
39	2005079	1001050	F	2	8.795	33.90	67.0
40	2005029	1001050	F	1	8.609	20.34	69.0
41	2005003	1001050	F	1	8.529	20.54	73.0
42	2005075	1001050	F	2	8.490	31.85	76.0
43	2005061	1001050	F	2	8.330	30.70	82.0
44	2005064	1001050	F	2	8.120	30.26	91.0
45	2005031	1001050	F	1	7.907	17.80	100.0
46	2005062	1001050	F	2	7.511	26.18	109.0

m_bv=8.5549

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
47	2017074	1076067	F	2	14.410	66.84	4.0
48	2017019	1076067	F	1	13.230	59.80	8.0

49	2017078	1076067	F	3	11.960	106.33	15.5
50	2017039	1076067	F	1	11.500	44.50	17.0
51	2017067	1076067	F	3	11.450	103.96	18.0
52	2017022	1076067	F	1	10.720	42.30	25.0
53	2017052	1076067	F	2	10.650	40.56	26.5
54	2017068	1076067	F	3	10.460	90.34	28.0
55	2017008	1076067	F	1	10.280	38.00	32.0
56	2017014	1076067	F	1	10.230	41.80	33.0
57	2017042	1076067	F	2	9.892	55.82	37.0
58	2017064	1076067	F	3	9.714	87.02	40.0
59	2017054	1076067	F	3	9.713	85.45	41.0
60	2017010	1076067	F	1	9.513	34.30	46.0
61	2017033	1076067	F	1	9.285	35.11	49.0
62	2017059	1076067	F	3	9.172	77.84	53.0
63	2017044	1076067	F	2	9.169	31.06	54.0
64	2017023	1076067	F	1	8.928	30.63	59.0
65	2017057	1076067	F	3	8.576	75.54	70.0
66	2017005	1076067	F	1	8.562	29.10	71.0
67	2017050	1076067	F	2	8.527	45.15	74.0
68	2017058	1076067	F	3	8.469	70.60	77.0
69	2017070	1076067	F	3	8.404	72.61	80.0
70	2017049	1076067	F	2	8.351	42.17	81.0
71	2017034	1076067	F	1	8.284	27.50	84.0
72	2017030	1076067	F	1	8.231	25.05	86.0
73	2017032	1076067	F	1	8.176	28.80	88.0
74	2017063	1076067	F	3	8.160	70.04	90.0
75	2017062	1076067	F	2	8.116	41.31	92.0
76	2017017	1076067	F	1	8.031	27.90	94.0
77	2017060	1076067	F	2	8.008	41.04	95.0
78	2017009	1076067	F	1	8.003	25.86	96.0
79	2017024	1076067	F	1	7.947	26.48	98.0
80	2017043	1076067	F	2	7.925	39.63	99.0
81	2017026	1076067	F	1	7.541	21.15	106.0
82	2017025	1076067	F	1	7.527	22.48	108.0
83	2017072	1076067	F	2	7.347	36.08	114.0
84	2017002	1076067	F	1	7.299	23.30	117.0
85	2017001	1076067	F	1	7.012	21.55	127.0
86	2017047	1076067	F	2	6.912	33.39	130.0
87	2017065	1076067	F	2	6.881	32.85	133.0
88	2017037	1076067	F	1	6.570	20.30	145.0
89	2017040	1076067	F	1	6.284	18.57	156.0
90	2017066	1076067	F	3	6.250	54.82	157.0
91	2017061	1076067	F	2	6.217	29.41	160.0
92	2017048	1076067	F	2	5.877	26.77	175.0
93	2017041	1076067	F	3	5.547	47.58	189.0
94	2017053	1076067	F	3	5.319	46.85	195.0
95	2017045	1076067	F	3	4.561	43.36	232.0

------------------------------------ m_bv=6.9602 ------------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
96	2004079	1001067	F	2	12.010	62.73	14.0
97	2000004	1001067	F	1	8.981	41.60	57.0
98	2004027	1001067	F	1	8.932	43.90	58.0
99	2004057	1001067	F	2	8.905	42.92	60.0
100	2004037	1001067	F	1	8.820	42.00	65.0
101	2004032	1001067	F	1	8.420	39.90	79.0
102	2004008	1001067	F	1	8.175	37.30	89.0
103	2004072	1001067	F	2	7.993	36.82	97.0
104	2004058	1001067	F	2	7.770	33.04	102.0
105	2004006	1001067	F	1	7.720	37.40	103.0
106	2004009	1001067	F	1	7.428	34.00	111.0
107	2004035	1001067	F	1	7.351	32.71	113.0
108	2004003	1001067	F	1	7.321	32.20	115.0
109	2004005	1001067	F	1	7.300	33.40	116.0
110	2004068	1001067	F	3	7.247	77.13	119.0
111	2004049	1001067	F	2	7.054	30.26	125.0
112	2004038	1001067	F	1	6.876	29.34	134.0
113	2004020	1001067	F	1	6.775	30.74	139.0
114	2004067	1001067	F	2	6.688	44.36	142.0
115	2004026	1001067	F	1	6.673	29.02	143.5
116	2004017	1001067	F	1	6.200	27.23	162.0
117	2004075	1001067	F	3	6.166	65.05	163.0

118	2004078	1001067	F	3	6.108	65.63	164.0
119	2004025	1001067	F	1	6.072	26.62	166.0
120	2004056	1001067	F	2	6.057	24.28	168.5
121	2004030	1001067	F	1	5.552	22.49	188.0
122	2004018	1001067	F	1	5.309	21.50	196.0
123	2004044	1001067	F	3	5.239	58.69	200.0
124	2004001	1001067	F	1	4.855	20.05	221.0
125	2004043	1001067	F	3	4.526	54.42	234.0
126	2004052	1001067	F	2	4.149	26.28	247.0
127	2004074	1001067	F	3	4.054	46.41	252.0

------------------------------------- m_bv=6.4305 ------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
128	2016070	1076042	F	2	10.820	57.53	22.5
129	2016077	1076042	F	2	9.726	46.83	38.0
130	2016036	1076042	F	1	8.729	44.50	68.0
131	2016001	1076042	F	1	8.558	41.60	72.0
132	2016066	1076042	F	2	8.498	41.62	75.0
133	2016039	1076042	F	1	8.440	39.60	78.0
134	2016030	1076042	F	1	8.307	38.90	83.0
135	2016064	1076042	F	3	8.107	87.96	93.0
136	2016054	1076042	F	3	7.591	85.45	104.0
137	2016048	1076042	F	3	7.384	81.94	112.0
138	2016063	1076042	F	3	7.255	79.75	118.0
139	2016003	1076042	F	1	7.136	33.10	120.0
140	2016044	1076042	F	2	7.131	32.49	121.0

------------------------------------- m_bv=6.4305 ------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
141	2016071	1076042	F	2	7.117	33.82	122.0
142	2016056	1076042	F	3	7.102	78.72	123.0
143	2016017	1076042	F	1	7.065	31.90	124.0
144	2016058	1076042	F	2	6.995	31.75	128.0
145	2016043	1076042	F	2	6.967	29.71	129.0
146	2016013	1076042	F	1	6.903	32.28	131.5
147	2016023	1076042	F	1	6.903	32.28	131.5
148	2016002	1076042	F	1	6.804	30.60	136.0
149	2016076	1076042	F	2	6.798	47.14	138.0
150	2016038	1076042	F	1	6.765	31.49	140.0
151	2016045	1076042	F	2	6.553	24.25	146.0
152	2016020	1076042	F	1	6.507	30.25	147.0
153	2016033	1076042	F	1	6.487	29.90	148.0
154	2016008	1076042	F	1	6.426	27.30	150.0
155	2016073	1076042	F	3	6.336	70.41	154.0
156	2016007	1076042	F	1	5.780	25.73	179.0
157	2016068	1076042	F	2	5.717	39.74	181.0
158	2016006	1076042	F	1	5.708	24.50	182.0
159	2016046	1076042	F	2	5.559	37.07	187.0
160	2016022	1076042	F	1	5.510	21.14	190.5
161	2016005	1076042	F	1	5.341	22.96	194.0
162	2016025	1076042	F	1	5.248	24.50	198.0
163	2016010	1076042	F	1	5.242	22.84	199.0
164	2016069	1076042	F	3	5.175	61.65	205.0
165	2016079	1076042	F	2	5.022	32.64	211.0
166	2016012	1076042	F	1	5.011	20.49	213.0
167	2016062	1076042	F	3	4.503	54.95	236.0
168	2016057	1076042	F	3	4.391	59.29	238.0
169	2016060	1076042	F	2	4.279	29.41	239.0
170	2016047	1076042	F	2	4.203	28.12	246.0
171	2016053	1076042	F	3	3.806	54.05	269.0
172	2016072	1076042	F	2	3.644	26.45	279.5
173	2016078	1076042	F	3	2.252	43.32	408.0

------------------------------------- m_bv=5.4543 ------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
174	2063064	1001076	F	3	7.046	80.31	126.0
175	2063067	1001076	F	3	6.844	80.00	135.0

176	2063061	1001076	F	2	6.802	32.57	137.0
177	2063049	1001076	F	2	6.313	30.53	155.0
178	2063050	1001076	F	2	6.207	28.73	161.0
179	2063003	1001076	F	1	6.106	29.10	165.0
180	2063071	1001076	F	3	4.713	67.29	226.0
181	2063078	1001076	F	3	4.205	60.23	244.0
182	2063047	1001076	F	2	4.110	32.21	249.0
183	2063055	1001076	F	3	2.197	43.36	414.5

------------------------------------ m_bv=5.0656 ------------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
184	2052064	1026051	F	2	9.006	47.34	56.0
185	2052050	1026051	F	3	6.724	80.34	141.0
186	2052053	1026051	F	3	6.360	75.73	152.0
187	2052067	1026051	F	3	6.338	75.35	153.0
188	2052018	1026051	F	1	5.855	31.90	176.0
189	2052043	1026051	F	3	5.722	71.15	180.0
190	2052076	1026051	F	2	4.867	39.61	220.0
191	2052071	1026051	F	3	3.821	59.22	266.5
192	2052048	1026051	F	2	3.575	31.75	286.0
193	2052052	1026051	F	2	3.332	29.18	304.0
194	2052065	1026051	F	2	3.053	21.34	328.0
195	2052046	1026051	F	3	2.134	44.66	423.0

------------------------------------ m_bv=4.7914 ------------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
196	2019064	1076054	F	2	9.646	53.74	43.0
197	2019052	1076054	F	3	8.227	101.39	87.0
198	2019070	1076054	F	3	7.832	93.13	101.0
199	2019047	1076054	F	3	7.562	96.35	105.0
200	2019016	1076054	F	1	6.243	35.60	158.0
201	2019051	1076054	F	2	6.228	31.69	159.0
202	2019007	1076054	F	1	6.057	34.00	168.5
203	2019009	1076054	F	1	6.041	35.29	170.0
204	2019046	1076054	F	3	6.031	76.63	172.0
205	2019011	1076054	F	1	5.835	31.80	177.0
206	2019075	1076054	F	3	5.784	81.82	178.0
207	2019054	1076054	F	2	5.672	30.07	183.0
208	2019031	1076054	F	1	5.568	30.40	186.0
209	2019049	1076054	F	2	5.510	30.45	190.5
210	2019012	1076054	F	1	5.406	26.08	193.0
211	2019024	1076054	F	1	5.227	29.30	202.0
212	2019010	1076054	F	1	5.198	28.80	203.0
213	2019006	1076054	F	1	5.068	26.60	209.0
214	2019058	1076054	F	3	5.009	71.79	214.0
215	2019048	1076054	F	3	4.969	68.00	215.0
216	2019014	1076054	F	1	4.884	28.16	218.0
217	2019059	1076054	F	3	4.845	69.01	222.0
218	2019001	1076054	F	1	4.596	26.40	228.0
219	2019002	1076054	F	1	4.593	24.80	229.0
220	2019032	1076054	F	1	4.572	26.00	230.0
221	2019008	1076054	F	1	4.549	25.60	233.0
222	2019017	1076054	F	1	4.525	23.64	235.0
223	2019020	1076054	F	1	3.912	22.61	261.0
224	2019062	1076054	F	3	3.890	60.62	264.0
225	2019080	1076054	F	2	3.774	32.23	270.0
226	2019036	1076054	F	1	3.766	20.14	271.0
227	2019071	1076054	F	2	3.576	17.95	285.0
228	2019022	1076054	F	1	3.458	19.60	293.0

------------------------------------ m_bv=4.7914 ------------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
229	2019034	1076054	F	1	3.266	19.46	307.0
230	2019023	1076054	F	1	3.224	18.76	311.0
231	2019033	1076054	F	1	3.207	16.91	312.5
232	2019004	1076054	F	1	3.191	18.20	316.0
233	2019030	1076054	F	1	3.187	18.12	317.5

234	2019038	1076054	F	2	3.114	30.42	325.0
235	2019067	1076054	F	3	2.922	53.58	335.0
236	2019074	1076054	F	2	2.475	27.39	376.0
237	2019050	1076054	F	2	2.257	23.68	406.0
238	2019053	1076054	F	2	1.133	18.68	556.0

-- m_bv=2.8847 ------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
239	2024050	1001079	F	3	7.5390	113.74	107.0
240	2024041	1001079	F	2	5.2300	37.24	201.0
241	2024045	1001079	F	3	5.1210	88.36	207.0
242	2024008	1001079	F	1	4.7640	36.10	225.0
243	2024017	1001079	F	1	4.7050	35.10	227.0
244	2024012	1001079	F	1	3.7480	29.80	272.0
245	2024058	1001079	F	3	3.6670	76.18	277.0
246	2024051	1001079	F	3	3.4500	75.63	294.0
247	2024031	1001079	F	1	3.4140	28.82	297.0
248	2024018	1001079	F	1	3.3730	26.56	300.0
249	2024055	1001079	F	3	3.2800	74.31	306.0
250	2024044	1001079	F	2	3.1870	26.02	317.5
251	2024047	1001079	F	3	3.1750	72.53	319.0
252	2024063	1001079	F	2	3.1470	25.34	320.0
253	2024042	1001079	F	3	2.8630	70.36	339.0
254	2024010	1001079	F	1	2.8000	26.22	342.0
255	2024034	1001079	F	1	2.6250	26.38	360.0
256	2024006	1001079	F	1	2.4980	21.10	374.0
257	2024019	1001079	F	1	2.3520	23.30	387.5
258	2024004	1001079	F	1	2.2890	23.80	401.0
259	2024009	1001079	F	1	2.1980	22.26	413.0
260	2024016	1001079	F	1	2.1920	22.15	416.0
261	2024057	1001079	F	3	2.1860	62.00	417.0
262	2024015	1001079	F	1	1.9760	21.61	439.0
263	2024075	1001079	F	3	1.7720	59.67	470.5
264	2024013	1001079	F	1	1.7300	20.56	476.0
265	2024053	1001079	F	3	1.5480	54.30	505.0
266	2024011	1001079	F	1	1.5270	20.25	510.0
267	2024003	1001079	F	1	1.4220	18.46	522.0
268	2024059	1001079	F	3	1.0320	54.92	570.0
269	2024032	1001079	F	1	0.9990	19.10	574.0
270	2024046	1001079	F	2	0.5007	27.30	679.0

-- m_bv=2.7428 ------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
271	2064047	1001046	F	2	6.3830	41.06	151
272	2064063	1001046	F	2	5.2990	32.05	197
273	2064004	1001046	F	1	4.8700	33.10	219
274	2064007	1001046	F	1	4.5660	29.50	231
275	2064069	1001046	F	2	4.2340	28.04	240
276	2064073	1001046	F	3	4.2160	71.32	242
277	2064053	1001046	F	2	2.4090	18.94	381
278	2064054	1001046	F	2	2.1450	28.52	421
279	2064044	1001046	F	2	1.9970	32.26	436
280	2064043	1001046	F	2	1.8020	25.82	468
281	2064062	1001046	F	3	1.6030	51.99	497
282	2064080	1001046	F	2	1.5970	25.48	499
283	2064064	1001046	F	3	0.7123	44.70	636
284	2064058	1001046	F	3	0.1730	41.80	738
285	2064067	1001046	F	3	-0.8643	35.14	895

-- m_bv=2.7232 ------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
286	2036050	1076059	F	3	7.4350	98.03	110.0
287	2036048	1076059	F	3	6.6730	96.04	143.5
288	2036076	1076059	F	2	6.0630	40.53	167.0
289	2036043	1076059	F	3	6.0360	93.04	171.0
290	2036056	1076059	F	3	5.6630	86.71	184.0
291	2036066	1076059	F	3	4.9450	82.34	216.0

351	2012011	1026045	F	1	3.129	27.59	323.0
352	2012068	1026045	F	2	2.894	24.63	336.5
353	2012018	1026045	F	1	2.373	24.13	386.0

------------------------------------ m_bv=2.463 ------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
354	2012021	1026045	F	1	2.2780	20.95	403.0
355	2012030	1026045	F	1	1.9980	20.90	435.0
356	2012024	1026045	F	1	1.6770	23.25	486.0
357	2012050	1026045	F	2	1.6700	21.06	489.0
358	2012015	1026045	F	1	1.5170	20.54	512.0
359	2012019	1026045	F	1	1.2230	18.69	542.5
360	2012040	1026045	F	1	1.2230	18.69	542.5
361	2012067	1026045	F	3	1.1660	56.11	552.0
362	2012052	1026045	F	2	0.8815	27.98	601.0
363	2012069	1026045	F	2	0.8679	29.31	605.0
364	2012055	1026045	F	2	0.6819	29.28	646.0
365	2012059	1026045	F	3	0.3327	49.78	710.0
366	2012071	1026045	F	2	0.2944	24.27	719.0

------------------------------------ m_bv=2.2502 ------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
367	2043047	1001078	F	2	3.9350	31.25	259.0
368	2043063	1001078	F	3	3.9340	79.52	260.0
369	2043045	1001078	F	2	3.9060	51.07	262.0
370	2043021	1001078	F	1	3.3780	28.59	299.0
371	2043031	1001078	F	1	3.3610	28.30	302.0
372	2043058	1001078	F	3	3.3030	73.51	305.0
373	2043039	1001078	F	1	3.1990	28.67	314.0
374	2043049	1001078	F	3	3.1370	70.69	321.0
375	2043013	1001078	F	1	3.1220	28.92	324.0
376	2043038	1001078	F	1	2.7830	26.30	344.0
377	2043061	1001078	F	2	2.6300	38.80	358.0
378	2043067	1001078	F	3	2.5890	66.08	365.0
379	2043004	1001078	F	1	2.4210	24.85	378.0
380	2043065	1001078	F	3	2.4170	66.28	379.0
381	2043057	1001078	F	2	2.4070	38.13	382.0
382	2043075	1001078	F	3	2.3520	65.19	387.5
383	2043019	1001078	F	1	2.2940	24.26	398.5
384	2043012	1001078	F	1	2.0040	20.90	434.0
385	2043011	1001078	F	1	1.4140	20.26	523.0
386	2043078	1001078	F	3	0.8820	52.75	600.0
387	2043068	1001078	F	3	0.5658	50.51	666.0
388	2043043	1001078	F	2	0.5169	24.82	676.0
389	2043041	1001078	F	3	0.1552	46.67	742.0
390	2043048	1001078	F	3	-0.1175	46.73	773.0
391	2043042	1001078	F	2	-0.3322	19.79	807.0

------------------------------------ m_bv=1.9712 ------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
392	2008045	1051080	F	3	6.4430	98.35	149.0
393	2062044	1051080	F	2	4.8350	42.24	223.0
394	2008072	1051080	F	2	4.8330	36.81	224.0
395	2008015	1051080	F	2	4.1350	32.79	248.0
396	2008010	1051080	F	1	3.9560	33.40	256.0
397	2062047	1051080	F	2	3.9510	35.06	258.0
398	2062063	1051080	F	2	3.7320	36.03	273.0
399	2008049	1051080	F	3	3.7020	76.85	275.0
400	2062043	1051080	F	2	3.6610	33.26	278.0
401	2008034	1051080	F	1	3.5330	30.90	288.0
402	2062054	1051080	F	2	3.3710	50.20	301.0
403	2008079	1051080	F	2	3.2310	42.43	310.0
404	2008044	1051080	F	2	3.0440	26.78	329.0
405	2008005	1051080	F	1	2.8940	26.31	336.5
406	2008013	1051080	F	1	2.2490	23.18	409.0
407	2008009	1051080	F	1	2.1180	20.96	424.0

408	2062080	1051080	F	2	2.0930	42.58	426.0
409	2062041	1051080	F	2	2.0130	41.23	432.0
410	2008076	1051080	F	2	1.9310	34.45	446.0
411	2008054	1051080	F	3	1.8600	59.67	455.0
412	2008002	1051080	F	1	1.8380	20.91	459.0
413	2008063	1051080	F	3	1.8340	59.22	461.0
414	2062060	1051080	F	2	1.7110	37.67	479.0
415	2008046	1051080	F	3	1.3840	56.27	527.0
416	2062014	1051080	F	1	1.2460	22.50	539.0
417	2008070	1051080	F	2	1.2240	30.27	541.0
418	2008067	1051080	F	2	1.1950	31.34	547.0
419	2062046	1051080	F	2	1.1070	33.68	558.0
420	2008011	1051080	F	1	0.9876	17.41	575.0
421	2008039	1051080	F	1	0.7515	16.53	629.0
422	2062055	1051080	F	2	0.5827	32.59	663.0
423	2008058	1051080	F	3	0.4959	47.46	680.0
424	2062077	1051080	F	3	0.4875	60.52	683.0
425	2062042	1051080	F	3	0.4365	54.97	690.0
426	2062069	1051080	F	3	0.3100	57.51	715.0
427	2062068	1051080	F	3	0.2635	56.72	723.0
428	2062059	1051080	F	3	-0.1760	52.39	784.0
429	2062045	1051080	F	3	-0.3482	49.47	812.0
430	2008068	1051080	F	2	-0.3852	20.15	819.0
431	2062067	1051080	F	3	-0.4845	48.72	837.0
432	2062078	1051080	F	3	-1.2250	47.10	947.0

------------------------------------- m_bv=1.7837 -----------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
433	2042026	1001058	F	3	5.021	91.94	212
434	2042073	1001058	F	3	3.262	79.29	308
435	2042079	1001058	F	3	2.747	70.56	348
436	2042010	1001058	F	3	2.337	69.86	389

------------------------------------- m_bv=1.7837 -----------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
437	2042062	1001058	F	3	2.33200	66.65	390
438	2042067	1001058	F	3	2.29800	66.06	396
439	2042027	1001058	F	3	2.29600	69.15	397
440	2042034	1001058	F	3	2.11600	67.67	425
441	2042021	1001058	F	3	2.05900	63.57	428
442	2042032	1001058	F	3	1.80500	63.95	467
443	2042049	1001058	F	3	1.77000	64.92	472
444	2042070	1001058	F	3	1.75100	63.03	475
445	2042007	1001058	F	3	1.56700	61.48	502
446	2042048	1001058	F	3	1.36900	61.24	529
447	2042077	1001058	F	3	1.36000	57.96	531
448	2042015	1001058	F	3	1.05300	52.77	568
449	2042052	1001058	F	3	0.90750	56.54	594
450	2042020	1001058	F	3	0.76760	55.73	624
451	2042001	1001058	F	3	0.43800	50.14	689
452	2042017	1001058	F	3	0.25600	54.86	725
453	2042025	1001058	F	3	-0.05423	49.60	764

------------------------------------- m_bv=1.5419 -----------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
454	2079068	1076047	F	2	4.90600	43.12	217.0
455	2079011	1076047	F	1	4.20500	38.00	244.0
456	2079069	1076047	F	2	3.64400	34.21	279.5
457	2079022	1076047	F	1	2.76000	29.10	347.0
458	2079048	1076047	F	2	1.82000	37.62	463.0
459	2079057	1076047	F	3	1.72100	63.92	478.0
460	2079078	1076047	F	3	0.93110	58.34	590.0
461	2079017	1076047	F	1	0.85360	20.20	607.0
462	2079072	1076047	F	2	0.81490	31.51	620.0
463	2079053	1076047	F	2	0.74150	14.65	631.0
464	2079073	1076047	F	2	0.07563	26.78	747.0
465	2079055	1076047	F	3	-0.03827	51.27	760.0

466	2079045	1076047	F	3	-0.31320	49.73	804.0
467	2079076	1076047	F	3	-0.53400	50.67	844.0

------------------------------------- m_bv=1.5402 ------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
468	2045072	1001055	F	3	4.490	91.52	237
469	2045069	1001055	F	2	4.068	37.64	251
470	2045076	1001055	F	3	3.708	79.83	274
471	2045014	1001055	F	1	2.618	29.20	362
472	2045024	1001055	F	1	2.542	27.90	371
473	2045033	1001055	F	1	2.414	27.30	380
474	2045019	1001055	F	1	2.385	26.80	385

------------------------------------- m_bv=1.5402 ------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
475	2045041	1001055	F	3	2.1970	69.82	414.5
476	2045043	1001055	F	3	1.9430	67.06	445.0
477	2045022	1001055	F	1	1.9180	23.57	447.0
478	2045020	1001055	F	1	1.8650	25.80	452.0
479	2045035	1001055	F	1	1.6730	24.10	487.5
480	2045017	1001055	F	1	1.5410	23.42	506.5
481	2045054	1001055	F	3	1.3660	66.65	530.0
482	2045011	1001055	F	1	1.2520	23.20	537.0
483	2045028	1001055	F	1	1.1780	21.96	549.0
484	2045063	1001055	F	3	1.1420	59.73	555.0
485	2045039	1001055	F	1	0.7507	19.39	630.0
486	2045005	1001055	F	1	0.6355	20.56	651.0
487	2045009	1001055	F	1	0.5966	19.90	657.0
488	2045016	1001055	F	1	0.5730	19.50	664.0
489	2045012	1001055	F	1	0.5624	19.32	668.0
490	2045040	1001055	F	1	0.5488	19.09	670.0
491	2045029	1001055	F	1	0.5400	18.94	671.0
492	2045036	1001055	F	1	0.5353	18.86	672.0
493	2045010	1001055	F	1	0.4408	20.38	688.0
494	2045003	1001055	F	1	0.3204	19.90	713.0
495	2045079	1001055	F	3	-0.6766	50.75	870.0

------------------------------------- m_bv=1.433 ------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
496	2035005	1026054	F	1	9.2130	76.60	52
497	2035078	1026054	F	2	5.1800	43.60	204
498	2035067	1026054	F	3	4.0760	88.76	250
499	2035077	1026054	F	3	3.6740	86.63	276
500	2035070	1026054	F	2	2.7350	28.68	349
501	2035071	1026054	F	2	2.6720	30.73	354
502	2035008	1026054	F	1	2.1390	26.90	422
503	2035027	1026054	F	1	1.9640	25.50	442
504	2035058	1026054	F	2	1.9090	41.21	448
505	2035076	1026054	F	2	1.8720	24.97	451
506	2035060	1026054	F	3	1.8640	68.43	453
507	2035037	1026054	F	1	1.8610	25.30	454
508	2035020	1026054	F	1	1.8190	24.60	464
509	2035075	1026054	F	2	1.6780	38.86	485
510	2035006	1026054	F	1	1.6250	25.99	494
511	2035062	1026054	F	3	1.5320	69.05	508
512	2035079	1026054	F	3	1.4230	62.52	521
513	2035064	1026054	F	3	1.2000	61.86	545
514	2035038	1026054	F	1	1.1750	24.60	550
515	2035001	1026054	F	1	0.9589	22.50	583
516	2035011	1026054	F	1	0.9465	22.29	586
517	2035026	1026054	F	1	0.8745	21.07	603
518	2035012	1026054	F	1	0.8008	19.82	622

m_bv=1.433

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
519	2035056	1026054	F	3	0.75890	60.62	627
520	2035018	1026054	F	1	0.56530	20.51	667
521	2035063	1026054	F	3	0.53380	53.68	673
522	2035050	1026054	F	2	0.49340	34.38	682
523	2035029	1026054	F	1	0.44500	18.47	687
524	2035023	1026054	F	1	0.40080	17.72	696
525	2035010	1026054	F	1	0.37830	18.90	700
526	2035015	1026054	F	1	0.34220	19.85	708
527	2035024	1026054	F	1	0.16000	16.76	741
528	2035052	1026054	F	3	0.12890	54.62	743
529	2035068	1026054	F	2	0.05466	26.94	751
530	2035045	1026054	F	3	-0.64460	49.31	858
531	2035047	1026054	F	3	-0.64770	50.82	859
532	2035059	1026054	F	3	-0.67060	48.87	867
533	2035061	1026054	F	2	-1.03500	24.08	919

m_bv=1.1039

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
534	2034065	1026047	F	3	5.9530	105.43	173.0
535	2034046	1026047	F	3	3.9680	84.26	255.0
536	2034079	1026047	F	2	3.8210	38.16	266.5
537	2034015	1026047	F	1	3.6230	36.90	281.0
538	2034054	1026047	F	2	3.2470	31.55	309.0
539	2034031	1026047	F	1	2.7910	30.60	343.0
540	2034027	1026047	F	1	2.3070	30.20	394.5
541	2034011	1026047	F	1	2.1600	27.70	419.0
542	2034051	1026047	F	3	2.0190	69.95	431.0
543	2034058	1026047	F	3	1.9750	70.76	440.0
544	2034078	1026047	F	2	1.8830	42.78	450.0
545	2034017	1026047	F	1	1.8400	25.40	458.0
546	2034034	1026047	F	1	1.8130	26.50	466.0
547	2034041	1026047	F	2	1.6900	41.07	482.5
548	2034068	1026047	F	2	1.6140	25.73	495.0
549	2034013	1026047	F	1	1.5690	25.49	501.0
550	2034008	1026047	F	1	1.5580	25.30	503.0
551	2034042	1026047	F	2	1.5410	36.98	506.5
552	2034056	1026047	F	2	1.4360	24.26	520.0
553	2034044	1026047	F	3	1.2450	63.07	540.0
554	2034014	1026047	F	1	1.2100	24.09	544.0
555	2034029	1026047	F	1	0.9502	22.80	585.0
556	2034036	1026047	F	1	0.8813	21.63	602.0
557	2034037	1026047	F	1	0.8465	21.04	613.0
558	2034001	1026047	F	1	0.8176	20.55	617.0
559	2034076	1026047	F	2	0.7600	20.61	626.0
560	2034024	1026047	F	1	0.6829	21.39	644.0
561	2034077	1026047	F	2	0.6827	31.79	645.0
562	2034020	1026047	F	1	0.5915	21.40	659.5

m_bv=1.1039

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
563	2034035	1026047	F	1	0.5915	21.40	659.5
564	2034026	1026047	F	1	0.5874	19.77	662.0
565	2034038	1026047	F	1	0.4522	20.60	686.0
566	2034009	1026047	F	1	0.4221	20.09	691.0
567	2034023	1026047	F	1	0.4204	20.06	692.0
568	2034039	1026047	F	1	0.3938	19.61	698.0
569	2034025	1026047	F	1	0.2929	19.46	721.0
570	2034067	1026047	F	3	0.2406	56.96	730.0
571	2034045	1026047	F	3	0.2382	56.92	731.0
572	2034063	1026047	F	3	-0.1216	52.38	775.0
573	2034066	1026047	F	2	-0.3293	27.12	806.0
574	2034053	1026047	F	3	-0.4398	53.23	825.0
575	2034069	1026047	F	2	-0.5866	25.88	852.0
576	2034080	1026047	F	3	-0.8355	46.52	889.0
577	2034075	1026047	F	2	-0.8569	24.42	893.0

578	2034064	1026047	F	3	-2.3740	37.61	1129.0
579	2034070	1026047	F	3	-2.7940	35.16	1173.0

------------------------------------ m_bv=1.0021 ------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
580	2015016	1026072	F	3	2.15700	83.57	420.0
581	2015064	1026072	F	2	1.75800	51.94	473.0
582	2015005	1026072	F	2	1.63900	35.86	492.0
583	2015020	1026072	F	2	1.50100	30.40	513.5
584	2015049	1026072	F	1	1.50000	35.60	515.0
585	2015041	1026072	F	2	1.41000	47.60	524.0
586	2015063	1026072	F	1	1.15700	32.90	553.0
587	2015080	1026072	F	3	0.81550	76.43	619.0
588	2015045	1026072	F	1	0.61750	30.00	654.0
589	2015025	1026072	F	3	0.25120	66.86	726.0
590	2015001	1026072	F	2	-0.08972	37.78	771.0
591	2015047	1026072	F	1	-0.12000	25.30	774.0
592	2015048	1026072	F	1	-0.22980	25.00	793.0
593	2015023	1026072	F	1	-0.24160	24.80	795.0
594	2015067	1026072	F	3	-0.24560	63.12	796.0
595	2015019	1026072	F	1	-0.47520	22.40	833.0
596	2015002	1026072	F	1	-0.48470	23.80	838.0
597	2015073	1026072	F	2	-0.49990	37.07	840.0
598	2015077	1026072	F	1	-0.53780	22.90	846.0
599	2015011	1026072	F	3	-0.61080	60.05	853.0
600	2015058	1026072	F	1	-0.71010	23.10	874.0
601	2015068	1026072	F	3	-0.76540	60.55	878.0
602	2015038	1026072	F	2	-0.87100	33.90	897.0
603	2015039	1026072	F	1	-0.90240	21.40	901.0
604	2015017	1026072	F	1	-0.93190	20.90	904.0
605	2015027	1026072	F	2	-1.00100	31.70	912.0
606	2015003	1026072	F	1	-1.05300	20.40	922.0

------------------------------------ m_bv=1.0021 ------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
607	2015043	1026072	F	1	-1.053	20.40	922.0
608	2015008	1026072	F	1	-1.157	20.20	933.0
609	2015033	1026072	F	2	-1.180	31.78	937.5
610	2015055	1026072	F	3	-1.194	57.97	941.0
611	2015069	1026072	F	1	-1.219	19.16	945.5
612	2015006	1026072	F	1	-1.409	17.50	985.0
613	2015075	1026072	F	1	-1.460	18.19	991.0
614	2015021	1026072	F	2	-1.470	29.99	994.0
615	2015071	1026072	F	1	-1.475	13.25	996.0
616	2015070	1026072	F	1	-1.511	17.33	1003.0
617	2015037	1026072	F	1	-1.654	18.02	1023.0
618	2015012	1026072	F	1	-1.694	18.90	1032.0
619	2015072	1026072	F	1	-1.737	16.62	1035.0
620	2015007	1026072	F	1	-1.848	16.29	1052.0
621	2015036	1026072	F	1	-1.913	16.76	1058.0
622	2015034	1026072	F	3	-1.917	53.52	1059.0
623	2015066	1026072	F	1	-1.937	16.34	1061.0
624	2015018	1026072	F	1	-1.940	16.29	1064.0
625	2015059	1026072	F	1	-1.993	16.96	1076.0
626	2015013	1026072	F	1	-2.032	16.30	1085.0
627	2015061	1026072	F	1	-2.152	15.83	1099.0
628	2015065	1026072	F	2	-2.177	24.24	1105.0
629	2015014	1026072	F	1	-2.227	16.12	1114.0
630	2015028	1026072	F	1	-2.244	15.83	1116.0
631	2015035	1026072	F	1	-2.356	15.49	1126.0
632	2015015	1026072	F	1	-2.457	13.77	1138.0
633	2015051	1026072	F	1	-2.481	11.80	1140.5
634	2015032	1026072	F	1	-2.593	14.60	1151.0
635	2015050	1026072	F	1	-2.667	14.90	1155.5
636	2015056	1026072	F	3	-2.841	45.65	1177.0
637	2015062	1026072	F	1	-3.066	11.26	1190.0
638	2015029	1026072	F	3	-3.106	44.28	1193.0

--------------------------------------- m_bv=0.8064 ---------------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
639	2020045	1076052	F	3	3.9530	94.22	257.0
640	2020041	1076052	F	2	3.0270	34.92	330.0
641	2020016	1076052	F	1	2.7800	29.70	345.5
642	2020051	1076052	F	2	2.7800	30.74	345.5
643	2020019	1076052	F	1	2.3200	29.70	392.0
644	2020028	1076052	F	1	2.2550	28.60	407.0
645	2020018	1076052	F	1	1.8180	29.00	465.0
646	2020061	1076052	F	3	1.5500	70.66	504.0
647	2020044	1076052	F	3	1.3210	73.02	533.0
648	2020008	1076052	F	1	1.2510	27.20	538.0
649	2020058	1076052	F	2	1.0820	25.36	565.0
650	2020020	1076052	F	1	0.9848	22.68	576.0

--------------------------------------- m_bv=0.8064 ---------------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
651	2020034	1076052	F	1	0.91290	21.46	593
652	2020012	1076052	F	1	0.89690	22.75	597
653	2020070	1076052	F	3	0.73980	64.72	633
654	2020049	1076052	F	2	0.67520	34.08	647
655	2020079	1076052	F	3	0.60310	60.84	656
656	2020052	1076052	F	3	0.59410	62.25	658
657	2020001	1076052	F	1	0.52750	21.17	674
658	2020035	1076052	F	1	0.38110	20.25	699
659	2020053	1076052	F	3	0.24320	57.86	729
660	2020015	1076052	F	1	0.22590	20.74	732
661	2020011	1076052	F	1	0.08419	21.46	746
662	2020038	1076052	F	1	-0.04318	19.30	761
663	2020066	1076052	F	3	-0.07440	58.72	768
664	2020075	1076052	F	3	-0.18640	55.26	785
665	2020037	1076052	F	1	-0.26320	17.13	798
666	2020040	1076052	F	1	-0.46230	20.00	830
667	2020076	1076052	F	2	-1.12900	23.79	931
668	2020006	1076052	F	1	-1.35700	14.19	979
669	2020057	1076052	F	3	-2.49200	41.15	1142

--------------------------------------- m_bv=0.7372 ---------------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
670	2078066	1076060	F	3	3.5130	89.13	291.0
671	2078055	1076060	F	2	2.5000	48.65	373.0
672	2078043	1076060	F	1	2.3140	30.40	393.0
673	2078012	1076060	F	2	2.2360	30.12	410.0
674	2078033	1076060	F	1	2.0710	29.40	427.0
675	2078076	1076060	F	1	1.1670	25.00	551.0
676	2078069	1076060	F	1	0.8468	22.70	612.0
677	2078080	1076060	F	2	0.7090	22.96	637.0
678	2078003	1076060	F	1	0.6863	23.10	643.0
679	2078026	1076060	F	1	0.5706	22.70	665.0
680	2078005	1076060	F	1	0.3724	20.90	703.0
681	2078052	1076060	F	3	0.2208	59.84	733.0
682	2078004	1076060	F	1	-0.3334	18.30	808.0
683	2078037	1076060	F	1	-0.8609	15.60	894.0
684	2078063	1076060	F	1	-1.0180	14.50	914.0
685	2078058	1076060	F	2	-1.2310	24.42	950.0
686	2078020	1076060	F	3	-1.2320	49.25	951.5

--------------------------------------- m_bv=0.7136 ---------------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
687	2077055	1076055	F	2	3.504	39.62	292
688	2077069	1076055	F	2	3.404	37.93	298

-- m_bv=0.7136 ------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
689	2077072	1076055	F	3	2.6230	85.45	361.0
690	2077052	1076055	F	2	2.5840	34.95	367.0
691	2077008	1076055	F	1	2.3070	33.90	394.5
692	2077079	1076055	F	2	1.9810	32.53	438.0
693	2077018	1076055	F	1	1.7030	29.90	480.0
694	2077045	1076055	F	3	1.5220	74.58	511.0
695	2077064	1076055	F	2	0.8215	39.41	616.0
696	2077047	1076055	F	3	0.3510	65.66	705.0
697	2077075	1076055	F	3	0.2943	66.26	720.0
698	2077058	1076055	F	3	-0.3864	57.84	820.0
699	2077073	1076055	F	3	-0.4790	56.27	835.0
700	2077059	1076055	F	3	-0.8255	56.64	888.0
701	2077041	1076055	F	3	-1.1800	49.06	937.5
702	2077071	1076055	F	3	-1.6190	47.86	1017.0
703	2077067	1076055	F	3	-1.7760	49.89	1042.0
704	2077063	1076055	F	3	-1.9850	46.35	1074.0

-- m_bv=0.6378 ------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
705	2064041	1076046	F	3	5.05800	78.72	210.0
706	2060077	1076046	F	2	1.85200	33.72	457.0
707	2060055	1076046	F	3	1.09500	73.85	561.0
708	2060028	1076046	F	1	0.93730	28.10	587.0
709	2060076	1076046	F	3	-0.03275	64.09	759.0
710	2060059	1076046	F	3	-0.22320	60.86	789.0
711	2060064	1076046	F	2	-0.56890	33.26	849.0
712	2060058	1076046	F	2	-1.02400	30.22	916.5
713	2060050	1076046	F	3	-1.35300	55.76	977.5

-- m_bv=0.557 ------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
714	2031063	1026043	F	1	3.6180	36.90	282
715	2031007	1026043	F	1	2.6940	30.60	353
716	2031026	1026043	F	2	1.9580	25.41	444
717	2031047	1026043	F	3	1.5290	63.28	509
718	2031076	1026043	F	1	1.4640	23.80	519
719	2031039	1026043	F	2	1.0050	35.78	572
720	2031075	1026043	F	1	0.9367	21.10	588
721	2031067	1026043	F	1	0.8683	21.50	604
722	2031062	1026043	F	1	0.8270	20.80	614
723	2031054	1026043	F	1	0.8229	20.73	615
724	2031021	1026043	F	1	0.7408	20.90	632
725	2031028	1026043	F	2	0.3480	30.89	706
726	2031003	1026043	F	1	0.3194	20.00	714

-- m_bv=0.557 ------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
727	2031045	1026043	F	3	0.25110	57.23	727
728	2031077	1026043	F	1	0.24870	18.80	728
729	2031016	1026043	F	1	0.17790	17.60	737
730	2031069	1026043	F	1	0.06755	17.29	750
731	2031055	1026043	F	1	-0.96750	13.79	908
732	2031073	1026043	F	1	-1.24000	12.30	955
733	2031010	1026043	F	1	-1.49700	11.05	1001
734	2031020	1026043	F	1	-2.47400	8.54	1139

-- m_bv=0.4865 --

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
735	2047071	1051073	F	3	3.9040	89.96	263.0
736	2047027	1051073	F	1	2.6500	35.00	357.0
737	2047045	1051073	F	2	2.5430	32.66	370.0
738	2047034	1051073	F	1	2.3900	33.70	383.0
739	2047054	1051073	F	2	2.0360	28.74	430.0
740	2047041	1051073	F	2	1.8290	29.92	462.0
741	2047010	1051073	F	1	0.8484	24.74	610.0
742	2047064	1051073	F	3	0.8098	68.72	621.0
743	2047002	1051073	F	1	0.6944	23.69	642.0
744	2047025	1051073	F	1	0.5887	23.46	661.0
745	2047023	1051073	F	1	0.5262	22.40	675.0
746	2047019	1051073	F	1	0.3220	22.06	711.0
747	2047011	1051073	F	1	0.2595	21.00	724.0
748	2047072	1051073	F	2	0.1269	33.84	744.0
749	2047062	1051073	F	2	-0.2826	31.58	801.0
750	2047066	1051073	F	3	-0.4388	52.23	824.0
751	2047051	1051073	F	3	-0.8668	52.78	896.0
752	2047073	1051073	F	2	-1.5270	22.97	1006.5
753	2047046	1051073	F	2	-1.5610	22.40	1011.5
754	2047049	1051073	F	3	-1.7720	45.24	1041.0
755	2047052	1051073	F	3	-2.8630	39.23	1179.0

-- m_bv=0.3336 --

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
756	2030021	1051078	F	1	2.48200	34.40	375
757	2030010	1051078	F	1	1.08600	26.34	563
758	2030018	1051078	F	1	1.06900	26.06	566
759	2030008	1051078	F	1	1.04800	25.70	569
760	2030005	1051078	F	1	0.96620	24.31	580
761	2030014	1051078	F	1	0.70670	21.47	639
762	2030003	1051078	F	1	0.37550	22.10	701
763	2030022	1051078	F	1	0.28120	20.50	722
764	2030013	1051078	F	1	-0.05409	21.06	763

-- m_bv=0.3336 --

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
765	2030004	1051078	F	1	-0.1597	20.83	781
766	2030016	1051078	F	1	-0.2317	19.61	794
767	2030001	1051078	F	1	-0.3101	18.28	803
768	2030012	1051078	F	1	-0.3633	20.50	813
769	2030009	1051078	F	1	-0.3767	17.15	817
770	2030023	1051078	F	1	-1.5150	11.90	1004

-- m_bv=-0.0532 --

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
771	2071046	1026055	F	2	2.93700	39.53	333.0
772	2071047	1026055	F	2	2.66100	39.54	356.0
773	2071050	1026055	F	3	0.69550	71.66	640.5
774	2071066	1026055	F	3	0.62210	75.10	653.0
775	2071077	1026055	F	2	0.41320	26.40	694.0
776	2071079	1026055	F	3	0.30470	71.28	717.0
777	2071045	1026055	F	3	-0.02911	67.18	756.0
778	2071032	1026055	F	1	-0.06858	25.00	767.0
779	2071037	1026055	F	1	-0.37430	24.50	815.0
780	2071080	1026055	F	3	-0.44630	64.79	828.0
781	2071073	1026055	F	2	-0.90630	33.69	902.0
782	2071057	1026055	F	2	-1.14200	34.38	932.0
783	2071002	1026055	F	1	-1.22700	19.40	948.5
784	2071024	1026055	F	1	-1.27800	20.11	962.0
785	2071027	1026055	F	1	-1.29200	19.87	966.0
786	2071038	1026055	F	1	-1.72100	18.84	1033.0

m_bv=-0.2671

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
787	2033049	1026071	F	3	1.72600	74.72	477
788	2033065	1026071	F	2	1.65500	47.09	491
789	2033071	1026071	F	2	1.60100	28.99	498
790	2033050	1026071	F	3	1.49700	70.83	516
791	2033074	1026071	F	2	1.40500	28.79	525
792	2033033	1026071	F	1	1.37200	30.33	528
793	2033022	1026071	F	1	1.27000	28.60	536
794	2033017	1026071	F	1	0.91970	28.90	592
795	2033052	1026071	F	2	0.86670	43.09	606
796	2033054	1026071	F	3	0.70690	65.24	638
797	2033023	1026071	F	1	0.65570	21.30	649
798	2033037	1026071	F	1	0.50790	26.60	677
799	2033003	1026071	F	1	0.46790	22.80	685
800	2033036	1026071	F	1	0.20530	23.03	734
801	2033034	1026071	F	1	-0.01484	22.42	755
802	2033021	1026071	F	1	-0.15530	21.60	778

m_bv=-0.2671

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
803	2033024	1026071	F	1	-0.3352	20.11	809.0
804	2033060	1026071	F	3	-0.3751	56.26	816.0
805	2033030	1026071	F	1	-0.4366	18.39	823.0
806	2033014	1026071	F	1	-0.4669	21.00	831.0
807	2033070	1026071	F	2	-0.4743	20.35	832.0
808	2033035	1026071	F	1	-0.5494	19.60	847.0
809	2033001	1026071	F	1	-0.7719	18.95	879.0
810	2033069	1026071	F	2	-0.8053	30.35	883.0
811	2033016	1026071	F	1	-0.8846	18.60	899.0
812	2033051	1026071	F	3	-1.0530	52.57	922.0
813	2033061	1026071	F	2	-1.1670	25.78	936.0
814	2033009	1026071	F	1	-1.2560	16.98	959.0
815	2033019	1026071	F	1	-1.2560	16.98	959.0
816	2033066	1026071	F	2	-1.8950	22.80	1056.0
817	2033080	1026071	F	2	-2.5780	20.58	1148.0
818	2033079	1026071	F	3	-2.7980	41.72	1174.0
819	2033077	1026071	F	3	-3.1070	39.60	1194.5
820	2033078	1026071	F	3	-3.5570	36.65	1228.0

m_bv=-0.2979

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
821	2049036	1051066	F	1	2.00900	36.59	433.0
822	2049054	1051066	F	3	1.80100	79.26	469.0
823	2049041	1051066	F	3	1.19600	75.24	546.0
824	2049019	1051066	F	1	1.10100	32.13	559.0
825	2049002	1051066	F	1	1.06200	29.90	567.0
826	2049053	1051066	F	3	0.90250	71.83	595.0
827	2049077	1051066	F	3	0.76020	72.54	625.0
828	2049028	1051066	F	1	0.72670	28.90	634.0
829	2049001	1051066	F	1	0.61240	25.40	655.0
830	2049008	1051066	F	1	0.37270	26.02	702.0
831	2049063	1051066	F	3	0.29540	66.22	718.0
832	2049060	1051066	F	3	0.02383	67.86	752.0
833	2049035	1051066	F	1	0.00070	29.08	754.0
834	2089029	1051066	F	3	-0.08401	64.47	770.0
835	2049003	1051066	F	1	-0.15600	23.30	779.0
836	2049007	1051066	F	1	-0.61860	21.70	855.0
837	2089007	1051066	F	3	-0.65630	61.01	861.0
838	2049015	1051066	F	1	-0.66400	19.37	864.0
839	2089025	1051066	F	3	-1.07400	58.61	925.0
840	2049017	1051066	F	1	-1.47800	18.06	997.0
841	2089030	1051066	F	3	-1.57800	53.18	1016.0
842	2049055	1051066	F	3	-1.73400	52.11	1034.0
843	2049043	1051066	F	3	-1.86000	49.96	1053.5
844	2089027	1051066	F	3	-2.01600	50.44	1081.0
845	2089013	1051066	F	3	-2.03000	50.21	1083.0
846	2089015	1051066	F	3	-4.66000	33.72	1282.0

m_bv=-0.3134

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
847	2039061	1076056	F	2	2.2190	34.81	411.0
848	2039041	1076056	F	3	1.9600	80.27	443.0
849	2039020	1076056	F	1	1.3150	32.50	534.0
850	2039007	1076056	F	1	0.8501	30.86	608.0
851	2039024	1076056	F	1	0.6955	29.80	640.5
852	2039021	1076056	F	1	0.4937	27.94	681.0
853	2039045	1076056	F	2	-0.7379	17.46	875.0
854	2039033	1076056	F	1	-0.8157	21.35	886.0
855	2039044	1076056	F	2	-0.8378	32.94	890.0
856	2039058	1076056	F	2	-1.2580	32.06	961.0
857	2039026	1076056	F	1	-1.4190	18.92	987.0
858	2039067	1076056	F	3	-2.0870	53.79	1089.0
859	2039080	1076056	F	3	-4.4520	37.11	1273.0

m_bv=-0.3611

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
860	2054056	1026067	F	3	3.0720	85.48	327.0
861	2054010	1026067	F	3	2.4640	84.55	377.0
862	2054001	1026067	F	3	1.6690	75.75	490.0
863	2054065	1026067	F	3	0.3389	62.56	709.0
864	2054011	1026067	F	1	-0.2106	21.10	788.0
865	2054042	1026067	F	1	-0.9281	18.30	903.0
866	2054030	1026067	F	1	-1.2070	16.70	943.5
867	2054044	1026067	F	1	-1.3380	17.60	975.0
868	2054047	1026067	F	1	-1.4320	16.00	989.0
869	2054058	1026067	F	3	-6.0390	27.79	1325.0

m_bv=-0.3741

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
870	2058016	1076058	F	1	0.4844	25.20	684
871	2058051	1076058	F	2	-0.2986	23.89	802
872	2058049	1076058	F	2	-1.3080	30.19	971

m_bv=-0.4002

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
873	2025053	1001049	F	3	5.161	108.15	206.0
874	2025012	1001049	F	2	4.020	46.77	254.0
875	2025054	1001049	F	3	3.417	87.95	296.0
876	2025024	1001049	F	2	3.207	39.23	312.5
877	2025030	1001049	F	2	2.603	53.96	364.0
878	2025068	1001049	F	3	1.772	78.78	470.5
879	2025001	1001049	F	3	1.630	74.82	493.0

m_bv=-0.4002

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
880	2025047	1001049	F	3	1.3090	75.62	535.0
881	2025005	1001049	F	2	0.6380	42.50	650.0
882	2025010	1001049	F	2	0.3213	37.13	712.0
883	2025079	1001049	F	3	0.1655	62.47	740.0
884	2025060	1001049	F	1	-0.0317	22.30	758.0
885	2025051	1001049	F	1	-0.3397	20.20	810.0
886	2025041	1001049	F	1	-0.4826	20.90	836.0
887	2025036	1001049	F	2	-0.4853	32.82	839.0
888	2025061	1001049	F	3	-0.5374	59.92	845.0
889	2025065	1001049	F	2	-0.5744	32.87	850.0
890	2025043	1001049	F	2	-0.6145	32.19	854.0
891	2025058	1001049	F	1	-0.6808	19.10	871.0
892	2025034	1001049	F	1	-0.6867	19.00	872.0

893	2025016	1001049	F	1	-0.7987	17.10	882.0
894	2025026	1001049	F	1	-0.8200	18.30	887.0
895	2025056	1001049	F	1	-0.9871	18.59	910.0
896	2025037	1001049	F	1	-1.0240	17.96	916.5
897	2025074	1001049	F	1	-1.1880	18.30	939.0
898	2025033	1001049	F	1	-1.2360	17.50	953.5
899	2025070	1001049	F	1	-1.2560	17.16	959.0
900	2025069	1001049	F	1	-1.2940	16.50	967.5
901	2025023	1001049	F	1	-1.3000	16.40	970.0
902	2025015	1001049	F	1	-1.3180	16.10	972.0
903	2025055	1001049	F	1	-1.4460	15.50	990.0
904	2025052	1001049	F	1	-1.4640	16.75	992.5
905	2025007	1001049	F	1	-1.6750	16.30	1030.0
906	2025072	1001049	F	1	-1.8260	15.30	1047.0
907	2025020	1001049	F	1	-1.8300	15.22	1048.0
908	2025025	1001049	F	1	-1.8320	15.20	1050.0
909	2025064	1001049	F	1	-1.9400	14.92	1064.0
910	2025059	1001049	F	1	-1.9430	13.31	1066.0
911	2025075	1001049	F	1	-2.1730	12.53	1104.0
912	2025022	1001049	F	1	-2.2530	14.30	1120.0
913	2025057	1001049	F	1	-2.3200	13.16	1122.0
914	2025045	1001049	F	1	-2.5160	11.40	1145.0
915	2025018	1001049	F	1	-2.5790	11.90	1149.0

------------------------------------ m_bv=-0.6686 ------------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
916	2044073	1001059	F	3	1.69700	77.81	481
917	2044076	1001059	F	2	0.90190	45.71	596
918	2044050	1001059	F	3	0.84970	75.93	609
919	2044031	1001059	F	1	0.18450	24.70	735
920	2044034	1001059	F	1	0.02155	25.06	753
921	2044019	1001059	F	1	-0.07819	24.93	769
922	2044051	1001059	F	2	-0.44210	35.41	826
923	2044002	1001059	F	1	-0.52420	22.05	843

------------------------------------ m_bv=-0.6686 ------------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
924	2044078	1001059	F	3	-0.5785	61.08	851.0
925	2044060	1001059	F	2	-0.6512	38.11	860.0
926	2044022	1001059	F	1	-0.7797	19.28	880.0
927	2044065	1001059	F	2	-1.2360	18.82	953.5
928	2044040	1001059	F	1	-1.3340	19.25	974.0
929	2044039	1001059	F	1	-1.4720	16.91	995.0
930	2044032	1001059	F	1	-1.5610	18.53	1011.5
931	2044011	1001059	F	1	-1.8600	18.13	1053.5
932	2044077	1001059	F	2	-2.4100	19.22	1134.0
933	2044042	1001059	F	2	-2.7620	22.62	1167.0

------------------------------------ m_bv=-0.7112 ------------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
934	2003055	1001044	F	3	5.43700	110.33	192.0
935	2003029	1001044	F	1	1.89900	33.80	449.0
936	2003022	1001044	F	1	1.39000	32.99	526.0
937	2003079	1001044	F	2	1.18600	47.74	548.0
938	2003005	1001044	F	1	1.02200	28.30	571.0
939	2003001	1001044	F	1	0.66070	25.30	648.0
940	2003056	1001044	F	2	-0.05736	25.09	765.0
941	2003002	1001044	F	1	-0.37730	21.75	818.0
942	2003007	1001044	F	1	-0.39570	23.00	821.0
943	2003006	1001044	F	1	-0.63290	22.10	857.0
944	2003051	1001044	F	2	-0.89660	34.28	900.0
945	2003010	1001044	F	1	-1.01200	18.80	913.0
946	2003008	1001044	F	1	-1.19600	18.80	942.0
947	2003054	1001044	F	3	-1.24800	56.30	957.0
948	2003070	1001044	F	2	-1.40000	30.43	983.0

949	2003044	1001044	F	3	-2.09800	49.69	1091.0
950	2003057	1001044	F	3	-2.16900	50.06	1103.0
951	2003073	1001044	F	3	-2.24500	48.76	1117.0
952	2003053	1001044	F	2	-2.48100	23.03	1140.5
953	2003050	1001044	F	3	-2.55600	45.05	1147.0
954	2003043	1001044	F	2	-2.63400	23.56	1154.0
955	2003048	1001044	F	2	-2.75600	26.17	1166.0
956	2003047	1001044	F	3	-3.79800	38.05	1240.0

------------------------------------ m_bv=-0.9988 ------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
957	2057073	1076045	F	2	1.1520	30.21	554.0
958	2057018	1076045	F	1	0.8833	29.30	599.0
959	2057038	1076045	F	1	0.7581	30.30	628.0
960	2057070	1076045	F	3	0.5068	69.11	678.0
961	2057055	1076045	F	3	-0.1677	67.04	782.5

------------------------------------ m_bv=-0.9988 ------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
962	2057065	1076045	F	3	-0.1677	67.04	782.5
963	2057045	1076045	F	2	-0.2246	24.04	790.0
964	2057053	1076045	F	2	-0.2282	23.98	791.0
965	2057058	1076045	F	3	-0.3684	66.76	814.0
966	2057075	1076045	F	3	-0.5186	61.09	842.0
967	2057052	1076045	F	2	-0.6288	21.87	856.0
968	2057046	1076045	F	2	-0.7550	19.73	876.0
969	2057066	1076045	F	2	-0.9416	32.18	906.0
970	2057060	1076045	F	2	-1.9450	26.09	1067.0
971	2057009	1076045	F	1	-1.9660	16.90	1070.0
972	2057043	1076045	F	2	-2.2010	23.31	1110.0
973	2057048	1076045	F	2	-2.6750	23.08	1157.0
974	2057079	1076045	F	2	-2.7090	22.51	1160.0
975	2057049	1076045	F	2	-3.3330	19.74	1212.0
976	2057074	1076045	F	3	-4.4460	35.08	1272.0

------------------------------------ m_bv=-1.0501 ------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
977	2053067	1026057	F	3	2.7140	97.36	352
978	2053030	1026057	F	1	0.9561	35.40	584
979	2053069	1026057	F	2	0.5515	34.26	669
980	2053054	1026057	F	3	-1.0750	69.01	926
981	2053043	1026057	F	3	-2.1890	57.93	1106
982	2053068	1026057	F	2	-3.5240	24.48	1224
983	2053058	1026057	F	3	-4.7840	40.46	1289

------------------------------------ m_bv=-1.0565 ------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
984	2022007	1001074	F	1	1.10000	33.40	560
985	2022051	1001074	F	2	0.41470	30.62	693
986	2022006	1001074	F	1	0.30590	29.30	716
987	2022058	1001074	F	2	-0.03133	27.74	757
988	2022059	1001074	F	3	-0.25590	69.09	797
989	2022065	1001074	F	2	-0.76010	24.75	877
990	2022038	1001074	F	1	-0.77990	26.50	881
991	2022055	1001074	F	3	-0.94220	66.82	907
992	2022044	1001074	F	2	-1.08800	23.87	927
993	2022041	1001074	F	2	-1.24500	36.83	956
994	2022053	1001074	F	3	-1.29000	60.92	965
995	2022021	1001074	F	1	-1.50800	20.40	1002
996	2022025	1001074	F	1	-1.66400	20.88	1026
997	2022013	1001074	F	1	-2.16300	17.10	1101
998	2022061	1001074	F	3	-2.24800	54.05	1118
999	2022075	1001074	F	3	-2.74200	50.36	1164

------------------------------------ m_bv=-1.0565 ----------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
1000	2022047	1001074	F	2	-3.064	24.72	1189

------------------------------------ m_bv=-1.0879 ----------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
1001	2059042	1076049	F	3	2.28200	90.36	402.0
1002	2059015	1076049	F	1	2.16600	37.50	418.0
1003	2059062	1076049	F	2	1.60700	33.75	496.0
1004	2059038	1076049	F	1	0.95950	31.10	582.0
1005	2059053	1076049	F	3	0.80000	74.59	623.0
1006	2059047	1076049	F	3	-0.04957	67.99	762.0
1007	2059059	1076049	F	3	-0.10520	71.73	772.0
1008	2059048	1076049	F	2	-0.20800	26.39	787.0
1009	2059067	1076049	F	2	-0.40160	24.67	822.0
1010	2059049	1076049	F	2	-0.65830	35.93	862.0
1011	2059051	1076049	F	3	-0.66980	65.28	866.0
1012	2059070	1076049	F	3	-0.84730	62.27	892.0
1013	2059055	1076049	F	2	-0.87190	22.94	898.0
1014	2059021	1076049	F	1	-0.98180	21.60	909.0
1015	2059078	1076049	F	2	-1.16600	19.51	935.0
1016	2059077	1076049	F	2	-1.55900	31.58	1010.0
1017	2059075	1076049	F	2	-2.29700	25.32	1121.0
1018	2059043	1076049	F	3	-2.32400	52.84	1124.0
1019	2059056	1076049	F	2	-2.45500	25.76	1137.0
1020	2059054	1076049	F	2	-2.68600	23.40	1159.0
1021	2059071	1076049	F	2	-3.02000	23.98	1186.0
1022	2059069	1076049	F	2	-3.11600	22.36	1196.5
1023	2059068	1076049	F	3	-3.17800	46.16	1201.0
1024	2059064	1076049	F	3	-3.85400	39.38	1242.0
1025	2059060	1076049	F	3	-4.56400	36.72	1275.5

------------------------------------ m_bv=-1.3169 ----------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
1026	2028056	1051071	F	3	2.66900	85.34	355.0
1027	2028070	1051071	F	2	1.69000	32.94	482.5
1028	2028005	1051071	F	1	1.09000	29.54	562.0
1029	2028010	1051071	F	1	0.07007	26.30	749.0
1030	2028013	1051071	F	1	-0.22970	25.90	792.0
1031	2028041	1051071	F	3	-0.31600	67.51	805.0
1032	2028040	1051071	F	1	-0.70280	21.00	873.0
1033	2028009	1051071	F	1	-0.81030	22.30	885.0
1034	2028031	1051071	F	1	-1.27900	20.60	963.5
1035	2028072	1051071	F	3	-1.74400	57.35	1037.0
1036	2028079	1051071	F	3	-1.97800	54.94	1072.0
1037	2028077	1051071	F	3	-2.00400	51.38	1079.0

------------------------------------ m_bv=-1.3169 ----------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
1038	2028054	1051071	F	2	-2.041	27.45	1086.0
1039	2028058	1051071	F	3	-2.206	52.63	1111.0
1040	2028076	1051071	F	2	-2.250	20.78	1119.0
1041	2028051	1051071	F	3	-2.667	44.82	1155.5
1042	2028067	1051071	F	3	-3.342	41.17	1213.0
1043	2028047	1051071	F	2	-3.687	18.28	1233.0
1044	2028068	1051071	F	3	-5.283	30.13	1307.0

------------------------------------- m_bv=-1.3675 ------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
1045	2032026	1026046	F	1	1.0040	32.30	573.0
1046	2032011	1026046	F	1	0.8867	35.00	598.0
1047	2032015	1026046	F	1	0.7180	33.70	635.0
1048	2032042	1026046	F	3	-0.2728	70.90	800.0
1049	2032023	1026046	F	1	-0.6691	24.23	865.0
1050	2032077	1026046	F	3	-1.2070	62.86	943.5
1051	2032006	1026046	F	1	-1.3940	21.30	982.0
1052	2032008	1026046	F	1	-1.4810	19.83	999.5
1053	2032060	1026046	F	2	-1.4810	31.80	999.5
1054	2032013	1026046	F	1	-1.6200	20.60	1018.0
1055	2032072	1026046	F	3	-1.7940	56.04	1043.0
1056	2032064	1026046	F	2	-1.8230	30.68	1045.5
1057	2032009	1026046	F	1	-2.0310	19.88	1084.0
1058	2032041	1026046	F	2	-2.1200	28.77	1094.0
1059	2032035	1026046	F	1	-2.1260	16.70	1097.0
1060	2032054	1026046	F	3	-2.1980	53.87	1109.0
1061	2032061	1026046	F	2	-2.6270	27.97	1153.0
1062	2032012	1026046	F	1	-2.7300	15.82	1161.0
1063	2032080	1026046	F	3	-3.0170	47.78	1185.0

------------------------------------- m_bv=-2.0227 ------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
1064	2027039	1051048	F	1	3.42900	22.80	295
1065	2027062	1051048	F	3	1.11500	82.84	557
1066	2027003	1051048	F	1	-0.06094	29.20	766
1067	2027070	1051048	F	2	-0.34340	28.57	811
1068	2027012	1051048	F	1	-0.51180	27.80	841
1069	2027056	1051048	F	2	-0.55670	45.25	848
1070	2027052	1051048	F	3	-0.66190	71.45	863
1071	2027049	1051048	F	2	-0.67080	26.14	868
1072	2027038	1051048	F	1	-0.67100	25.10	869
1073	2027060	1051048	F	2	-0.80940	23.79	884
1074	2027010	1051048	F	1	-1.04300	26.60	920
1075	2027045	1051048	F	3	-1.10300	67.09	928

------------------------------------- m_bv=-2.0227 ------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
1076	2027014	1051048	F	1	-1.232	23.40	951.5
1077	2027023	1051048	F	1	-1.279	22.60	963.5
1078	2027032	1051048	F	1	-1.341	23.10	976.0
1079	2027019	1051048	F	1	-1.353	22.90	977.5
1080	2027017	1051048	F	1	-1.416	23.40	986.0
1081	2027074	1051048	F	2	-1.523	21.06	1005.0
1082	2027013	1051048	F	1	-1.665	22.30	1027.0
1083	2027041	1051048	F	2	-1.666	21.75	1028.5
1084	2027005	1051048	F	1	-1.745	22.51	1038.0
1085	2027015	1051048	F	1	-1.758	22.28	1039.0
1086	2027029	1051048	F	1	-1.798	21.60	1044.0
1087	2027011	1051048	F	1	-1.831	22.60	1049.0
1088	2027035	1051048	F	1	-1.908	21.30	1057.0
1089	2027026	1051048	F	1	-1.992	23.00	1075.0
1090	2027021	1051048	F	1	-1.994	21.41	1077.0
1091	2027002	1051048	F	1	-2.068	20.14	1087.0
1092	2027059	1051048	F	3	-2.096	59.62	1090.0
1093	2027007	1051048	F	1	-2.113	20.95	1093.0
1094	2027054	1051048	F	2	-2.192	31.58	1107.0
1095	2027069	1051048	F	3	-2.323	58.90	1123.0
1096	2027024	1051048	F	1	-2.439	18.54	1136.0
1097	2027046	1051048	F	3	-2.499	55.91	1143.0
1098	2027025	1051048	F	1	-2.500	17.51	1144.0
1099	2027001	1051048	F	1	-2.676	19.20	1158.0
1100	2027028	1051048	F	1	-2.777	17.50	1170.0
1101	2027009	1051048	F	1	-2.818	18.36	1176.0
1102	2027053	1051048	F	3	-2.849	51.53	1178.0

1103	2027008	1051048	F	1	-2.921	18.17	1180.5
1104	2027022	1051048	F	1	-2.921	18.17	1180.5
1105	2027006	1051048	F	1	-3.055	15.90	1188.0
1106	2027076	1051048	F	3	-3.100	53.53	1192.0
1107	2027080	1051048	F	2	-3.206	25.30	1204.0
1108	2027050	1051048	F	2	-3.254	24.50	1208.0
1109	2027071	1051048	F	3	-3.287	50.36	1209.0
1110	2027047	1051048	F	3	-3.320	49.79	1211.0
1111	2027077	1051048	F	2	-3.351	24.41	1214.5
1112	2027079	1051048	F	3	-3.638	49.09	1230.0
1113	2027065	1051048	F	2	-3.669	29.94	1232.0
1114	2027058	1051048	F	2	-3.723	24.34	1235.0
1115	2027073	1051048	F	3	-3.785	45.03	1239.0
1116	2027078	1051048	F	2	-3.964	21.82	1248.0
1117	2027061	1051048	F	3	-4.006	45.97	1251.0
1118	2027057	1051048	F	2	-4.310	19.07	1267.5

------------------------------------ m_bv=-2.0591 ------------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
1119	2018013	1076050	F	3	1.501	89.75	513.5

------------------------------------ m_bv=-2.0591 ------------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
1120	2018028	1076050	F	3	0.35380	76.55	704.0
1121	2018059	1076050	F	2	0.07527	28.23	748.0
1122	2018018	1076050	F	1	-0.44960	26.10	829.0
1123	2018032	1076050	F	3	-1.11500	67.25	929.0
1124	2018049	1076050	F	2	-1.38300	22.23	981.0
1125	2018034	1076050	F	2	-1.40600	35.90	984.0
1126	2018027	1076050	F	3	-1.57100	68.89	1015.0
1127	2018033	1076050	F	2	-1.64500	34.97	1019.5
1128	2018071	1076050	F	1	-1.64700	21.40	1022.0
1129	2018079	1076050	F	1	-1.65500	21.27	1024.0
1130	2018039	1076050	F	2	-1.74000	33.36	1036.0
1131	2018017	1076050	F	1	-1.86500	22.40	1055.0
1132	2018073	1076050	F	1	-1.93400	19.66	1060.0
1133	2018042	1076050	F	1	-1.95000	19.40	1068.0
1134	2018023	1076050	F	1	-2.02000	18.20	1082.0
1135	2018003	1076050	F	1	-2.08500	21.78	1088.0
1136	2018076	1076050	F	2	-2.10500	33.42	1092.0
1137	2018063	1076050	F	1	-2.12200	19.60	1095.0
1138	2018064	1076050	F	1	-2.16400	18.88	1102.0
1139	2018004	1076050	F	1	-2.20800	19.70	1112.0
1140	2018058	1076050	F	3	-2.36800	56.93	1127.0
1141	2018072	1076050	F	1	-2.77500	17.90	1169.0
1142	2018069	1076050	F	1	-2.97900	16.00	1183.0
1143	2018060	1076050	F	1	-3.11600	16.80	1196.5
1144	2018061	1076050	F	1	-3.16500	14.40	1200.0
1145	2018026	1076050	F	1	-3.19500	13.90	1202.0
1146	2018038	1076050	F	1	-3.51100	13.22	1221.0
1147	2018056	1076050	F	1	-3.51500	13.15	1222.0
1148	2018067	1076050	F	1	-3.53000	12.90	1225.0
1149	2018053	1076050	F	1	-4.04000	12.05	1254.0
1150	2018066	1076050	F	1	-4.56400	10.98	1275.5

------------------------------------ m_bv=-2.1976 ------------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
1151	2048075	1051064	F	2	1.4740	37.91	518.0
1152	2048039	1051064	F	1	0.3993	32.70	697.0
1153	2048062	1051064	F	3	-1.4790	59.54	998.0
1154	2048026	1051064	F	1	-1.5340	21.77	1008.0
1155	2048011	1051064	F	1	-2.0080	19.98	1080.0
1156	2048065	1051064	F	3	-2.4010	53.27	1132.0
1157	2048047	1051064	F	2	-2.7670	26.89	1168.0
1158	2048046	1051064	F	2	-3.1070	25.80	1194.5

1159	2048058	1051064	F	3	-3.9500	41.06	1247.0
1160	2048045	1051064	F	3	-4.2330	40.93	1262.0
1161	2048074	1051064	F	3	-4.5680	39.94	1278.0

------------------------------------ m_bv=-2.3498 ------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
1162	2068059	1051063	F	3	0.8474	79.33	611
1163	2068061	1051063	F	2	-0.1300	42.58	776
1164	2068054	1051063	F	3	-0.1455	70.30	777
1165	2068041	1051063	F	2	-0.1573	23.38	780
1166	2068058	1051063	F	3	-2.4370	54.86	1135
1167	2068078	1051063	F	3	-2.7320	49.86	1162
1168	2068055	1051063	F	3	-2.8060	51.72	1175
1169	2068070	1051063	F	3	-3.7710	44.73	1237
1170	2068046	1051063	F	3	-3.7720	44.72	1238
1171	2068080	1051063	F	3	-4.0220	42.03	1253
1172	2068043	1051063	F	3	-4.2800	40.79	1265
1173	2068066	1051063	F	3	-4.7920	36.79	1290

------------------------------------ m_bv=-2.4251 ------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
1174	2041080	1001071	F	2	0.9340	35.52	589.0
1175	2041043	1001071	F	2	0.4088	34.42	695.0
1176	2041034	1001071	F	1	0.1158	33.10	745.0
1177	2041027	1001071	F	1	-0.1981	30.90	786.0
1178	2041071	1001071	F	3	-0.2721	75.84	799.0
1179	2041001	1001071	F	1	-0.4766	30.86	834.0
1180	2041037	1001071	F	1	-0.8466	27.71	891.0
1181	2041035	1001071	F	1	-1.0230	29.40	915.0
1182	2041020	1001071	F	1	-1.1230	26.15	930.0
1183	2041079	1001071	F	2	-1.1640	40.54	934.0
1184	2041015	1001071	F	1	-1.2270	27.50	948.5
1185	2041006	1001071	F	1	-1.4240	24.16	988.0
1186	2041003	1001071	F	1	-1.4640	23.48	992.5
1187	2041032	1001071	F	1	-1.5270	23.98	1006.5
1188	2041030	1001071	F	1	-1.6460	23.52	1021.0
1189	2041012	1001071	F	1	-1.6570	24.90	1025.0
1190	2041041	1001071	F	2	-1.7600	21.06	1040.0
1191	2041017	1001071	F	1	-1.8420	21.76	1051.0
1192	2041076	1001071	F	3	-1.9400	61.60	1064.0
1193	2041008	1001071	F	1	-1.9590	22.90	1069.0
1194	2041026	1001071	F	1	-1.9710	22.69	1071.0
1195	2041036	1001071	F	1	-2.1250	21.65	1096.0
1196	2041072	1001071	F	2	-2.1460	22.33	1098.0
1197	2041016	1001071	F	1	-2.1550	21.14	1100.0
1198	2041033	1001071	F	1	-2.2390	19.71	1115.0
1199	2041004	1001071	F	1	-2.3330	18.12	1125.0
1200	2041046	1001071	F	3	-2.3910	60.21	1131.0
1201	2041055	1001071	F	2	-2.4090	31.91	1133.0
1202	2041013	1001071	F	1	-2.5850	20.09	1150.0
1203	2041078	1001071	F	2	-2.9240	29.43	1182.0
1204	2041049	1001071	F	2	-3.0770	28.39	1191.0
1205	2041067	1001071	F	2	-3.2240	27.47	1206.0
1206	2041069	1001071	F	3	-3.2890	52.78	1210.0

------------------------------------ m_bv=-2.4251 ------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
1207	2041047	1001071	F	2	-3.554	25.00	1227
1208	2041061	1001071	F	3	-3.609	50.48	1229
1209	2041050	1001071	F	3	-3.656	48.12	1231
1210	2041063	1001071	F	3	-3.861	46.20	1243
1211	2041077	1001071	F	3	-4.345	42.68	1269
1212	2041051	1001071	F	3	-4.367	45.43	1270
1213	2041045	1001071	F	3	-4.645	40.72	1281
1214	2041070	1001071	F	2	-4.666	20.18	1284
1215	2041060	1001071	F	3	-5.302	37.38	1308

1216	2041062	1001071	F	3	-5.924	34.65	1322
1217	2041064	1001071	F	3	-5.985	33.61	1324
1218	2041054	1001071	F	3	-6.257	33.69	1331

------------------------------------ m_bv=-3.0802 ------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
1219	2046021	1051067	F	1	0.1803	35.10	736.0
1220	2046028	1051067	F	1	-0.9373	30.20	905.0
1221	2046046	1051067	F	1	-1.0270	31.80	918.0
1222	2046039	1051067	F	1	-1.2190	30.10	945.5
1223	2046075	1051067	F	2	-1.2940	29.87	967.5
1224	2046042	1051067	F	1	-1.3270	28.27	973.0
1225	2046001	1051067	F	1	-1.5690	27.30	1014.0
1226	2046043	1051067	F	1	-1.6450	27.56	1019.5
1227	2046045	1051067	F	1	-1.9390	25.70	1062.0
1228	2046018	1051067	F	1	-2.0010	24.66	1078.0
1229	2046057	1051067	F	2	-2.3760	22.46	1130.0
1230	2046037	1051067	F	1	-2.5450	21.68	1146.0
1231	2046080	1051067	F	2	-3.0360	20.63	1187.0
1232	2046073	1051067	F	1	-3.1190	21.30	1198.0
1233	2046030	1051067	F	1	-3.2090	19.79	1205.0
1234	2046033	1051067	F	1	-3.2260	19.50	1207.0
1235	2046059	1051067	F	3	-3.3590	55.62	1217.0
1236	2046065	1051067	F	1	-3.3830	19.95	1218.0
1237	2046054	1051067	F	1	-3.8100	17.40	1241.0
1238	2046016	1051067	F	1	-4.3820	15.50	1271.0
1239	2046071	1051067	F	1	-4.5800	13.70	1279.0
1240	2046070	1051067	F	1	-4.8340	12.53	1292.0
1241	2046049	1051067	F	3	-4.8530	44.35	1293.0
1242	2046067	1051067	F	2	-4.9220	21.43	1296.0
1243	2046035	1051067	F	2	-4.9680	20.65	1297.0
1244	2046064	1051067	F	1	-5.2820	12.73	1306.0
1245	2046063	1051067	F	1	-5.3310	11.90	1311.0
1246	2046076	1051067	F	3	-6.2530	34.65	1330.0

------------------------------------ m_bv=-3.1254 ------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
1247	2011005	1026060	F	1	-0.4429	32.80	827.0
1248	2011004	1026060	F	1	-1.0710	28.40	924.0
1249	2011051	1026060	F	3	-1.1930	74.08	940.0
1250	2011013	1026060	F	1	-1.6780	25.90	1031.0
1251	2011044	1026060	F	2	-1.9820	37.40	1073.0
1252	2011022	1026060	F	1	-2.1960	23.37	1108.0
1253	2011054	1026060	F	2	-2.2230	22.39	1113.0
1254	2011027	1026060	F	1	-2.6140	19.40	1152.0
1255	2011074	1026060	F	3	-2.7530	58.55	1165.0
1256	2011021	1026060	F	1	-2.7790	21.29	1171.0
1257	2011042	1026060	F	3	-2.7860	61.12	1172.0
1258	2011036	1026060	F	1	-3.1550	18.04	1199.0
1259	2011072	1026060	F	2	-3.3510	28.24	1214.5
1260	2011068	1026060	F	3	-3.5230	53.30	1223.0
1261	2011043	1026060	F	3	-3.7610	50.83	1236.0
1262	2011078	1026060	F	2	-3.9760	23.88	1249.0
1263	2011062	1026060	F	3	-3.9820	50.20	1250.0
1264	2011045	1026060	F	2	-4.0100	26.44	1252.0
1265	2011065	1026060	F	2	-4.1900	24.95	1258.0
1266	2011055	1026060	F	2	-4.2170	22.93	1260.0
1267	2011064	1026060	F	3	-4.2210	49.28	1261.0
1268	2011077	1026060	F	2	-4.3090	22.92	1266.0
1269	2011063	1026060	F	3	-4.8190	46.95	1291.0
1270	2011071	1026060	F	3	-5.7770	40.07	1316.0

------------------------------------ m_bv=-4.1905 ------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
1271	2037031	1076043	F	1	1.351	42.52	532.0
1272	2037034	1076043	F	1	-1.666	30.40	1028.5

1273	2037037	1076043	F	1	-1.823	29.30	1045.5
1274	2037061	1076043	F	2	-2.371	39.78	1128.0
1275	2037020	1076043	F	1	-2.987	23.62	1184.0
1276	2037032	1076043	F	1	-3.198	21.60	1203.0
1277	2037012	1076043	F	1	-3.439	20.63	1219.0
1278	2037067	1076043	F	3	-3.545	58.78	1226.0
1279	2037018	1076043	F	1	-3.690	19.50	1234.0
1280	2037024	1076043	F	1	-3.880	19.40	1244.0
1281	2037068	1076043	F	2	-4.665	25.87	1283.0
1282	2037057	1076043	F	3	-5.325	45.78	1309.0
1283	2037055	1076043	F	2	-5.583	21.22	1314.0
1284	2037069	1076043	F	3	-6.160	39.43	1328.0
1285	2037060	1076043	F	3	-6.716	36.24	1344.0
1286	2037078	1076043	F	3	-6.938	32.47	1348.0
1287	2037049	1076043	F	3	-6.967	36.66	1349.0
1288	2037074	1076043	F	3	-7.827	29.89	1367.0

------------------------------------ m_bv=-4.6267 ------------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
1289	2013018	1026080	F	1	-1.547	36.30	1009.0
1290	2013079	1026080	F	3	-1.563	82.23	1013.0
1291	2013071	1026080	F	3	-3.910	67.40	1245.0
1292	2013053	1026080	F	2	-3.921	22.07	1246.0
1293	2013061	1026080	F	2	-4.196	23.65	1259.0
1294	2013041	1026080	F	2	-4.250	19.61	1263.0
1295	2013038	1026080	F	1	-4.271	21.33	1264.0
1296	2013022	1026080	F	1	-4.310	23.80	1267.5
1297	2013007	1026080	F	1	-4.460	18.13	1274.0
1298	2013027	1026080	F	1	-4.636	21.40	1280.0
1299	2013049	1026080	F	3	-4.688	60.46	1285.0
1300	2013013	1026080	F	1	-4.705	20.23	1286.0
1301	2013062	1026080	F	3	-5.021	54.82	1299.0
1302	2013068	1026080	F	2	-5.044	18.63	1300.0
1303	2013046	1026080	F	2	-5.057	32.46	1302.0
1304	2013050	1026080	F	2	-5.129	29.69	1303.0
1305	2013072	1026080	F	2	-5.789	26.30	1317.0
1306	2013066	1026080	F	2	-6.080	22.92	1326.0
1307	2013074	1026080	F	3	-6.898	46.41	1347.0
1308	2013076	1026080	F	3	-7.059	42.12	1352.0

------------------------------------ m_bv=-4.7695 ------------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
1309	2014067	1026052	F	3	-1.365	79.53	980
1310	2014013	1026052	F	1	-4.780	16.02	1288
1311	2014057	1026052	F	3	-6.455	41.62	1337
1312	2014042	1026052	F	2	-6.478	17.93	1339

------------------------------------ m_bv=-4.837 ------------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
1313	2081031	1001069	F	3	2.857	119.14	340
1314	2081003	1001069	F	2	-2.739	40.33	1163
1315	2081059	1001069	F	2	-3.358	36.08	1216
1316	2081077	1001069	F	1	-4.096	19.41	1256
1317	2081037	1001069	F	3	-5.018	48.05	1298
1318	2081011	1001069	F	1	-5.146	14.10	1304
1319	2081013	1001069	F	1	-5.908	12.10	1321
1320	2081044	1001069	F	1	-6.370	10.52	1335
1321	2081023	1001069	F	1	-6.474	10.31	1338
1322	2081049	1001069	F	1	-7.047	8.40	1351
1323	2081001	1001069	F	3	-7.151	33.75	1356
1324	2081043	1001069	F	1	-7.594	6.93	1365

------------------------------------ m_bv=-6.6232 ------------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv

1325	2040039	1076057	F	1	-3.447	28.18	1220
1326	2040038	1076057	F	1	-4.042	25.89	1255
1327	2040012	1076057	F	1	-4.772	21.32	1287
1328	2040001	1076057	F	1	-5.278	20.55	1305
1329	2040007	1076057	F	1	-5.327	19.72	1310
1330	2040042	1076057	F	2	-5.415	30.19	1312
1331	2040005	1076057	F	1	-5.484	18.61	1313
1332	2040067	1076057	F	3	-5.776	55.18	1315
1333	2040028	1076057	F	1	-5.883	18.10	1319
1334	2040013	1076057	F	1	-6.156	16.58	1327
1335	2040044	1076057	F	2	-6.326	35.04	1332
1336	2040047	1076057	F	2	-7.250	11.57	1360
1337	2040063	1076057	F	3	-7.515	42.86	1363
1338	2040059	1076057	F	3	-7.870	39.96	1368
1339	2040068	1076057	F	3	-8.505	35.44	1383
1340	2040046	1076057	F	3	-9.742	28.51	1400
1341	2040057	1076057	F	3	-9.840	28.41	1401
1342	2040061	1076057	F	3	-10.590	23.44	1414

------------------------------------ m_bv=-7.1591 ------------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
1343	2069052	1051076	F	3	-0.9998	99.35	911
1344	2069031	1051076	F	1	-4.5660	28.60	1277
1345	2069072	1051076	F	3	-6.1990	58.03	1329
1346	2069032	1051076	F	1	-6.3600	21.60	1334
1347	2069048	1051076	F	2	-6.5450	30.42	1340
1348	2069077	1051076	F	3	-6.7370	59.83	1345
1349	2069064	1051076	F	3	-7.0410	51.56	1350
1350	2069053	1051076	F	2	-7.1520	12.32	1357
1351	2069066	1051076	F	2	-7.1920	14.77	1358
1352	2069074	1051076	F	2	-7.2150	26.86	1359
1353	2069068	1051076	F	3	-7.3310	46.64	1361
1354	2069075	1051076	F	3	-7.9060	44.70	1370
1355	2069059	1051076	F	3	-7.9770	46.61	1371
1356	2069051	1051076	F	3	-8.0510	42.23	1372
1357	2069041	1051076	F	2	-8.3700	18.21	1379
1358	2069062	1051076	F	3	-8.4730	42.89	1382
1359	2069045	1051076	F	2	-8.5850	17.69	1384
1360	2069079	1051076	F	3	-8.6920	34.48	1385
1361	2069063	1051076	F	3	-8.7300	38.53	1386
1362	2069065	1051076	F	3	-9.0620	37.58	1392

------------------------------------ m_bv=-7.3699 ------------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
1363	2065073	1001065	F	2	-4.179	29.57	1257

------------------------------------ m_bv=-7.3699 ------------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
1364	2065055	1001065	F	2	-4.856	25.89	1294.0
1365	2065079	1001065	F	3	-4.860	70.99	1295.0
1366	2065072	1001065	F	3	-5.053	67.72	1301.0
1367	2065056	1001065	F	2	-5.863	35.37	1318.0
1368	2065065	1001065	F	3	-5.896	62.79	1320.0
1369	2065007	1001065	F	1	-5.934	22.20	1323.0
1370	2065060	1001065	F	3	-6.334	60.05	1333.0
1371	2065050	1001065	F	3	-6.403	60.43	1336.0
1372	2065064	1001065	F	3	-6.569	57.62	1341.0
1373	2065054	1001065	F	2	-6.579	32.59	1342.0
1374	2065046	1001065	F	2	-6.631	16.09	1343.0
1375	2065066	1001065	F	2	-6.745	29.78	1346.0
1376	2065061	1001065	F	2	-7.069	16.47	1353.0
1377	2065036	1001065	F	1	-7.073	18.50	1354.0
1378	2065051	1001065	F	3	-7.573	49.96	1364.0
1379	2065070	1001065	F	2	-7.724	24.11	1366.0

1380	2065047	1001065	F	2	-8.060	21.53	1373.0
1381	2065068	1001065	F	3	-8.085	45.97	1374.0
1382	2065076	1001065	F	2	-8.119	22.09	1375.0
1383	2065053	1001065	F	3	-8.382	44.05	1380.0
1384	2065059	1001065	F	3	-8.966	40.39	1389.0
1385	2065077	1001065	F	3	-9.014	39.57	1391.0
1386	2065071	1001065	F	2	-9.350	15.26	1394.0
1387	2065062	1001065	F	3	-10.020	33.49	1403.5
1388	2065078	1001065	F	3	-10.020	33.53	1403.5
1389	2065043	1001065	F	3	-10.420	28.31	1411.5
1390	2065067	1001065	F	3	-10.580	28.68	1413.0

-- m_bv=-9.9587 --

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
1391	2006079	1051059	F	2	-7.111	22.89	1355
1392	2006042	1051059	F	2	-7.391	24.39	1362
1393	2006038	1051059	F	2	-7.875	19.31	1369
1394	2006004	1051059	F	3	-8.186	56.06	1376
1395	2006031	1051059	F	1	-8.234	18.42	1377
1396	2006054	1051059	F	2	-8.302	29.24	1378
1397	2006070	1051059	F	2	-8.383	18.49	1381
1398	2006043	1051059	F	3	-8.752	54.27	1387
1399	2006035	1051059	F	1	-8.787	15.30	1388
1400	2006056	1051059	F	2	-8.993	26.88	1390
1401	2006037	1051059	F	3	-9.199	48.25	1393
1402	2006080	1051059	F	3	-9.528	45.80	1395
1403	2006001	1051059	F	2	-9.548	23.72	1396
1404	2006068	1051059	F	1	-9.623	13.60	1397
1405	2006051	1051059	F	2	-9.633	22.28	1398
1406	2006010	1051059	F	3	-9.706	45.91	1399
1407	2006025	1051059	F	1	-9.861	12.70	1402

-- m_bv=-9.9587 --

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
1408	2006020	1051059	F	1	-10.11	11.60	1405.0
1409	2006071	1051059	F	1	-10.14	11.10	1406.0
1410	2006077	1051059	F	1	-10.26	10.63	1407.0
1411	2006059	1051059	F	3	-10.32	43.36	1408.0
1412	2006045	1051059	F	1	-10.37	11.80	1409.0
1413	2006021	1051059	F	3	-10.40	41.93	1410.0
1414	2006067	1051059	F	1	-10.42	11.10	1411.5
1415	2006049	1051059	F	1	-10.62	9.15	1415.0
1416	2006044	1051059	F	1	-10.64	8.82	1416.0
1417	2006078	1051059	F	1	-10.69	9.57	1417.0
1418	2006076	1051059	F	1	-10.76	10.00	1418.0
1419	2006022	1051059	F	1	-11.00	9.00	1419.0
1420	2006003	1051059	F	1	-11.18	9.10	1420.0
1421	2006057	1051059	F	1	-11.34	7.90	1421.0
1422	2006013	1051059	F	1	-11.35	7.78	1422.0
1423	2006065	1051059	F	1	-11.60	6.64	1423.0
1424	2006007	1051059	F	1	-11.61	6.43	1424.0
1425	2006039	1051059	F	1	-11.83	5.93	1425.0
1426	2006024	1051059	F	1	-12.09	6.14	1426.0
1427	2006061	1051059	F	1	-12.63	4.83	1427.0

Appendix 2b

Breeding values and ranking of male *Oreochromis niloticus (generation 2)* reared in three culture environments.
(fish_ID = fish identification; env= culture environment, 1 = extensive, 2 = semi-intensive, 3 = intensive; bv = breeding value of individual fish; wt = final weight; rank_bv = ranks based on breeding values; m_bv = breeding value of family).

------------------------------------- m_bv=17.94 ---------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
1	2005020	1001050	M	1	17.94	106.7	1

------------------------------------- m_bv=6.2164 ---------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
2	2064079	1001076	M	3	9.676	118.40	4
3	2063063	1001076	M	3	8.802	122.53	5
4	2063042	1001076	M	3	7.808	110.36	6
5	2063045	1001076	M	3	7.286	106.19	7
6	2063074	1001076	M	2	6.722	46.78	10
7	2063058	1001076	M	2	6.580	50.62	11
8	2063075	1001076	M	2	6.503	47.76	12
9	2063062	1001076	M	3	6.365	103.06	14
10	2063013	1001076	M	1	4.878	37.90	32
11	2063027	1001076	M	1	3.954	31.60	58
12	2063080	1001076	M	2	3.507	46.92	66
13	2063070	1001076	M	3	2.516	67.46	105

------------------------------------- m_bv=5.4305 ---------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
14	2052014	1026051	M	1	10.200	80.60	2
15	2052054	1026051	M	3	10.150	135.25	3
16	2052077	1026051	M	3	6.432	101.88	13
17	2052030	1026051	M	1	5.835	44.00	16
18	2052008	1026051	M	1	5.740	42.40	19
19	2052072	1026051	M	3	5.619	94.34	22
20	2052068	1026051	M	3	5.507	92.45	24
21	2052004	1026051	M	1	5.429	41.80	25
22	2052080	1026051	M	3	5.106	90.33	29
23	2052041	1026051	M	3	4.788	84.93	36
24	2052016	1026051	M	1	4.768	38.40	38
25	2052060	1026051	M	3	4.733	84.01	40
26	2052044	1026051	M	2	4.657	39.12	43
27	2052070	1026051	M	3	4.655	84.24	44
28	2052078	1026051	M	3	3.914	77.92	60
29	2052073	1026051	M	3	3.777	78.72	61
30	2052079	1026051	M	2	3.742	50.15	63
31	2052045	1026051	M	2	2.697	43.35	96

------------------------------------- m_bv=5.0945 ---------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
32	2016074	1076042	M	2	6.256	44.16	15
33	2016055	1076042	M	2	3.933	46.92	59

--- m_bv=4.978 ---

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
34	2064074	1001046	M	3	7.164	116.58	8
35	2064056	1001046	M	3	6.771	116.16	9
36	2064050	1001046	M	3	5.689	105.63	20
37	2064068	1001046	M	3	5.421	105.77	26
38	2064051	1001046	M	3	5.084	100.05	30
39	2064060	1001046	M	2	4.648	44.38	45
40	2064001	1001046	M	1	4.044	40.90	52
41	2064009	1001046	M	1	4.028	42.20	54
42	2064025	1001046	M	1	3.481	37.60	67
43	2064071	1001046	M	3	3.450	84.84	68

--- m_bv=3.262 ---

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
44	2036028	1076059	M	1	3.262	38.8	75

--- m_bv=2.99 ---

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
45	2079059	1076047	M	2	5.6320	64.75	21
46	2079033	1076047	M	1	4.7670	63.10	39
47	2079050	1076047	M	2	1.0670	52.92	178
48	2079077	1076047	M	2	0.4939	47.88	235

--- m_bv=2.8569 ---

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
49	2067048	1051075	M	3	5.0310	111.23	31
50	2067055	1051075	M	3	3.9660	100.97	57
51	2067040	1051075	M	1	3.1250	45.20	80
52	2067002	1051075	M	1	2.8990	39.80	87
53	2067015	1051075	M	1	2.8950	41.30	88
54	2067031	1051075	M	1	2.8230	43.20	92
55	2067035	1051075	M	1	2.5340	38.30	103
56	2067011	1051075	M	1	2.4650	38.70	108
57	2067072	1051075	M	2	2.4340	37.64	110
58	2067009	1051075	M	1	0.3966	28.60	240

--- m_bv=2.8141 ---

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
59	2043044	1001078	M	3	5.755	108.79	18
60	2044055	1001078	M	3	5.420	107.79	27

--- m_bv=2.8141 ---

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
61	2043022	1001078	M	1	4.3220	52.35	48
62	2043076	1001078	M	2	4.1720	49.28	50
63	2043054	1001078	M	2	4.0510	47.23	51
64	2043036	1001078	M	1	4.0350	49.05	53
65	2043032	1001078	M	1	3.5950	46.27	65
66	2043023	1001078	M	1	3.2380	43.33	76
67	2044080	1001078	M	3	3.2340	92.59	77
68	2043051	1001078	M	3	3.1110	92.06	82
69	2043005	1001078	M	1	2.9340	42.86	86
70	2043024	1001078	M	1	1.7890	34.38	138
71	2043008	1001078	M	1	1.0410	29.51	180
72	2043029	1001078	M	1	1.0300	27.76	184
73	2043040	1001078	M	1	1.0130	29.02	185

74	2043079	1001078	M	2	0.9252	45.75	195
75	2043015	1001078	M	1	-1.8260	16.80	463

-- m_bv=2.2491 ----------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
76	2012003	1026045	M	1	4.7760	57.02	37
77	2012044	1026045	M	3	4.2300	106.46	49
78	2012016	1026045	M	1	3.7740	47.85	62
79	2012070	1026045	M	3	3.2810	93.48	74
80	2012054	1026045	M	2	3.1220	42.50	81
81	2012014	1026045	M	1	2.5430	41.02	102
82	2012020	1026045	M	1	2.1780	36.40	120
83	2012001	1026045	M	1	1.4730	35.37	154
84	2012025	1026045	M	1	1.3740	33.68	162
85	2012022	1026045	M	1	0.8615	29.68	200
86	2012010	1026045	M	1	0.7211	27.30	205
87	2012007	1026045	M	1	0.4839	26.40	236
88	2012013	1026045	M	1	0.4202	25.32	239

-- m_bv=2.025 ----------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
89	2008055	1051080	M	3	5.772	118.14	17
90	2008056	1051080	M	3	5.570	116.29	23
91	2008048	1051080	M	3	3.664	98.02	64
92	2008029	1051080	M	1	2.832	42.40	91
93	2062008	1051080	M	1	2.611	45.60	100
94	2062071	1051080	M	3	2.456	90.73	109
95	2008007	1051080	M	1	2.381	39.44	112
96	2062075	1051080	M	3	2.198	89.48	119
97	2008071	1051080	M	3	2.029	79.66	126
98	2008004	1051080	M	1	2.019	36.42	127

-- m_bv=2.025 ----------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
99	2008023	1051080	M	1	1.88000	37.19	134
100	2008012	1051080	M	1	1.67200	35.21	147
101	2062056	1051080	M	3	1.45600	89.38	155
102	2008037	1051080	M	1	1.44600	34.51	157
103	2008019	1051080	M	1	1.38300	35.00	161
104	2008074	1051080	M	3	1.32500	83.33	165
105	2008028	1051080	M	1	1.04000	32.30	181
106	2062048	1051080	M	2	0.68460	54.57	211
107	2008014	1051080	M	1	0.67460	26.11	212
108	2062066	1051080	M	3	0.00312	75.68	278
109	2008043	1051080	M	2	-0.57050	37.26	329

-- m_bv=1.8778 ----------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
110	2042005	1001058	M	3	4.7970	113.08	35.0
111	2042045	1001058	M	3	3.3230	100.58	73.0
112	2042035	1001058	M	3	3.2000	95.37	79.0
113	2042044	1001058	M	3	2.9800	94.77	85.0
114	2042024	1001058	M	3	2.8930	93.29	89.0
115	2042054	1001058	M	3	2.7190	91.89	95.0
116	2042004	1001058	M	3	2.4870	94.21	106.5
117	2042008	1001058	M	3	2.1630	88.72	122.0
118	2042055	1001058	M	3	1.7720	82.09	140.0
119	2042041	1001058	M	3	1.3310	82.41	163.0
120	2042066	1001058	M	3	1.1500	82.47	174.0
121	2042042	1001058	M	3	0.6861	76.16	210.0
122	2042002	1001058	M	3	-0.7294	66.21	353.0
123	2042012	1001058	M	3	-2.4830	52.09	530.0

------------------------------------- m_bv=1.7727 ---------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
124	2024024	1001079	M	1	4.00100	48.10	55.5
125	2024064	1001079	M	3	2.76600	84.29	94.0
126	2024079	1001079	M	2	2.67700	37.62	98.0
127	2024067	1001079	M	3	2.52700	84.92	104.0
128	2024026	1001079	M	1	2.36100	35.90	113.0
129	2024037	1001079	M	1	1.64100	34.63	149.0
130	2024029	1001079	M	1	1.50000	33.80	153.0
131	2024025	1001079	M	1	1.20500	30.36	172.0
132	2024035	1001079	M	1	0.57610	21.25	227.0
133	2024060	1001079	M	2	0.19700	40.84	256.0
134	2024076	1001079	M	2	0.04844	25.83	270.0

------------------------------------- m_bv=1.432 ---------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
135	2004065	1001067	M	3	1.432	53.42	159

------------------------------------- m_bv=1.3793 ---------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
136	2031017	1026043	M	3	5.4110	122.83	28
137	2031002	1026043	M	3	4.8060	115.69	34
138	2031022	1026043	M	3	4.6960	116.95	41
139	2031013	1026043	M	3	4.6600	117.90	42
140	2031011	1026043	M	2	3.3620	50.73	70
141	2031079	1026043	M	3	3.3330	98.51	72
142	2031018	1026043	M	3	3.0530	101.58	84
143	2031006	1026043	M	2	2.0940	40.15	124
144	2031034	1026043	M	3	1.2610	91.49	169
145	2031065	1026043	M	2	0.5218	33.79	231
146	2031068	1026043	M	2	-0.4479	43.89	320
147	2031056	1026043	M	1	-0.5282	29.00	325
148	2031050	1026043	M	2	-0.8403	41.92	358
149	2031025	1026043	M	2	-0.9529	40.01	369
150	2031061	1026043	M	2	-1.2050	40.42	394
151	2031042	1026043	M	2	-1.2810	43.82	401
152	2031072	1026043	M	1	-1.4050	23.50	421
153	2031038	1026043	M	1	-1.7100	23.01	451

------------------------------------- m_bv=1.2898 ---------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
154	2045044	1001055	M	3	4.36200	106.48	47.0
155	2045042	1001055	M	2	4.00100	53.64	55.5
156	2045045	1001055	M	2	3.34700	48.79	71.0
157	2045058	1001055	M	2	2.87400	45.46	90.0
158	2045027	1001055	M	1	2.58600	48.90	101.0
159	2045064	1001055	M	3	2.01400	91.64	128.0
160	2045001	1001055	M	1	1.87100	39.90	135.0
161	2045002	1001055	M	1	1.74000	40.80	141.0
162	2045030	1001055	M	1	1.72200	40.50	143.0
163	2045004	1001055	M	1	1.44500	35.80	158.0
164	2045006	1001055	M	1	0.99880	32.92	186.0
165	2045021	1001055	M	1	0.97680	35.67	188.0
166	2045049	1001055	M	3	0.87340	80.11	198.0
167	2045038	1001055	M	1	0.86360	33.75	199.0
168	2045048	1001055	M	2	0.82980	52.95	201.0
169	2045052	1001055	M	2	0.10410	48.45	264.0
170	2045067	1001055	M	2	-0.00091	46.67	279.0
171	2045066	1001055	M	2	-0.15840	44.00	293.0
172	2045032	1001055	M	1	-0.37020	26.88	315.0
173	2045056	1001055	M	2	-0.71960	42.29	350.0

-- m_bv=1.2898 ----------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
174	2045075	1001055	M	3	-2.274	65.78	507

-- m_bv=0.9096 ----------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
175	2034050	1026047	M	3	4.87500	119.89	33
176	2034047	1026047	M	2	1.65800	40.48	148
177	2035048	1026047	M	3	0.25200	78.60	251
178	2034019	1026047	M	1	0.05885	32.62	268
179	2034028	1026047	M	1	-0.26730	28.65	304
180	2034057	1026047	M	3	-1.11900	65.08	386

-- m_bv=0.6524 ----------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
181	2035030	1026054	M	1	2.39800	45.30	111
182	2035019	1026054	M	1	1.51000	39.60	152
183	2035036	1026054	M	1	1.45100	38.60	156
184	2035033	1026054	M	1	1.29400	40.63	167
185	2035017	1026054	M	1	0.93840	36.16	193
186	2035021	1026054	M	1	0.69710	35.19	209
187	2035028	1026054	M	1	0.66820	34.70	215
188	2035080	1026054	M	2	0.03854	48.48	273
189	2035034	1026054	M	1	0.01810	28.36	276
190	2035065	1026054	M	3	-0.72390	71.34	351
191	2035054	1026054	M	2	-1.11300	41.44	385

-- m_bv=0.564 ----------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
192	2047024	1051073	M	1	2.6700	50.90	99
193	2047031	1051073	M	1	2.1750	48.76	121
194	2047015	1051073	M	1	2.0030	47.40	129
195	2047059	1051073	M	2	1.9510	47.55	131
196	2047022	1051073	M	1	1.8540	43.30	136
197	2047055	1051073	M	3	1.2700	90.53	168
198	2047033	1051073	M	1	0.6715	38.87	213
199	2047008	1051073	M	1	0.6568	38.62	219
200	2047004	1051073	M	1	0.5422	39.80	228
201	2047032	1051073	M	1	0.5363	39.70	229
202	2047068	1051073	M	3	0.5089	85.43	232
203	2047012	1051073	M	1	0.4950	39.00	234
204	2047021	1051073	M	1	0.1966	35.50	257
205	2047040	1051073	M	1	-0.1391	32.93	290

-- m_bv=0.564 ----------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
206	2047039	1051073	M	1	-0.2442	32.71	301
207	2047026	1051073	M	1	-0.3476	34.08	313
208	2047016	1051073	M	1	-0.6248	30.94	342
209	2047030	1051073	M	1	-0.7464	32.00	354
210	2047043	1051073	M	2	-0.9854	46.16	373
211	2047079	1051073	M	2	-1.1620	41.61	391

m_bv=0.5366

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
212	2033057	1026071	M	3	3.3770	112.03	69.0
213	2033055	1026071	M	2	2.3330	49.18	115.0
214	2033044	1026071	M	3	2.3300	103.64	116.0
215	2033042	1026071	M	2	1.7070	46.36	145.0
216	2033053	1026071	M	2	1.6760	45.83	146.0
217	2033058	1026071	M	3	0.7060	88.60	208.0
218	2033018	1026071	M	1	-0.4917	39.27	323.0
219	2033046	1026071	M	2	-0.6366	50.34	344.0
220	2033004	1026071	M	1	-1.0800	29.30	381.5
221	2033056	1026071	M	3	-1.1350	74.56	388.0
222	2033043	1026071	M	3	-1.1710	73.94	392.0
223	2033026	1026071	M	1	-1.1760	27.67	393.0

m_bv=0.4015

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
224	2054013	1026067	M	2	3.0580	55.65	83
225	2054033	1026067	M	3	2.6800	105.34	97
226	2054037	1026067	M	2	1.6280	45.46	150
227	2054062	1026067	M	2	1.2270	40.22	171
228	2054049	1026067	M	1	0.1125	35.90	261
229	2054070	1026067	M	1	-0.6464	32.40	346
230	2054032	1026067	M	1	-2.2170	24.50	501
231	2054002	1026067	M	2	-2.6300	37.27	539

m_bv=0.3326

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
232	2078048	1076060	M	3	4.5600	128.70	46
233	2078077	1076060	M	1	1.9300	45.70	133
234	2078022	1076060	M	3	1.0310	87.59	183
235	2078042	1076060	M	1	0.8936	37.50	197
236	2078015	1076060	M	1	0.6305	34.60	224
237	2078029	1076060	M	2	0.3352	55.61	245

m_bv=0.3326

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
238	2078062	1076060	M	1	-0.5910	29.50	331.0
239	2078031	1076060	M	1	-0.6867	31.00	348.0
240	2078001	1076060	M	1	-0.9117	22.50	361.0
241	2078068	1076060	M	1	-1.4710	25.50	425.0
242	2078040	1076060	M	2	-2.0610	36.83	479.5

m_bv=0.2988

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
243	2020069	1076052	M	2	2.28000	45.63	117
244	2020010	1076052	M	1	1.53300	41.30	151
245	2020021	1076052	M	1	0.04034	31.60	272
246	2020036	1076052	M	1	-0.12970	33.40	287
247	2020030	1076052	M	1	-0.62470	29.69	341
248	2020025	1076052	M	1	-1.30600	24.39	407

m_bv=-0.0868

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
249	2077050	1076055	M	3	1.84600	100.34	137.0
250	2077046	1076055	M	2	0.60710	37.29	226.0
251	2077002	1076055	M	1	0.45160	38.30	237.0
252	2077034	1076055	M	1	0.30870	39.00	247.0

253	2077044	1076055	M	3	0.19920	84.90	255.0
254	2077035	1076055	M	1	0.08687	36.80	265.0
255	2077042	1076055	M	2	-1.29400	45.64	404.5
256	2077070	1076055	M	3	-2.90000	55.76	561.0

------------------------------------- m_bv=-0.1418 --------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
257	2025050	1001049	M	1	-0.1418	36	292

------------------------------------- m_bv=-0.2716 --------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
258	2057054	1076045	M	3	2.4870	110.45	106.5
259	2057062	1076045	M	3	1.2990	101.23	166.0
260	2057057	1076045	M	3	-0.5974	84.69	333.0
261	2057059	1076045	M	2	-0.7625	33.61	355.0
262	2057001	1076045	M	1	-1.0470	34.00	379.0
263	2057068	1076045	M	3	-1.4250	80.03	423.0

------------------------------------- m_bv=-0.2716 --------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
264	2057019	1076045	M	1	-1.855	28.1	469

------------------------------------- m_bv=-0.3404 --------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
265	2060065	1076046	M	2	3.22700	60.11	78
266	2060040	1076046	M	1	2.35200	53.60	114
267	2060049	1076046	M	2	1.16900	47.07	173
268	2060011	1076046	M	1	0.95690	44.00	190
269	2060004	1076046	M	1	0.92150	43.40	196
270	2060073	1076046	M	2	0.82150	42.74	202
271	2060027	1076046	M	1	0.81540	41.60	203
272	2060080	1076046	M	3	0.78250	90.36	204
273	2060068	1076046	M	2	0.20480	40.09	254
274	2060044	1076046	M	3	0.02804	82.25	275
275	2060033	1076046	M	1	-0.03418	35.00	281
276	2060057	1076046	M	3	-0.12910	85.83	286
277	2060048	1076046	M	3	-0.25830	83.64	302
278	2060051	1076046	M	2	-0.26650	35.22	303
279	2060071	1076046	M	3	-0.91260	78.79	362
280	2060043	1076046	M	3	-0.94670	76.65	368
281	2060079	1076046	M	2	-1.08800	49.39	383
282	2060075	1076046	M	2	-1.38500	47.48	416
283	2060070	1076046	M	3	-1.45800	75.78	424
284	2060054	1076046	M	3	-1.68200	73.55	448
285	2060045	1076046	M	3	-2.06700	70.15	481
286	2060042	1076046	M	2	-2.24600	40.68	505
287	2060052	1076046	M	3	-2.43000	79.61	524
288	2060046	1076046	M	3	-4.54600	49.97	644

------------------------------------- m_bv=-0.5147 --------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
289	2068062	1051063	M	2	1.78200	57.78	139
290	2068075	1051063	M	2	1.73200	56.94	142
291	2068056	1051063	M	2	1.05100	46.94	179
292	2068049	1051063	M	2	0.63810	46.19	223
293	2068065	1051063	M	2	0.03196	45.28	274
294	2068020	1051063	M	1	-0.50990	41.30	324
295	2068044	1051063	M	3	-0.59700	89.14	332
296	2068042	1051063	M	2	-0.62410	62.26	340
297	2068068	1051063	M	3	-0.82250	88.44	357
298	2068063	1051063	M	3	-1.36400	82.38	411
299	2068072	1051063	M	2	-1.95000	50.71	474

300	2068076	1051063	M	2	-2.80800	43.96	555
301	2068069	1051063	M	2	-3.25100	41.14	581

-- m_bv=-0.6817 ----------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_b
302	2003046	1001044	M	3	1.41100	104.47	160
303	2003026	1001044	M	1	0.65530	43.90	220
304	2003038	1001044	M	1	0.29370	40.89	249
305	2003035	1001044	M	1	0.23990	43.10	252
306	2003018	1001044	M	1	-0.07174	42.50	283
307	2003021	1001044	M	1	-0.18700	34.30	295
308	2003024	1001044	M	1	-0.27220	39.10	306
309	2003030	1001044	M	1	-0.60850	34.96	335
310	2003076	1001044	M	2	-0.69740	36.05	349
311	2003016	1001044	M	1	-0.94420	32.39	367
312	2003013	1001044	M	1	-1.88000	33.69	470
313	2003027	1001044	M	1	-2.14000	27.73	494
314	2003071	1001044	M	2	-2.16300	43.98	499
315	2003065	1001044	M	3	-3.18000	57.85	577

-- m_bv=-0.7043 ----------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
316	2028057	1051071	M	3	2.7700	116.68	93.0
317	2028046	1051071	M	3	2.1140	113.35	123.0
318	2028073	1051071	M	3	2.0420	113.69	125.0
319	2028043	1051071	M	3	1.7180	106.64	144.0
320	2028048	1051071	M	3	0.9960	99.08	187.0
321	2028053	1051071	M	2	0.7178	44.52	206.0
322	2028019	1051071	M	1	0.5228	43.30	230.0
323	2028049	1051071	M	3	0.3904	88.81	241.0
324	2028029	1051071	M	1	0.1228	41.20	259.0
325	2028017	1051071	M	1	-0.3540	37.80	314.0
326	2028035	1051071	M	1	-0.4247	36.60	317.0
327	2028011	1051071	M	1	-0.6134	33.40	337.0
328	2028027	1051071	M	1	-0.6193	33.30	339.0
329	2028034	1051071	M	1	-0.8832	33.51	359.0
330	2028024	1051071	M	1	-1.0430	33.92	378.0
331	2028006	1051071	M	1	-1.0800	33.30	381.5
332	2028075	1051071	M	3	-1.3080	78.74	408.0
333	2028015	1051071	M	1	-1.3600	33.23	409.0
334	2028003	1051071	M	1	-1.5600	31.40	434.0
335	2028007	1051071	M	1	-1.5720	31.20	436.5
336	2028025	1051071	M	1	-1.7990	27.35	459.5
337	2028074	1051071	M	2	-1.8360	48.05	466.0
338	2028012	1051071	M	1	-1.8500	29.61	468.0
339	2028039	1051071	M	1	-2.1190	28.17	491.0
340	2028062	1051071	M	2	-2.2810	45.19	509.0
341	2028014	1051071	M	1	-2.4080	26.39	522.0
342	2028018	1051071	M	1	-2.4490	25.69	526.0
343	2028066	1051071	M	2	-2.7940	39.61	553.0
344	2028042	1051071	M	3	-3.4640	62.49	600.0

-- m_bv=-0.7794 ----------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
345	2058027	1076058	M	1	1.1420	48.80	175
346	2058004	1076058	M	1	0.7153	40.00	207
347	2058055	1076058	M	2	0.6693	43.38	214
348	2058006	1076058	M	1	0.6654	45.40	217
349	2058015	1076058	M	1	0.6419	45.00	222
350	2058077	1076058	M	3	0.5047	90.43	233
351	2058080	1076058	M	3	0.3901	91.61	242
352	2058047	1076058	M	3	0.1107	85.31	262
353	2058034	1076058	M	1	-0.1075	40.10	284
354	2058041	1076058	M	3	-0.1933	84.84	296
355	2058013	1076058	M	1	-0.6114	37.80	336
356	2058069	1076058	M	3	-0.9361	80.05	366
357	2058063	1076058	M	3	-0.9815	79.28	371
358	2058058	1076058	M	3	-1.2820	74.19	402

359	2058052	1076058	M	2	-1.5940	48.72	439
360	2058050	1076058	M	3	-1.6280	79.25	442
361	2058065	1076058	M	2	-2.0910	44.98	486
362	2058073	1076058	M	3	-2.1240	67.71	492
363	2058064	1076058	M	3	-2.7340	66.73	548
364	2058071	1076058	M	2	-2.8850	39.31	560
365	2058042	1076058	M	3	-4.0380	58.68	626

------------------------------------- m_bv=-0.926 ---------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
366	2049025	1051066	M	1	1.1070	47.80	177.0
367	2049038	1051066	M	1	0.6478	43.13	221.0
368	2049034	1051066	M	1	-0.2852	39.80	307.0
369	2049040	1051066	M	1	-0.2933	38.10	308.0
370	2049010	1051066	M	1	-1.4100	28.53	422.0
371	2049027	1051066	M	1	-1.5720	28.91	436.5
372	2049024	1051066	M	1	-1.7190	29.53	452.0
373	2049037	1051066	M	1	-2.0400	27.21	478.0
374	2049016	1051066	M	1	-2.7690	24.22	551.0

------------------------------------- m_bv=-0.9527 ---------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
375	2044021	1001059	M	1	1.9360	52.80	132
376	2044005	1001059	M	1	0.9570	44.00	189
377	2044038	1001059	M	1	0.3374	41.30	244
378	2044063	1001059	M	3	0.3012	86.88	248
379	2044056	1001059	M	3	0.1144	91.52	260
380	2044064	1001059	M	3	0.0632	100.02	267
381	2044059	1001059	M	3	-0.1604	86.86	294
382	2044001	1001059	M	1	-0.4237	36.20	316
383	2044045	1001059	M	3	-0.4305	82.28	318

------------------------------------- m_bv=-0.9527 ---------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
384	2044024	1001059	M	1	-0.6325	32.66	343.0
385	2044041	1001059	M	3	-0.7944	77.67	356.0
386	2045059	1001059	M	3	-0.9205	84.90	364.0
387	2044012	1001059	M	1	-0.9848	32.93	372.0
388	2044033	1001059	M	1	-1.1420	31.83	390.0
389	2044030	1001059	M	1	-1.2930	32.39	403.0
390	2044029	1001059	M	1	-1.6680	29.16	446.0
391	2044013	1001059	M	1	-1.7940	28.58	457.5
392	2044016	1001059	M	1	-1.9390	26.11	473.0
393	2044026	1001059	M	1	-2.1000	28.08	487.0
394	2044070	1001059	M	2	-2.2850	43.14	510.0
395	2044004	1001059	M	1	-2.3280	27.32	514.0
396	2044035	1001059	M	1	-2.4910	24.57	531.0
397	2044003	1001059	M	1	-2.4980	24.44	532.0
398	2044018	1001059	M	1	-2.6900	22.75	543.5

------------------------------------- m_bv=-1.1274 ---------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
399	2039076	1076056	M	2	0.95320	46.09	191
400	2039074	1076056	M	3	0.60730	93.19	225
401	2039018	1076056	M	1	0.38940	43.30	243
402	2039004	1076056	M	1	0.33040	42.30	246
403	2039003	1076056	M	1	0.27150	41.30	250
404	2039002	1076056	M	1	0.10500	41.60	263
405	2039072	1076056	M	3	-0.00759	90.57	280
406	2039030	1076056	M	1	-0.07099	43.30	282
407	2039064	1076056	M	3	-0.14160	91.42	291
408	2039006	1076056	M	1	-0.19710	39.60	297
409	2039015	1076056	M	1	-0.23020	40.60	299
410	2039038	1076056	M	1	-0.88400	37.32	360
411	2039017	1076056	M	1	-0.97360	35.80	370
412	2039010	1076056	M	1	-1.06900	34.19	380

413	2039019	1076056	M	1	-1.12000	33.32	387
414	2039043	1076056	M	2	-1.26800	52.15	400
415	2039075	1076056	M	2	-1.37400	50.34	413
416	2039009	1076056	M	1	-1.37800	32.07	414
417	2039046	1076056	M	3	-1.47300	73.53	426
418	2039053	1076056	M	3	-1.48300	74.92	429
419	2039011	1076056	M	1	-1.51300	31.34	431
420	2039031	1076056	M	1	-1.69200	29.86	449
421	2039014	1076056	M	1	-1.77400	31.60	456
422	2039060	1076056	M	2	-2.11300	44.06	490
423	2039059	1076056	M	2	-2.22400	43.73	503
424	2039013	1076056	M	1	-2.36700	27.79	516
425	2039056	1076056	M	2	-2.44500	43.11	525
426	2039063	1076056	M	2	-2.75800	40.93	550
427	2039052	1076056	M	2	-2.78100	38.97	552

------------------------------------ m_bv=-1.1274 ---------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
428	2039070	1076056	M	3	-5.143	50.33	675

------------------------------------ m_bv=-1.1772 ---------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
429	2059029	1076049	M	1	-0.1254	39.20	285
430	2059039	1076049	M	1	-0.2683	39.90	305
431	2059079	1076049	M	2	-3.1380	40.68	574

------------------------------------ m_bv=-1.2628 ---------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
432	2071063	1026055	M	3	0.43790	93.79	238
433	2071062	1026055	M	3	0.22940	85.57	253
434	2071071	1026055	M	2	0.06612	45.45	266
435	2071019	1026055	M	1	-0.13380	37.90	288
436	2071020	1026055	M	1	-0.33280	39.21	310
437	2071012	1026055	M	1	-0.34160	37.50	312
438	2071022	1026055	M	1	-0.48810	39.70	321
439	2071018	1026055	M	1	-0.49100	39.65	322
440	2071042	1026055	M	3	-0.53740	86.62	327
441	2071067	1026055	M	3	-0.91540	81.77	363
442	2071036	1026055	M	1	-0.93400	35.26	365
443	2071005	1026055	M	1	-0.99770	34.18	375
444	2071011	1026055	M	1	-1.00800	37.12	376
445	2071029	1026055	M	1	-1.23400	33.30	398
446	2071053	1026055	M	3	-1.24400	73.08	399
447	2071004	1026055	M	1	-1.30000	32.18	406
448	2071014	1026055	M	1	-1.40000	33.60	420
449	2071076	1026055	M	2	-1.59300	48.54	438
450	2071061	1026055	M	2	-1.59600	50.05	440
451	2071003	1026055	M	1	-1.68000	28.86	447
452	2071055	1026055	M	3	-1.76700	72.02	455
453	2071051	1026055	M	2	-1.81000	47.98	461
454	2071065	1026055	M	3	-2.40300	70.59	520
455	2071043	1026055	M	2	-2.60500	42.31	538
456	2071054	1026055	M	3	-2.64800	68.00	540
457	2071052	1026055	M	3	-2.65700	67.85	541
458	2071072	1026055	M	3	-2.71400	66.89	546
459	2071026	1026055	M	1	-3.26100	22.35	583

------------------------------------ m_bv=-1.8884 ---------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
460	2048060	1051064	M	3	2.2250	117.61	118.0
461	2048044	1051064	M	3	1.9790	116.56	130.0
462	2048077	1051064	M	3	1.3300	110.25	164.0
463	2048034	1051064	M	1	-0.5876	40.90	330.0
464	2048051	1051064	M	3	-0.6071	93.01	334.0
465	2048071	1051064	M	3	-0.6171	92.84	338.0

466	2048079	1051064	M	3	-0.6500	89.16	347.0
467	2048063	1051064	M	3	-1.1360	84.04	389.0
468	2048027	1051064	M	1	-1.2940	38.29	404.5
469	2048001	1051064	M	1	-1.3960	35.00	419.0
470	2048032	1051064	M	1	-1.5200	36.02	432.0
471	2048014	1051064	M	1	-1.5280	29.63	433.0
472	2048064	1051064	M	3	-1.6090	83.82	441.0
473	2048019	1051064	M	1	-1.6400	37.10	443.0
474	2048078	1051064	M	2	-1.7940	33.97	457.5
475	2048030	1051064	M	1	-1.8320	36.97	464.0
476	2048025	1051064	M	1	-1.8420	33.68	467.0
477	2048018	1051064	M	1	-1.9380	32.06	472.0
478	2048037	1051064	M	1	-2.0800	32.77	482.0
479	2048023	1051064	M	1	-2.2190	33.53	502.0
480	2048038	1051064	M	1	-2.2440	31.55	504.0
481	2048002	1051064	M	1	-2.2750	32.58	508.0
482	2048009	1051064	M	1	-2.4520	31.15	527.0
483	2048040	1051064	M	1	-2.5290	29.83	534.0
484	2048006	1051064	M	1	-2.6850	27.19	542.0
485	2048054	1051064	M	3	-2.8130	72.77	556.0
486	2048061	1051064	M	2	-3.3900	41.25	591.0
487	2048041	1051064	M	2	-3.6860	39.36	606.0
488	2048070	1051064	M	2	-4.0200	36.81	623.0
489	2048052	1051064	M	2	-4.0700	37.54	627.0
490	2048053	1051064	M	2	-4.3470	34.40	639.0
491	2048066	1051064	M	2	-4.3870	35.28	640.0
492	2048072	1051064	M	2	-4.6620	32.18	652.0

------------------------------------- m_bv=-1.8937 -------------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
493	2022046	1001074	M	3	0.9457	100.35	192
494	2022066	1001074	M	2	0.1441	43.16	258
495	2022045	1001074	M	3	-0.2159	90.02	298
496	2022063	1001074	M	2	-0.5451	39.28	328
497	2022052	1001074	M	2	-0.6414	42.33	345
498	2022005	1001074	M	1	-1.0370	37.70	377
499	2022032	1001074	M	1	-1.2330	37.50	397
500	2022003	1001074	M	1	-1.3900	36.40	418
501	2022026	1001074	M	1	-1.6990	32.72	450
502	2022035	1001074	M	1	-1.7440	33.52	453
503	2022012	1001074	M	1	-1.7640	33.18	454
504	2022019	1001074	M	1	-1.8830	34.30	471

------------------------------------- m_bv=-1.8937 -------------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
505	2022064	1001074	M	3	-2.061	77.46	479.5
506	2022039	1001074	M	1	-2.141	31.47	495.0
507	2022011	1001074	M	1	-2.159	32.74	498.0
508	2022034	1001074	M	1	-2.347	31.10	515.0
509	2022004	1001074	M	1	-2.481	30.40	529.0
510	2022036	1001074	M	1	-2.543	27.79	535.0
511	2022070	1001074	M	3	-2.690	71.49	543.5
512	2022029	1001074	M	1	-2.709	29.65	545.0
513	2022074	1001074	M	2	-2.958	43.65	563.0
514	2022079	1001074	M	2	-3.189	39.72	578.0
515	2022054	1001074	M	2	-3.769	36.14	608.0
516	2022067	1001074	M	2	-5.338	28.26	678.0

------------------------------------- m_bv=-2.0237 -------------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
517	2032068	1026046	M	2	0.9276	55.42	194.0
518	2032049	1026046	M	2	0.6583	46.17	218.0
519	2032076	1026046	M	3	-0.1390	91.86	289.0
520	2032071	1026046	M	3	-0.4375	88.36	319.0
521	2032046	1026046	M	3	-0.7241	85.06	352.0
522	2032001	1026046	M	1	-1.1100	37.00	384.0
523	2032063	1026046	M	3	-1.4820	83.14	427.5
524	2032033	1026046	M	1	-1.5000	36.63	430.0

525	2032004	1026046	M	1	-1.8350	30.95	465.0
526	2032044	1026046	M	3	-1.9560	76.67	475.0
527	2032029	1026046	M	1	-1.9930	32.97	476.5
528	2032036	1026046	M	1	-2.0820	31.46	483.5
529	2032025	1026046	M	1	-2.1060	32.60	488.0
530	2032005	1026046	M	1	-2.2650	34.60	506.0
531	2032043	1026046	M	3	-2.3790	77.29	517.0
532	2032037	1026046	M	1	-2.3800	32.64	518.0
533	2032047	1026046	M	2	-2.4220	48.59	523.0
534	2032016	1026046	M	1	-2.5100	32.01	533.0
535	2032017	1026046	M	1	-2.9840	27.08	564.0
536	2032066	1026046	M	2	-3.0360	42.86	566.0
537	2032058	1026046	M	2	-3.3720	40.28	589.0
538	2032067	1026046	M	2	-3.3760	40.21	590.0
539	2032022	1026046	M	1	-3.4140	26.04	592.0
540	2032075	1026046	M	2	-3.4530	40.46	597.5
541	2032073	1026046	M	3	-3.5920	64.53	604.0
542	2032014	1026046	M	1	-3.6550	23.52	605.0

------------------------------------- m_bv=-2.039 ----------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
543	2018021	1076050	M	3	1.24200	110.30	170
544	2018015	1076050	M	1	1.03600	52.80	182
545	2018046	1076050	M	2	0.04937	44.92	269
546	2018012	1076050	M	2	0.00801	45.78	277
547	2018074	1076050	M	3	-0.24000	94.54	300
548	2018001	1076050	M	3	-1.38000	81.46	415
549	2018007	1076050	M	1	-2.15200	33.10	497
550	2018010	1076050	M	1	-2.40100	32.00	519
551	2018052	1076050	M	2	-2.72200	46.32	547
552	2018043	1076050	M	1	-3.03000	30.70	565
553	2018035	1076050	M	1	-3.07200	29.98	572
554	2018029	1076050	M	1	-3.23400	27.24	580
555	2018024	1076050	M	1	-3.43300	23.87	593
556	2018025	1076050	M	1	-4.03300	21.50	624
557	2018002	1076050	M	2	-4.13300	34.89	633
558	2018077	1076050	M	1	-5.12900	18.52	674

------------------------------------- m_bv=-2.0525 ----------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
559	2041056	1001071	M	3	-1.993	85.65	476.5
560	2041025	1001071	M	1	-2.112	29.63	489.0

------------------------------------- m_bv=-2.6588 ----------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
561	2053065	1026057	M	3	0.04634	98.91	271.0
562	2053015	1026057	M	1	-0.98560	39.90	374.0
563	2053028	1026057	M	1	-1.21100	39.20	395.0
564	2053071	1026057	M	3	-1.22100	88.35	396.0
565	2053079	1026057	M	2	-1.37200	35.95	412.0
566	2053075	1026057	M	3	-1.38800	83.95	417.0
567	2053066	1026057	M	3	-1.66600	85.48	445.0
568	2053037	1026057	M	1	-2.08200	33.80	483.5
569	2053045	1026057	M	3	-2.13000	77.62	493.0
570	2053042	1026057	M	2	-3.15300	43.21	575.0
571	2053055	1026057	M	2	-3.36500	41.18	587.5
572	2053060	1026057	M	2	-3.45300	42.82	597.5
573	2053052	1026057	M	2	-3.73500	41.16	607.0
574	2053077	1026057	M	2	-4.08800	38.30	629.0
575	2053063	1026057	M	3	-4.10500	62.86	631.0
576	2053061	1026057	M	3	-4.17500	63.24	634.0
577	2053048	1026057	M	2	-4.65900	33.29	651.0
578	2053044	1026057	M	2	-5.11700	23.97	673.0

-- m_bv=-2.7835 ------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
579	2011016	1026060	M	1	-0.3326	51.80	309
580	2011025	1026060	M	1	-0.5367	49.90	326
581	2011018	1026060	M	1	-1.5640	46.54	435
582	2011029	1026060	M	1	-2.2930	37.30	512
583	2011014	1026060	M	1	-2.4800	38.80	528
584	2011050	1026060	M	2	-2.7370	35.48	549
585	2011058	1026060	M	3	-2.7970	81.19	554
586	2011001	1026060	M	1	-2.8300	34.43	558
587	2011049	1026060	M	2	-2.9530	31.82	562
588	2011009	1026060	M	1	-3.0630	33.60	569
589	2011033	1026060	M	1	-3.0690	33.50	570
590	2011015	1026060	M	1	-3.3040	32.64	584
591	2011059	1026060	M	2	-3.3630	31.12	586
592	2011030	1026060	M	1	-3.4540	30.09	599
593	2011012	1026060	M	1	-3.8730	26.11	615
594	2011040	1026060	M	1	-3.9670	27.64	620
595	2011076	1026060	M	2	-4.7030	39.62	656

-- m_bv=-3.2483 ------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
596	2037066	1076043	M	2	-1.362	45.91	410.0
597	2037016	1076043	M	1	-1.482	44.40	427.5
598	2037079	1076043	M	2	-1.653	45.67	444.0
599	2037076	1076043	M	2	-1.813	44.52	462.0
600	2037029	1076043	M	1	-2.087	43.52	485.0
601	2037043	1076043	M	2	-2.148	40.39	496.0
602	2037073	1076043	M	3	-2.319	88.89	513.0
603	2037007	1076043	M	1	-2.547	40.40	536.0
604	2037075	1076043	M	3	-2.822	85.05	557.0
605	2037070	1076043	M	3	-3.179	83.68	576.0
606	2037053	1076043	M	3	-3.345	79.30	585.0
607	2037071	1076043	M	3	-3.365	78.96	587.5
608	2037017	1076043	M	1	-3.434	33.17	594.0
609	2037036	1076043	M	1	-3.441	33.05	595.0
610	2037033	1076043	M	1	-3.833	32.64	613.0
611	2037062	1076043	M	3	-3.836	72.54	614.0
612	2037021	1076043	M	1	-3.886	33.30	617.0
613	2037040	1076043	M	1	-4.079	33.15	628.0
614	2037035	1076043	M	1	-4.453	28.38	642.0
615	2037054	1076043	M	2	-4.646	44.88	650.0
616	2037052	1076043	M	2	-5.602	38.03	690.0
617	2037072	1076043	M	3	-6.130	57.06	701.0

-- m_bv=-3.5573 ------------------------------

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
618	2046022	1051067	M	3	1.1200	119.05	176.0
619	2046068	1051067	M	3	0.6659	109.78	216.0
620	2046012	1051067	M	3	-0.3370	100.58	311.0
621	2046003	1051067	M	1	-3.4490	34.40	596.0
622	2046040	1051067	M	1	-3.4720	29.32	601.0
623	2046009	1051067	M	1	-3.5340	31.40	602.0
624	2046024	1051067	M	2	-3.7710	48.72	609.0
625	2046047	1051067	M	1	-3.7910	28.60	610.0
626	2046031	1051067	M	1	-3.9500	30.59	619.0
627	2046017	1051067	M	2	-3.9940	46.50	622.0
628	2046011	1051067	M	1	-4.0340	27.60	625.0
629	2046051	1051067	M	1	-4.1110	27.86	632.0
630	2046005	1051067	M	2	-4.5510	41.74	645.0
631	2046060	1051067	M	1	-4.6930	25.80	655.0
632	2046010	1051067	M	1	-4.7580	24.69	659.0
633	2046020	1051067	M	2	-4.7760	39.48	660.0
634	2046002	1051067	M	1	-4.8730	24.30	663.5
635	2046014	1051067	M	1	-5.0450	22.95	668.0
636	2046055	1051067	M	3	-6.2350	50.53	704.0

-- m_bv=-4.18 --

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
637	2027044	1051048	M	3	-4.18	60.14	635

-- m_bv=-4.4617 --

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
638	2014064	1026052	M	3	-2.207	97.99	500
639	2014024	1026052	M	1	-2.286	48.90	511
640	2014028	1026052	M	1	-2.406	45.30	521
641	2014032	1026052	M	1	-2.834	39.60	559
642	2014011	1026052	M	1	-3.039	40.81	567
643	2014010	1026052	M	1	-3.071	38.70	571
644	2014002	1026052	M	1	-3.260	38.62	582
645	2014054	1026052	M	3	-3.818	83.16	611
646	2014005	1026052	M	1	-3.825	35.28	612
647	2014027	1026052	M	1	-3.926	35.13	618
648	2014008	1026052	M	1	-4.097	35.35	630
649	2014025	1026052	M	1	-4.196	33.68	636
650	2014030	1026052	M	1	-4.223	30.10	637
651	2014014	1026052	M	1	-4.240	32.94	638
652	2014004	1026052	M	1	-4.535	32.61	643
653	2014036	1026052	M	1	-4.574	30.40	646
654	2014001	1026052	M	1	-4.605	31.42	648
655	2014016	1026052	M	1	-4.735	27.66	657
656	2014046	1026052	M	2	-4.869	46.73	662

-- m_bv=-4.4617 --

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
657	2014041	1026052	M	3	-4.873	73.08	663.5
658	2014012	1026052	M	1	-4.887	26.65	665.0
659	2014020	1026052	M	1	-4.960	28.53	666.0
660	2014018	1026052	M	1	-5.054	26.93	669.0
661	2014009	1026052	M	1	-5.071	21.97	670.0
662	2014071	1026052	M	3	-5.106	70.68	671.0
663	2014031	1026052	M	1	-5.107	27.60	672.0
664	2014038	1026052	M	1	-5.330	26.94	677.0
665	2014043	1026052	M	2	-5.487	40.92	683.0
666	2014063	1026052	M	2	-5.750	42.71	692.0
667	2014078	1026052	M	2	-5.949	37.78	697.0
668	2014050	1026052	M	2	-6.057	37.50	698.0
669	2014077	1026052	M	3	-6.294	63.03	707.0
670	2014048	1026052	M	2	-6.564	35.16	711.0

-- m_bv=-4.6767 --

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
671	2081047	1001069	M	1	-3.130	38.87	573
672	2081055	1001069	M	3	-3.535	82.53	603
673	2081078	1001069	M	1	-7.365	17.02	720

-- m_bv=-5.3518 --

Obs	fish_ID	sire	sex	env	bv	wt	rank_bv
674	2040056	1076057	M	3	-1.799	111.64	459.5
675	2040050	1076057	M	3	-2.583	95.22	537.0
676	2040053	1076057	M	3	-3.048	98.26	568.0
677	2040045	1076057	M	2	-3.223	45.46	579.0
678	2040062	1076057	M	2	-3.874	40.66	616.0
679	2040051	1076057	M	3	-3.993	91.61	621.0
680	2040043	1076057	M	2	-4.617	35.87	649.0
681	2040003	1076057	M	1	-4.691	36.70	653.0
682	2040014	1076057	M	1	-5.010	39.10	667.0
683	2040016	1076057	M	1	-5.391	34.20	679.0
684	2040006	1076057	M	1	-5.423	30.53	681.0
685	2040036	1076057	M	1	-5.437	33.41	682.0

pendix 3a.

seed production by four stocks of *O. niloticus* in April, 2000.

One-way Analysis of Variance (ANOVA)

Source of variation	Degrees of freedom	Sum of squares	Mean square
ments (between columns)	3	7.077E+07	2.359E+07
uals (within columns)	284	1.879E+08	661490
	287	2.586E+08	

5.663
value is < 0.0001, considered extremely significant.
tion among column means is significantly greater than expected
ance.

ett's test for homogeneity of variances.

assumes that all columns come from populations with equal
The following calculations test that assumption.

ett statistic (corrected) = 94.464
value is < 0.0001.
test suggests that the difference among the SDs is
mely significant.
ANOVA assumes populations with equal SDs, you should consider
forming your data (reciprocal or log) or selecting a
rametric test.

Non parametric test

Tukey-Kramer Multiple Comparisons Test
e value of q is greater than 3.663 then the P value is less
0.05.

Comparison	Mean Difference	q	P value
NA Stock vs YE Stock	-930.00	9.703	*** P<0.001
NA Stock vs KP Stock	335.00	3.495	ns P>0.05
NA Stock vs FS Stock	208.00	2.170	ns P>0.05
YE Stock vs KP Stock	1265.0	13.198	*** P<0.001
YE Stock vs FS Stock	1138.0	11.873	*** P<0.001
KP Stock vs FS Stock	-127.00	1.325	ns P>0.05

Difference	Mean Difference	Lower 95% CI	Upper 95% CI
NA Stock - YE Stock	-930.00	-1281.1	-578.94
NA Stock - KP Stock	335.00	-16.059	686.06

NA Stock - FS Stock	208.00	-143.06	559.06
YE Stock - KP Stock	1265.0	913.94	1616.1
YE Stock - FS Stock	1138.0	786.94	1489.1
KP Stock - FS Stock	-127.00	-478.06	224.06

Summary of Data

Group	Number of Points	Mean	Standard Deviation	Standard Error of Mean	Median
NA Stock	72	1280.0	553.00	65.172	Unknown
YE Stock	72	2210.0	745.00	87.799	Unknown
KP Stock	72	945.00	430.00	50.676	Unknown
FS Stock	72	1072.0	1265.0	149.08	Unknown

Group	Minimum	Maximum	Lower 95% Confidence Interval	Upper 95% Confidence Interval
NA Stock	Unknown	Unknown	1149.9	1410.1
YE Stock	Unknown	Unknown	2034.7	2385.3
KP Stock	Unknown	Unknown	843.83	1046.2
FS Stock	Unknown	Unknown	774.38	1369.6

* * *

Appendix 3b

Fish seed production by four stocks of *O. niloticus* in May, 2000.

One-way Analysis of Variance (ANOVA)

Source of variation	Degrees of freedom	Sum of squares	Mean square
Treatments (between columns)	3	3.625E+07	1.208E+07
Residuals (within columns)	284	1.217E+08	428584
Total	287	1.580E+08	

F = 28.193
The P value is < 0.0001, considered extremely significant.
Variation among column means is significantly greater than expected by chance.

Bartlett's test for homogeneity of variances.

ANOVA assumes that all columns come from populations with equal SDs. The following calculations test that assumption.

Bartlett statistic (corrected) = 47.754
The P value is < 0.0001.
This test suggests that the difference among the SDs is extremely significant.
Since ANOVA assumes populations with equal SDs, you should consider transforming your data (reciprocal or log) or selecting a nonparametric test.

Non parametric test

Tukey-Kramer Multiple Comparisons Test
If the value of q is greater than 3.663 then the P value is less than 0.05.

Comparison	Mean Difference	q		P value
NA Stock vs YE Stock	-701.00	9.086	***	P<0.001
NA Stock vs KP Stock	-27.000	0.3500	ns	P>0.05
NA Stock vs FS Stock	258.00	3.344	ns	P>0.05
YE Stock vs KP Stock	674.00	8.736	***	P<0.001
YE Stock vs FS Stock	959.00	12.430	***	P<0.001
KP Stock vs FS Stock	285.00	3.694	*	P<0.05

Difference	Mean Difference	Lower 95% CI	Upper 95% CI
NA Stock - YE Stock	-701.00	-983.58	-418.42
NA Stock - KP Stock	-27.000	-309.58	255.58

NA Stock - FS Stock	258.00	-24.576	540.58
YE Stock - KP Stock	674.00	391.42	956.58
YE Stock - FS Stock	959.00	676.42	1241.6
KP Stock - FS Stock	285.00	2.424	567.58

Summary of Data

Group	Number of Points	Mean	Standard Deviation	Standard Error of Mean	Median
NA Stock	72	1246.0	496.00	58.454	Unknown
YE Stock	72	1947.0	817.00	96.284	Unknown
KP Stock	72	1273.0	405.00	47.730	Unknown
FS Stock	72	988.00	798.00	94.045	Unknown

Group	Minimum	Maximum	Lower 95% Confidence Interval	Upper 95% Confidence Interval
NA Stock	Unknown	Unknown	1129.3	1362.7
YE Stock	Unknown	Unknown	1754.8	2139.2
KP Stock	Unknown	Unknown	1177.7	1368.3
FS Stock	Unknown	Unknown	800.25	1175.7

* * *

Appendix 3c

Fish seed production by four stocks of *O. niloticus* in June, 2000.

One-way Analysis of Variance (ANOVA)

Source of variation	Degrees of freedom	Sum of squares	Mean square
Treatments (between columns)	3	6.980E+07	2.327E+07
Residuals (within columns)	284	3.666E+08	1290885
Total	287	4.364E+08	

F = 18.024
The P value is < 0.0001, considered extremely significant.
Variation among column means is significantly greater than expected by chance.

Bartlett's test for homogeneity of variances.

ANOVA assumes that all columns come from populations with equal SDs. The following calculations test that assumption.

Bartlett statistic (corrected) = 49.086
The P value is < 0.0001.
This test suggests that the difference among the SDs is extremely significant.
Since ANOVA assumes populations with equal SDs, you should consider transforming your data (reciprocal or log) or selecting a nonparametric test.

Non parametric test

Tukey-Kramer Multiple Comparisons Test

If the value of q is greater than 3.663 then the P value is less than 0.05.

Comparison	Mean Difference	q	P value
NA stock vs YE stock	-907.00	6.774	*** P<0.001
NA stock vs KP stock	34.000	0.2539	ns P>0.05
NA stock vs FS stock	439.00	3.279	ns P>0.05
YE stock vs KP stock	941.00	7.028	*** P<0.001
YE stock vs FS stock	1346.0	10.052	*** P<0.001
KP stock vs FS stock	405.00	3.025	ns P>0.05

Difference	Mean Difference	Lower 95% CI	Upper 95% CI
NA stock - YE stock	-907.00	-1397.4	-416.59
NA stock - KP stock	34.000	-456.41	524.41

NA stock - FS stock	439.00	-51.413	929.41
YE stock - KP stock	941.00	450.59	1431.4
YE stock - FS stock	1346.0	855.59	1836.4
KP stock - FS stock	405.00	-85.413	895.41

Summary of Data

Group	Number of Points	Mean	Standard Deviation	Standard Error of Mean	Median
NA stock	72	1886.0	665.00	78.371	Unknown
YE stock	72	2793.0	1569.0	184.91	Unknown
KP stock	72	1852.0	1092.0	128.69	Unknown
FS stock	72	1447.0	1033.0	121.74	Unknown

Group	Minimum	Maximum	Lower 95% Confidence Interval	Upper 95% Confidence Interval
NA stock	Unknown	Unknown	1729.5	2042.5
YE stock	Unknown	Unknown	2423.9	3162.1
KP stock	Unknown	Unknown	1595.1	2108.9
FS stock	Unknown	Unknown	1204.0	1690.0

* * *

Appendix 3d

Fish seed production by four stocks of *O. niloticus* in July, 2000.

One-way Analysis of Variance (ANOVA)

Source of variation	Degrees of freedom	Sum of squares	Mean square
Treatments (between columns)	3	2.555E+07	8516784
Residuals (within columns)	284	2.522E+08	887980
Total	287	2.777E+08	

F = 9.591
The P value is < 0.0001, considered extremely significant.
Variation among column means is significantly greater than expected by chance.

Bartlett's test for homogeneity of variances.

ANOVA assumes that all columns come from populations with equal SDs. The following calculations test that assumption.

Bartlett statistic (corrected) = 13.247
The P value is 0.0041.
This test suggests that the difference among the SDs is very significant.
Since ANOVA assumes populations with equal SDs, you should consider transforming your data (reciprocal or log) or selecting a nonparametric test.

Non parametric test

Tukey-Kramer Multiple Comparisons Test
If the value of q is greater than 3.663 then the P value is less than 0.05.

Comparison	Mean Difference	q		P value
NA stock vs YE stock	89.000	0.8014	ns	P>0.05
NA stock vs KP stock	250.00	2.251	ns	P>0.05
NA stock vs FS stock	769.00	6.925	***	P<0.001
YE stock vs KP stock	161.00	1.450	ns	P>0.05
YE stock vs FS stock	680.00	6.123	***	P<0.001
KP stock vs FS stock	519.00	4.673	**	P<0.01

Difference	Mean Difference	Lower 95% CI	Upper 95% CI
NA stock - YE stock	89.000	-317.74	495.74
NA stock - KP stock	250.00	-156.74	656.74

NA stock - FS stock	769.00	362.26	1175.7
YE stock - KP stock	161.00	-245.74	567.74
YE stock - FS stock	680.00	273.26	1086.7
KP stock - FS stock	519.00	112.26	925.74

Summary of Data

Group	Number of Points	Mean	Standard Deviation	Standard Error of Mean	Median
NA stock	72	1387.0	1083.0	127.63	Unknown
YE stock	72	1298.0	721.00	84.971	Unknown
KP stock	72	1137.0	890.00	104.89	Unknown
FS stock	72	618.00	1033.0	121.74	Unknown

Group	Minimum	Maximum	Lower 95% Confidence Interval	Upper 95% Confidence Interval
NA stock	Unknown	Unknown	1132.2	1641.8
YE stock	Unknown	Unknown	1128.4	1467.6
KP stock	Unknown	Unknown	927.61	1346.4
FS stock	Unknown	Unknown	374.97	861.03

* * *

Appendix 3e

Fish seed production by four stocks of *O. niloticus* in August, 2000

One-way Analysis of Variance (ANOVA)

Source of variation	Degrees of freedom	Sum of squares	Mean square
Treatments (between columns)	3	2.460E+07	8201442
Residuals (within columns)	284	1.453E+08	511796
Total	287	1.700E+08	

F = 16.025
The P value is < 0.0001, considered extremely significant.
Variation among column means is significantly greater than expected by chance.

Bartlett's test for homogeneity of variances.

ANOVA assumes that all columns come from populations with equal SDs. The following calculations test that assumption.

Bartlett statistic (corrected) = 212.35
The P value is < 0.0001.
This test suggests that the difference among the SDs is extremely significant.
Since ANOVA assumes populations with equal SDs, you should consider transforming your data (reciprocal or log) or selecting a nonparametric test.

Non parametric test

Tukey-Kramer Multiple Comparisons Test
If the value of q is greater than 3.663 then the P value is less than 0.05.

Comparison	Mean Difference	q		P value
NA stock vs YE stock	30.000	0.3558	ns	P>0.05
NA stock vs KP stock	-65.000	0.7710	ns	P>0.05
NA stock vs FS stock	-682.00	8.089	***	P<0.001
YE stock vs KP stock	-95.000	1.127	ns	P>0.05
YE stock vs FS stock	-712.00	8.445	***	P<0.001
KP stock vs FS stock	-617.00	7.318	***	P<0.001

Difference	Mean Difference	Lower 95% CI	Upper 95% CI
NA stock - YE stock	30.000	-278.79	338.79
NA stock - KP stock	-65.000	-373.79	243.79

NA stock - FS stock	-682.00	-990.79	-373.21
YE stock - KP stock	-95.000	-403.79	213.79
YE stock - FS stock	-712.00	-1020.8	-403.21
KP stock - FS stock	-617.00	-925.79	-308.21

Summary of Data

Group	Number of Points	Mean	Standard Deviation	Standard Error of Mean	Median
NA stock	72	323.00	309.00	36.416	Unknown
YE stock	72	293.00	374.00	44.076	Unknown
KP stock	72	388.00	391.00	46.080	Unknown
FS stock	72	1005.0	1288.0	151.79	Unknown

Group	Minimum	Maximum	Lower 95% Confidence Interval	Upper 95% Confidence Interval
NA stock	Unknown	Unknown	250.30	395.70
YE stock	Unknown	Unknown	205.01	380.99
KP stock	Unknown	Unknown	296.01	479.99
FS stock	Unknown	Unknown	701.97	1308.0

* * *

Appendix 3f

Fish seed production by four stocks of *O. niloticus* in September, 2000.

One-way Analysis of Variance (ANOVA)

Source of variation	Degrees of freedom	Sum of squares	Mean square
Treatments (between columns)	3	1.064E+07	3547218
Residuals (within columns)	284	4.677E+07	164685
Total	287	5.741E+07	

F = 21.539
The P value is < 0.0001, considered extremely significant.
Variation among column means is significantly greater than expected by chance.

Bartlett's test for homogeneity of variances.

ANOVA assumes that all columns come from populations with equal SDs. The following calculations test that assumption.

Bartlett statistic (corrected) = 88.891
The P value is < 0.0001.
This test suggests that the difference among the SDs is extremely significant.
Since ANOVA assumes populations with equal SDs, you should consider transforming your data (reciprocal or log) or selecting a nonparametric test.

Non parametric test

Tukey-Kramer Multiple Comparisons Test
If the value of q is greater than 3.663 then the P value is less than 0.05.

Comparison	Mean Difference	q	P value
NA stock vs YE stock	-476.00	9.953	*** P<0.001
NA stock vs KP stock	-265.00	5.541	*** P<0.001
NA stock vs FS stock	-460.00	9.618	*** P<0.001
YE stock vs KP stock	211.00	4.412	* P<0.05
YE stock vs FS stock	16.000	0.3345	ns P>0.05
KP stock vs FS stock	-195.00	4.077	* P<0.05

Difference	Mean Difference	Lower 95% CI	Upper 95% CI
NA stock - YE stock	-476.00	-651.16	-300.84
NA stock - KP stock	-265.00	-440.16	-89.836

NA stock - FS stock	-460.00	-635.16	-284.84
YE stock - KP stock	211.00	35.836	386.16
YE stock - FS stock	16.000	-159.16	191.16
KP stock - FS stock	-195.00	-370.16	-19.836

Summary of Data

Group	Number of Points	Mean	Standard Deviation	Standard Error of Mean	Median
NA stock	72	183.00	167.00	19.681	Unknown
YE stock	72	659.00	566.00	66.704	Unknown
KP stock	72	448.00	358.00	42.191	Unknown
FS stock	72	643.00	427.00	50.322	Unknown

Group	Minimum	Maximum	Lower 95% Confidence Interval	Upper 95% Confidence Interval
NA stock	Unknown	Unknown	143.71	222.29
YE stock	Unknown	Unknown	525.84	792.16
KP stock	Unknown	Unknown	363.77	532.23
FS stock	Unknown	Unknown	542.54	743.46

* * *

Appendix 3g

Rate of survival of four stocks of all-male *O. niloticus* in polyculture with *Heterobranchus longifilis*

One-way Analysis of Variance (ANOVA)

Source of variation	Degrees of freedom	Sum of squares	Mean square
Treatments (between columns)	3	1218.0	406.00
Residuals (within columns)	8	240.67	30.083
Total	11	1458.7	

F = 13.496
The P value is 0.0017, considered very significant.
Variation among column means is significantly greater than expected by chance.

Bartlett's test for homogeneity of variances.

ANOVA assumes that all columns come from populations with equal SDs. The following calculations test that assumption.

Bartlett's test cannot be performed because a sample size is too small.

Non parametric test

Tukey-Kramer Multiple Comparisons Test
If the value of q is greater than 4.529 then the P value is less than 0.05.

Comparison	Mean Difference	q		P value
NA vs YE	17.000	5.368	*	P<0.05
NA vs KP	9.000	2.842	ns	P>0.05
NA vs FS	27.333	8.632	**	P<0.01
YE vs KP	-8.000	2.526	ns	P>0.05
YE vs FS	10.333	3.263	ns	P>0.05
KP vs FS	18.333	5.789	*	P<0.05

Difference	Mean Difference	Lower 95% CI	Upper 95% CI
NA - YE	17.000	2.658	31.342
NA - KP	9.000	-5.342	23.342
NA - FS	27.333	12.992	41.675
YE - KP	-8.000	-22.342	6.342
YE - FS	10.333	-4.009	24.675
KP - FS	18.333	3.992	32.675

Summary of Data

Group	Number of Points	Mean	Standard Deviation	Standard Error of Mean	Median
NA	3	28.000	7.000	4.041	31.000
YE	3	11.000	6.557	3.786	12.000
KP	3	19.000	5.196	3.000	22.000
FS	3	0.6667	1.155	0.6667	0.000

Group	Minimum	Maximum	Lower 95% Confidence Interval	Upper 95% Confidence Interval
NA	20.000	33.000	10.610	45.390
YE	4.000	17.000	-5.291	27.291
KP	13.000	22.000	6.091	31.909
FS	0.000	2.000	-2.202	3.535

* * *

Appendix 3h

Rate of survival of four stocks of all-male *O. niloticus* in polyculture with *Heterotis niloticus*

One-way Analysis of Variance (ANOVA)

Source of variation	Degrees of freedom	Sum of squares	Mean square
Treatments (between columns)	3	5345.3	1781.8
Residuals (within columns)	8	71.587	8.948
Total	11	5416.9	

F = 199.12
The P value is < 0.0001, considered extremely significant.
Variation among column means is significantly greater than expected by chance.

Bartlett's test for homogeneity of variances.

ANOVA assumes that all columns come from populations with equal SDs. The following calculations test that assumption.

Bartlett's test cannot be performed because a sample size is too small.

Non parametric test

Tukey-Kramer Multiple Comparisons Test
If the value of q is greater than 4.529 then the P value is less than 0.05.

Comparison	Mean Difference	q	P value
NA vs YE	56.300	32.599	*** P<0.001
NA vs KP	39.433	22.832	*** P<0.001
NA vs FS	44.133	25.554	*** P<0.001
YE vs KP	-16.867	9.766	*** P<0.001
YE vs FS	-12.167	7.045	** P<0.01
KP vs FS	4.700	2.721	ns P>0.05

Difference	Mean Difference	Lower 95% CI	Upper 95% CI
NA - YE	56.300	48.478	64.122
NA - KP	39.433	31.611	47.255
NA - FS	44.133	36.311	51.955
YE - KP	-16.867	-24.689	-9.045
YE - FS	-12.167	-19.989	-4.345
KP - FS	4.700	-3.122	12.522

Summary of Data

Group	Number of Points	Mean	Standard Deviation	Standard Error of Mean	Median
NA	3	59.967	3.465	2.000	59.600
YE	3	3.667	1.155	0.6667	3.000
KP	3	20.533	3.055	1.764	21.200
FS	3	15.833	3.623	2.092	16.300

Group	Minimum	Maximum	Lower 95% Confidence Interval	Upper 95% Confidence Interval
NA	56.700	63.600	51.359	68.574
YE	3.000	5.000	0.7980	6.535
KP	17.200	23.200	12.944	28.123
FS	12.000	19.200	6.834	24.833

* * *