STATISTICAL APPROACH ON THE PATTERN OF DEVELOPMENT OF SHANK LENGTH IN DUCKS

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THESIS

Submitted in partial fulfilment of the
requirement for the degree

Master of Science in Agricultural Statistics

Faculty of Agriculture
Kerala Agricultural University

Department of Statistics
COLLEGE OF VETERINARY AND ANIMAL SCIENCES
Mannuthy, Trichur

1989

Dedicated to my mother

DECLARATION

I hereby declare that this thesis entitled "STATISTICAL APPROACH ON THE PATTERN OF DEVELOPMENT OF SHANK LENGTH IN DUCKS" is a bonafide record of research work done by me during the course of research and this thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Mannuthy,
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CERTIFICATE

Certified that this thesis entitled "STATISTICAL APPROACH ON THE PATTERN OF DEVELOPMENT OF SHANK LENGTH IN DUCKS" is a record of research work done independently by Miss SUNANDA,C. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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ACKNOWLEDGEMENT

With immense pleasure, I express my heartful gratitude and personal indebtedness to Dr. K.C.George, Professor and Head, Department of Statistics, College of Veterinary and Animal Sciences and the Chairman of my Advisory Committee for his inspiring guidance, constant encouragement, generous help and co-operation in the preparation of this thesis.

I extend my sincere gratitude to Sri.K.L.Sunny, Associate Professor, Directorate of Research, Sri.S.Krishnan, Assistant Professor, Department of Agricultural Statistics and Dr.G.Reghunathan Nair, Associate Professor, Department of Poultry Science for their valuable guidance, assistance and critical supervision at various stages in the preparation of this thesis.

I express my sincere thanks to the staff members of the Department of Poultry Science for their generous help and co-operation in conducting the experiment and collecting the data.

I am deeply indebted to my father and to my uncle for their valuable assistance and encouragement throughout the study.

I am thankful to Smt.Santha Bai,K.P., Junior Programmer, Department of Statistics for the valuable help rendered by her in the analysis of my data.

I extend my sincere thanks to the Staff members of the Department of Statistics, College of Veterinary and Animal Sciences for their valuable help and co-operation.

I also extend my gratitude and thanks to my colleagues and friends for their generous help and co-operation.

I am specially thankful to Mr. Vishnu Namboodiri, K. for his generous help and co-operation at all stages of my work.

I would like to express my sincere thanks to the Dean, College of Veterinary and Animal Sciences and to the Associate Dean, College of Horticulture for providing me the necessary facilities.

I am grateful to the Kerala Agricultural University for offering financial assistance in the form of fellowship.

Thanks are also due to Sri.V.T.Kurian for typing the manuscript neatly.

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CONTENTS

Introduction

INTRODUCTION

The agro-climatic environment form a natural gift to Kerala State which is ideal for duck farming. Duck farming in Kerala is found to be a profitable enterprise as it requires no elaborate housing, necessitates only low capital investment and brings quick returns from the outlay. In India ducks occupy second place to chicken so far as egg production is concerned. About five per cent of the egg production is from ducks. According to 1972 livestock census duck population in India is about 9 millions and total egg production is 400 millions (Indian Poultry Industry Year Book, 1986). West Bengal is having first place in duck farming followed by Assam, Tamil Nadu, Andhra Pradesh, Bihar, Kerala, Orissa, Jammu & Kashmir and Tripura. Duck population in Kerala is about 3.6 million and total egg production is about 36.348 million.

Eventhough ducks occupy second place to chicken, still now it is a neglected area among the farmers of developing countries like India. Lack of research work and adequate attention is one of the reasons for this. Recent studies show that duck farming is more economical than chicken.

Selection of birds having rapid growth rate is of great practical importance in livestock industry especially in poultry farming. This is an important factor indicating the feed conversion efficiency of the birds. A usual measure of growth employed to study the pattern of growth is the body weight as it is convenient to measure. Systematic changes in skeletal dimensions may bring about associated change in body weight. The relative magnitudes of differences in body weight and traits of conformation suggested that the rate of growth of skeletal measurements was comparatively slower than that of body weight and could be viewed to be under the control of different genetic mechanisms. Hence it may be supposed that prediction of body weight could be done based on some skeletal dimensions of breast, keel and shank bones.

Shank length is always a good index for predicting the body weight for birds especially in poultry. Various workers utilise different body parts to find out their correlations with body weight. Lerner (1939) tried to predict body weight from the live shank length and reported that in early stages, the body weight and shank length are more closely related than in mature birds. Chhabra <u>et al</u>. (1972), Unni <u>et al</u>. (1977), Verma <u>et al</u>. (1977) reported that body weight and shank length are highly correlated traits in poultry. Konchi *et al.* (1979) studied the relationship between shank length and body weight in Desi ducks. Indirabai and Surendran (1983) also observed a high correlation between shank length and body weight in chicks. But not much study has been conducted to investigate the pattern of development of shank length in ducks. The work done by Konchi *et al.* (1979) is merely based on the data but not on the rigorous statistical models for predicting the relationship of growth pattern of shank length. Hence it is high time to investigate the growth pattern of shank length over time through the different statistical models and to select the most appropriate model to predict the nature of growth of shank length.

Similarly no study has been done to compare the rate of growth of different genetic groups viz. Desi and White Pekin. It is generally believed that the growth rates of different genetic groups differ significantly as far as shank length is concerned. Hence a detailed study to investigate this aspect is essential.

As it is generally believed that there is high correlation between shank length and body weight at different periods of growth, the prediction of body weight through shank length and vice-versa is also important. If one can predict the body weight precisely through the data of shank length it will be very useful to the research workers to recommend the optimum attainable body weight through the knowledge of shank length and to recommend the stage of culling of the birds. Not much work has been undertaken in this aspect also.

The present investigation is aimed at to study all the points mentioned above. Under this investigation two groups - Desi and White Pekin ducklings were reared and the shank lengths and body weight were noted for a time period upto twelve weeks.

Through the data generated, a comparative study of pattern of development of shank length in ducks are done with the following objectives.

1. To examine the pattern of development of shank length in two breeds of ducks in University Duck Farm, Mannuthy.
2. To compare them (a) between genetic group (b) between males and females within each genetic group (c) between males of genetic group (d) between females of genetic group.
3. To fit appropriate growth curves for prediction of body weight through shank length at different stages of growth.

First objective can be met by fitting the different mathematical growth curves. The second objective will be met by performing analysis of variance of growth rates of the various mathematical models fitted. The third objective will be met by fitting the mathematical relationship between shank length and body weight for the same period of time by taking into consideration the high correlation prevalent between these two characters. Graphical study can also be initiated to find the suitable mathematical model for fitting the shank length data over a period of time.

Review of Literature

REVIEW OF LITERATURE

The body weight, which is the first measurable character of an animal has an economic importance, since it provides a basic background for future performances. Body weight is the usual measure of growth that we employ to study the growth pattern. Systematic changes in skeletal dimensions may bring about associated changes in body weight, also leading to the conclusion of genetic control on these traits.

Since variability in skeletal growth is much less then the veriability in body weight during growing period, selection for faster rate of growth would be more accurate if it is based on some of the skeletal measurements in live birds. Much work has been done by various workers based on skeletal dimensions of breast, keel, shank and thigh bones. Here shank length has been used to study the pattern of development of growth in ducks. But not much work has been done to investigate pattern of development of shank length in ducks.

While determining growth rate in nutrition studies with bacon pig, Wishart (1938) found that the weight curve was very regular and showed an upward curvature. He found that it was best to do curve fitting on the actual weight. The next stage was to fit a parabola (using orthogonal polynomial which yields to Aitken (1953) polynomial.

$$W = a_o + a_1 (2x - 16) + a_2 \left\{ \frac{6x(x-1)}{1.2} - 45x + 120 \right\}$$

where 'x' is the number of weeks and 'w' is the body weight.

As early as 1939, Lerner tried to predict the body weight from the live shank length and reported a correlation estimate of 0.659±0.032 and also found that in early stages, the body weight and shank length were more closely related than in mature birds.

The results of the experiment conducted by Collins _et al._ (195-) showed a high correlation between the breast angle and live weight and also showed that breast width was related positively to body weight.

Brant (1951) conducted an experiment on 595 birds to define rate of growth in domestic fowl. Early rate of growth is defined as the progressive augmentation of body as measured by the change in weight per unit of time. The method used was first, represent graphically the variables, second, select form of equation which will best describe the growth curve drawn and transform equation to linear form by substitution of variables, third, evaluate the constants of the equation by the method of least squares, fourth, submit the constants of the equation to method of analysis of variance. The equation $y = ae^{bx} + c$ gave excellent results for the evaluation of constant 'b', the rate of growth. In the between sex analysis, half of the individual analysis and all of the combined analysis showed highly significant differences in the rate of early growth between sexes as well as in breed group.

Growth pattern of the Cornish fowl was reported by Gilbreath and Upp (1952). Throughout the analysis the differences due to sex were apparent. The results showed that weight and shank length were best measurements used for mass and skeletal developments.

Cock (1964) reported that growth in shank length relative to body weight between two and ten weeks of age in fowl conforms closely to simple allometry. No appreciable correlation was found between shank length and shank width at a given body weight.

Roberts (1964) estimated the early growth rate in chicken using two leghorn lines. The graphs for males and females showed that an approach to linearity was measurable upto 7 to 8 weeks of age. He found that it was possible to measure the rate of change in body weight using the power function $y = at^b$ where 'y' is the body weight at time 't', 'a' is the body weight at time '0', 'b' is the rate of growth.

Mahelka (1965) conducted an experiment with 19 white pekin ducklings to find out the post-natal growth. He found that growth rate was maximum in the first 20 days and absolute weight gains were greatest at 30-50 days. It is concluded that the fattening of pekin ducks should finish at 60-65 days.

Roberts (1965) also conducted different experiment on chicks to find out growth rates.

While studying the relation between growth rate and feathering in ducks, Stasko (1966) showed that average body weight, length of breast bone and chest breadth were greater for 25 ducklings with rapid feathering parents than for the 31 progeny to show feathering parents.

The study for finding the duration of rearing ducklings for meat, conducted by Bozko and Radu (1966) showed that the dressing percentage was slightly greater at 50 and 54 days than at 45 days. But the percentage of edible carcasses was 2 per cent less at 54 than at 45 days. The caloric value of the meat was highest at 50 days and lowest at 54 days on account of the reduced percentage of fat, but the protein content of the meat increased progressively.

Susaki (1966) constracted growth curves from data on body weight of three crosses of broiler breeds upto 10 weeks of age. Curves of the type

$$y = ax^{b}$$

$$y = a + bx + cx^{2}$$

$$y = a + bx + c\,(\log x)$$

gave satisfactory fit to the data.

Laird and Howard (1967) outlined a new method of analysis of inheritance of growth based on the observation that the specific growth rate tends to undergo an exponential decay with increasing age. Young mice of eight inbred lines were weighed at birth and weekly thereafter for 10 weeks. The data so obtained was analysed by using Gompertz equation

$W = W_o \left\{ \exp \left[\frac{A_o}{x} \left(1 - \exp(-xt)\right) \right] \right\}$ where 'W' is the weight at time t, 'W_o' is the initial weight for the period of study and 'A_o' and 'x' are constants. 'A_o' is the initial specific growth rate and 'x' measures rate of exponential decay of 'A_o'.

Ricklefs (1968) on his experiment for studying the pattern of growth in birds with 105 species reported that growth patterns were highly correlated with parameters of life history, geographic locality and time of nesting season. According to his opinion, the shape of the growth curve was not related to the mode of development and growth rates were most highly related with brood size. The analysis of growth patterns in birds suggested that part of the diversity was related to energetic aspects of growth and development. For analysing growth pattern, he used logistic equation of the form

$$y = \frac{a}{1 + be^{-kt}}$$

, Gompertz equation of the form

$$y = ae^{-be^{-kt}}$$

and Von Vertalanffy equation of the form $y = a\,(1-be^{-kt})^3$

Pillai et al. (1969) found that the simple regression $W = Ae^{kt}$ where 'W' = body weight, 't' = time over which weight gain is measured and 'A' and 'k' were constants, yielded a very good fit.

Zelanka (1970) studied the growth of chickens during the early period of the post embryonal life. He used the exponential function $W = ae^{kt}$ and the power function $y = at^b$ (Roberts, 1964) to calculate growth from 2 to 22 days of age in 40 cockerals (experiment-1) and 90 chicks of both sexes (experiment-2). Growth was divided into two periods. Period 1 which ended at 14 days of age, was different from period 2 regardless of the function used. In period one of both the experiments and in period two of second experiment no significant difference in the accuracy of calculations was observed between the two functions. In period 2 of the second experiment, the power function was more accurate.

Liljedahl (1970) conducted a study on the course of growth in broiler chickens. A mathematical function of the logistic type $y = \frac{A + Be^{\lambda x}}{1 + ce^{\lambda x}}$ proved to fit the observed set of body weight means very closely. All the four parameters 'A', 'B', 'C' and ' λ ' are significantly different from zero. Statistically significant differences between two hatches were found in four parameters.

Kamar <u>et al</u>.(1971) studied the effect of crossing on the productivity of ducks and their growth. For this study he used pekin, Khaki Campbell, Pekin x K.C. and K.C. x Pekin groups. The study revealed that the differences between pure breds and crossbreds were not significant. But the differences between two cross breds were significant at fourth week of age. In all groups maximum rate of weight gain occured between 4 and 8 weeks of age with average gain 3.36, 2.86, 3.55 and 4.03 g respectively.

Chhabra <u>et al</u>. (1972) while conducting experiments on 603 chicks at 10 weeks of age involving white plymouth Rock, White Cornish and New Hampshire breeds and their crosses, observed that birds with longer live shanks yield heavier live body weight. The correlation of live shank length with live body weight and eviscerated weight were 0.3064 to 0.9582 and 0.2806 to 0.8614 respectively. These estimates were found to be highly significant in the case of all genetic groups.

Buffington et al. (1975) used different statistical models for the growth data of male and female wrelsted white turkeys. He found that the Gompertz equation of the form $W = A \exp\left[- \exp(-ct)\right]$ provided an excellent fit to the data of mean weights as well as the data of developing weight limits.

Ricklefs (1973) studied the pattern of growth in birds. Growth curves of most species were fitted with Gompertz equation and rate constants of the equations were used as an index of growth rate. The form of Gompertz curve was sigmoid. Other sigmoid curves used were the logistic curve and Von-Bertalanffy curve. The conversion factors used to convert logistic and Von-Bertalanffy constants to Gompertz constants were

$A_G = 0.68\ A_L$

$K_G = 0.83\ K_L$

Kanja et al.(197..) compared the growth intensity in pekin, pekin x Aylesburr, and Pekin x white ... and wild ducks.

While studying the relationship between shank length and body weight of crosses of meat type breeds of fowl, Rosovsky *et al.*(1975) found that the live shank length was highly correlated with body weight.

Sexual dimorphism in shank length in broiler breeds of poultry has been reported by Ulaganathan and Kusalumaran (1975), who found that males had larger shank length and body weight at 16 weeks of age.

Comparative studies on the growth of pekin domestic ducks and wild millards upto 28 weeks of age by Gibes (1975) revealed that weight gains and increases in linear measures were more rapid in pekin than in millard. In both, weight gains were fastest at fourth weeks of age and increases in body length at 5 weeks. After 5 weeks of age, growth rate declined in both wild and domestic ducks.

Singh *et al.* (1976) studied the growth rate in black Austrolop and white Leghorn chicks. He found that body weight of black Austrolop was always higher than those of the white Leghorn. Hussain (1976) also conducted an experiment to study the growth rate of white leghorn, light sussex, their reciprocal crosses, F_1, F_2 and back crosses.

Studies on the sexual dimorphism in shank length and its relationship with body weight in broiler breeds of poultry were conducted by Unni *et al.* (1977). Shank length and body weight of 489 broiler chicks belonging to White Cornish and White Plymouth Rock breeds were recorded at 10 weeks of age. Difference between the sexes was highly significant for both the traits studied. The phenotypic correlation coefficients between shank length and body weight at 10 weeks were 0.91, 0.86, 0.51 and 0.93 for white cornish male, white cornish female, white Plymouth Rock male and White Plymouth Rock female respectively. All these correlation coefficients were highly significant. The regression equations fitted for predicting the body weight from shank length were

$y = 205.3\ x - 762.1$

$y = 132.39\ x - 96.?1$

$y = 23.54\ x + 824.69$

$y = 75.89\ x + 268.77$

A study was conducted to find out the relationship between shank length and body weight at the end of 4th, 8th and 12th weeks in WL and RIR. From this study Verma et al. (1977) revealed that body weight was highly correlated with shank length. The regression equation of the type $y = a + b$ were obtained by least square technique and the significance of such regression equation were tested by F test.

Surendran and Viswanathan (1978) showed that body weight of calves could be estimated by body measurements. They found that body weight will be given by the correlation $W = 10^{-4} \times G.43^{3}$ where G is the chest girth.

Renchi et al. (1979) studied the relationship between shank length and body weight at 12 weeks of age in desi ducks. The means of shank length was 6.44±0.04 cm, 6.15± .. cm and 6.26±0.03 cm respectively in males, females and all ducks. The body weight was 1668.90±10.995 g ignoring sex. The body weight was 1668.90±10.995 g for males, 1466.40±1 .0 for females and 1567.65±11.12 g for all ducks ignoring sex. Highly significant differences between sex for body weight and shank length at 12 weeks indicated sexual dimorphism for these traits.

The phenotypic correlations between shank length and body weight were highly significant and positive. Regression equations were fitted for predicting body weight at 12 weeks from shank length in desi ducks.

Renchi et al. (1981) conducted an experiment to study some economic traits of desi ducks. They found that irrespective of age and housing system male ducklings had significantly higher body weight than females. The pattern of growth of desi ducklings till 12 weeks of age showed that the gain in weight was uniformly fast till around 11th week of age and there after a decline started.

While studying the growth patterns of body and abdominal fat weights in male broiler chicks, Ben-ya-Izen, [illegible] Becker (1981) found that the Gompertz equation was the best fit to the data of live weight, carcass weight, abdominal fat weight, percentage abdominal fat of live weight and percentage abdominal fat of carcass weight. The Gompertz equation for this study was in the form $W_t = W_0 \, e^{(L/K)(1-e^{-kt})}$. The other equations used were logistic of the form $y = A\,(1+e^{-kt})^{-m}$ and von Bertalanffy of the form $y = A\,(1-Be^{-kt})^{3}$ respectively.

Verma *et al.* (1981) found that thigh length could be used as an indicator of the body weight at 4th, 5th and 12th weeks of age in both the sexes and it may be estimated as per prediction equation.

A highly significant negative correlation between the percentage of breast weight and thigh weight was found by George *et al.* (1981).

Although linear regression was adequate for many situations, more complex functional relations were worked out by others. Jacob Thomas and Surendran (1984) found that curvilinear relations like exponential and Gompertz equation were good fit to the data of body weight of domestic fowl upto 24 weeks of age. Some of the most commonly used non linear relations were

Exponential growth curve – $y = ae^{bx}$

Modified exponential growth curve – $y = k + ab^x$

Gompertz curve – $y = ab^{c^x}$ and

Logistic curve – $y = \frac{1}{a + bc^x}$

Singh et al. (1983) found that in both White Rock and New Hampshire breeds, the maximum rate of gain was during 6-8 week of age. Phenotypic correlations between body weight was significantly correlated with 8 weeks weight (0.73 in WRs and 0.46 in NHs)

Indirabai and Narendran (19) revealed that most suitable patterns for expressing shark as function of age in weeks were linear and exponential. The modified exponential, Gompertz and logistic curves were found unsuitable.

Sharma et al. (1984) found that body weight was significantly correlated with all body measurements.

Misra et al. (198) found that genetic correlation between 8 weeks body weight and each of breast angle, shank length and keel length were positive in Red Cornish broiler.

chicken. The phenotypic and environmental correlations were also positive and high. Shank length was positively correlated with each of breast angle and keel length. Breast angle had a negative correlation with keel length at genetic, phenotypic and at the environmental level.

Kanoun (1984) predicted growth rate in chicken based on body measurements. He found that early body weight was always better than shank length at the same age as a predictor of final weight.

Growth rate on 15 male and 9 female upto 20 weeks of age was analysed by Arai et al. (1984). The growth pattern corresponded better to the Gompertz than to logistic curve.

Comparative performance of ducks reared under intensive and semi intensive system showed that the birds under intensive system have higher hen day egg production. Andrews et al. (1984) under this study showed that the pattern of body weight maintenance of birds in both the systems was the same.

Eswaran et al. (1984) found that irrespective of sex, the pattern of growth both in Khaki Campbell and desi ducklings showed a linear increase from day old to the age of housing at 18th week. Statistical analysis of the rate indicated that the rate of growth of desi males, desi females, Khaki Campbell females and males were in descending order. Analysis of body weight between two groups and between two sexes indicated that there was significant difference between genetic groups and between sexes in respect of body weight.

Campbell et al. (1985) found that for male and female pekin ducks respectively 56 day body weight average 2.15 and 2.14 kg daily gain 41.9 and 36.7 g, food consumption for kg gain 3.28 and 3.31 kg and carcass weight 1.34 and 1.31 kg.

Indirabai et al. (1985) fitted regression equations, exponential, modified exponential and Gompertz curve for predicting body weight from age. Indirabai and Nair (1985) revealed that there is high correlation between body weight and shank length of chicks. This implies that shank length can be made a criterion for selection for higher body weight. They also found that shank length has a positive correlation with age.

Pierce et al. (1985) conducted a static analysis of shank length and body weight at 20 weeks of age of layer type chickens. He expressed the growth of an animal part (y) (shank length) relative to body weight x in terms of exponential equation $y = \alpha x^{\beta}$. The derived values of 'α' and 'β' were estimated by least squares of the log transformed exponential equation. These parameters describe phenotypic and not genotypic differences in relative growth.

Singh et al. (1985) studied the relationship between body weight and some other physical parameters like shank length in broiler. Shank length accounted for 1..55 and 4.8 per cent of total variation in body weight on male and female respectively.

Sahoo et al. (1985) studied the growth in Khaki Campbell ducks and found that most rapid growth rate was observed upto 4 weeks of age, slow rate from 13 to 14 weeks.

Prathap et al. (1985) gave prediction equation by taking eight week body weight in white plymouth Rock as dependent trait while the independent traits were four week body weight, breast angle, shank length and keel length.

Grossman and Boheren (1985) conducted an experiment to determine whether the two parameters of logistic growth function, growth rate constant and age at the point of inflection were inherited traits in chickens. Results showed that growth rate constant has low heritability in each sex and line. No genetic correlations were evident among growth rate constant, age at the point of inflection and initial or maximum weight. These results showed that selection on growth rate constant or age at the point of inflection should not change the shape of growth curve.

Allene Woodard et al. (1986) found that shank length measurements of greater than or equal to 60 mm males and less than 60 mm for females was used to predict sexes in male and female chukars.

Anthony et al. (1986) used two weight selected lines of quail (HW lines selected for higher 4 week body weight and LW lines for lower 4 weeks body weight) to compare the effects of divergent selection for four week body weights on growth curves. Growth curves of HW lines best describe using Gompertz equation. The logistic equation best fit the growth curve of the LW line.

Michalik and Sochno (1987) found that correlations in the body weight with weight of lean and weight of fat in the carcass were 0.64 and 0.84 respectively vs 0.44-0.83 and 0.18-0.78 for body measurements. An index based on body weight, breast muscle thickness and keel length was a reliable prediction of carcass composition.

Ibe et al.(1987) fitted an allometric growth curve to the data on body weight (W) and the linear structural body parameters (y) like breast width, keel length, thigh length and shank length. It was of the form $y = \alpha W^{\beta}$

Sazzad (1988) in his experiment to find out growth pattern of desi ducks and Khaki Campbell ducks under rural condition showed that there was no significant difference between the growth rate of desi ducks with improved ducks under scavenging system of rearing.

Inheritance of body weights from day old to 20 weeks of age at biweekly interval was studied by Harpreet Singh *et al*.(1988). Data for this study contains body weights at fortnightly intervals from 0 to 20 weeks of age, shank and keel lengths at 4 weeks interval from 4 to 12 weeks and breast angle at 15th week of age. Phenotypic correlations of the body weight with shank length, keel length and breast angle at various ages were all positive and showed high values excepting those with the weight at hatching. Observations of high phenotypic and genotypic correlations indicated that body weight at any age except day old may be considered for evaluating growth upto 20 weeks of age.

Hamid et al. (1988) conducted a comparative study of performance of growing ducklings of khaki campbell, Indian runner and indigeneous ducks under farm conditions. Results showed that growth rate was significantly better in Khaki campbell ducklings as compared to that of Indian runner and Indegeneous ducklings where significant difference was also found between them.

Grossman *et al*.(1988) suggested a multiphase function to describe growth curves for Rhode Island Red and white

Leghorn males and females from hatching to 45 weeks of age. The multiphase function used here was derived from a sum of logistic functions

$$y_t = \sum_{i=i}^{n} \left\{ ai \left[1+\tan h \left[bi(t-ci) \right] \right] \right\}$$

with a first derivative at age t as

$$y_t' = \sum_{i=i}^{n} \left\{ aibi \left[1-\tan h^2 \left[bi\ (t-ci) \right] \right] \right\}$$

where 'y_t' is mean weight at age 't' and 'y_t' is the mean weight gain at age 't', 'n' is the number of growth phase, 'tan h' is the hyperbolic tangent for each phase, 'i' parameter, 'ai' is half asymptotic weight, 'bi' is the growth rate relative to 'ai' and 'ci' is age at maximum gain.

The advantage in describing growth in terms of curve is that it helps prediction. Further the inherent property of the curve would give a measure of rate of growth which eventually helps comparison of the rates of growth between groups.

Materials and Methods

MATERIALS AND METHODS

This study was initiated using day-old straight run ducklings of Desi eighty one in number and that of White Pekin (WP) seventy two in numbers from Kerala Agricultural University Duck Farm, Mannuthy. The ducklings were hatched on May 31, 1988 and June 4, 1988. They were serially numbered and wing banded for identification.

On the day of hatching the ducklings were placed in electrically operated, thermostatically controlled battery type brooders. They were allocated to different compartments of the brooder at random. A commercial all mash starter ration was fed *ad libitum* while the ducklings were brooded in the batteries. Fresh water was made available at all times

After a few weeks, the ducklings were moved to deep litter houses/pens. They were housed in two adjacent sections of a brooder house, divided into two sections. Adequate floor area and water space were made available. Necessary warmth was provided by infrared bulbs for four weeks. At this stage the birds were fairly well feathered and due to temperate weather only moderate brooder heat was required. All the ducklings were fed on same feed formula and the management practices were identical.

The shank length in centimetres were recorded on all days during first week. Thereafter it was measured at weekly intervals. The measurements were taken until the ducks attained an age of 12 weeks. Shank length measurements were taken from the right shank of the ducks. The measurements were taken from the exterior of the hook joint to a point between the sole pad and the outer toe of the ducks. These measurements were taken by the same person during the entire period of the experiment. Body weight in grams were also measured on all days during first week and thereafter at weekly intervals.

At the end of the experiment, the above measurements pertaining to 26 females and 26 males of white pekin group and 14 males and 25 females of Desi ducks were available. The remaining birds have lost their wing bands and some died during the course of the experiment.

The objectives of this study were

i) To examine the pattern of development of shank length in two breeds of ducks in University Duck Farm, Mannuthy.

ii) To compare them (a) between genetic group (b) between males and females within each genetic group (c) between males of genetic group (d) between females of genetic group.

iii) To fit appropriate growth curves for prediction of body weight through shank length at different stages of growth.

3.1. Growth Curve Models.

An organism follows its own growth patterns. Statistical models are the tools in analysing and understanding such growth patterns

Linear regression of the type

$y = a + bx$ where 'y' is the shank length at age 'x', was used to examine the relation between age and shank length. For fitting this curve, method of least squares was used.

In order to test the significance of the regression coefficients, linear regression equations were fitted for each bird. As the regression coefficient is a measure of rate of growth, the overall difference in the rate of growth of shank length can be ascertained by analysing the values of the regression coefficients of different groups as a one way classification.

Most of the living organisms have a sigmoid growth curve. It is therefore desirable to try curves which conform to this pattern to describe the pattern of development of shank length. The simplest of these curves was given by the exponential curve which is symbolically represented as

$$y = ab^x$$

where 'y' is the shank length at age 'x' and 'a' and 'b' are the constants to be determined. For fitting this curve also the method of least squares was used.

When growth curves are fitted the rate of growth at a unit of time can be taken as the ratio of the magnitude of shank length at that period to the magnitude of shank length on the previous period minus one. In the case of exponential, the rate of growth therefore is

$$\frac{ab^{x+1}}{ab^{x}} - 1 = b-1 \text{, only for } b>1$$

This shows that the rate of growth depends only on the values of 'b' and the growth rates will be equal if 'b' values are equal. This gives a measure for examining the equality of the rates of growth of the birds of the four groups. It is enough to analyse the 'b' values of the four groups as one way classification.

Modified exponential which has got the functional form $y = k + ab^x$ can also be used to represent the growth of an organism. The constants to be determined in this case are 'k', 'a' and 'b'. To determine these constants, the 'y' values are first divided into three mutually exclusive groups each containing 'n' consecutive values. If the partial sum of 'y' values of the three groups are s_1, s_2 and s_3 respectively, then the estimates of 'k', 'b' and 'a' are obtained as

$$k = \frac{s_1 s_3 - s_2^2}{n\,(s_1 - 2s_2 + s_3)}$$

$$b = \left(\frac{s_2 - s_3}{s_1 - s_2}\right)^{1/n} \quad \text{and}$$

$$a = \frac{(1-b)\,(s_1 - s_2)}{b\,(1-b^n)^2} \quad ---$$

The rate of growth in this case is

$$\frac{k + ab^{x+1}}{k + ab^x} - 1$$

which is the same as $\dfrac{ab^x(b-1)}{k + ab^x}$

Therefore growth rates will not differ significantly when the 'b' values do not differ significantly.

Another curve used to represent the data on shell length (y) is Gompertz curve which has got the form $y = ka^{b^x}$ where x represent the age. — —

Taking logarithms on both sides of this equation we get

$$\log y = \log k + (\log a)\,b^x$$

$$y = k_1 + AB^x \quad ---- (b)$$

where y = log y and A = log a and k_1 = log k . The equation (b) is similar to modified exponential. The logarithms of the 'y' values were computed first and using the ... values, the values of 'A', 'b' and 'k_1' were calculated as in the case of modified exponential. The values of 'a', 'c' and '...' in the form considered were given by

$a = \text{Anti log } A$

$K = \text{Anti log } K_1$

b = same as in the modified exponential.

The rate of growth in this case is $\left(\frac{Ka^{b^{x+1}}}{Ka^{b^{x}}} - 1\right)$ which is $\frac{a^{b^{x+1}}}{a^{b^{x}}} - 1$ which depends on the values of 'a^b'. The growth rates are equal if the values of 'a^b' are not significantly different. This gives a method for examining the equality of rate of growth of the birds of the four groups. It is enough to analyse the 'a^b' values of the four groups as one way classification.

Logistic curve which also describes growth in its simplest form is

$$y = \frac{a}{1 + 10^{b+cx}}$$

Fitting of this curve is done by the method of three selected points. Let 'y_0', 'y_1' and 'y_2' be the 'y' values at three selected equidistant points. The origin on the x-axis is at the point x_0 to x_1 or from x_1 to x_2. The three constants are obtained as

$$a = \frac{2\, y_0\, y_1\, y_2 - y_1^2\, (y_0 + y_2)}{y_0\, y_2 - y_1^2}$$

$$b = \log\left(\frac{a - y_0}{y_0}\right)$$

$$c = \frac{1}{n} \log \frac{y_0 (a-y_1)}{y_1 (a-y_0)}$$

The rate of growth in this case is

$$\frac{1+10^{b+cx}}{1+10^{b+c(x+1)}} - 1$$

Therefore rates of growth depend on the values of 'b' and 'c'

The Von-Bertalanffy curve considered was of the form $y = A(1-be^{-kt})$ where 'y' is the shank length at age 't', 'k' and 'b' are the constants to be determined and 'A' is the mature shank length.

The above curve is fitted as follows:

$$y = A(1-be^{-kt})$$

$$\frac{y}{A} = 1 - be^{-kt}$$

$$e^{-kt} = \frac{1-y/A}{b}$$

$$= \frac{1-y_1}{b} \quad \text{where } y_1 = \frac{y}{A}$$

Taking logarithm we get

$-kt = \log_e (1-y_1) - \log_e b$ which is of the form

$y = B + Ct$ where $y = \log_e (1-y_1)$, $B = \log_e b$ and $C = -k$

$$b = e^B \text{ and } K = -C$$

$$B = \bar{y} - C\bar{t}$$

$$C = \frac{N\Sigma ty - \Sigma t \Sigma y}{N\Sigma t^2 - (\Sigma t)^2}$$

The growth rate in this case is

$$\frac{A\left[1-be^{-k(t+1)}\right]}{A\left[1-be^{-kt}\right]} - 1$$

which is equal to $\dfrac{be^{-kt}(1-e^{-kt})}{1-be^{-kt}}$

The rate of growth depends on the values of 'b' and 'k'. So analysis of variance of 'be^{-k}' values were conducted to compare the growth rates of the four groups.

A second degree polynominal was also tried to fit the data. The form of the polynominal considered was $y=a+bx+cx^2$, where y is the shank length at age x in. 'a', 'b' and 'c' are the constants to be determined. These constants are obtained by considering x^2 as x_2 and proceeding as the method of multiple regression. The constants are obtained as

$$a = \frac{\left(\Sigma xy - \frac{\Sigma x \Sigma y}{n}\right)\left(\Sigma x^4 - (\Sigma x^2)^2/n\right) - \left[\Sigma x^2 y - \frac{(\Sigma x^2)^2 \Sigma y}{n}\right]\left[\Sigma x^3 - \frac{\Sigma x \Sigma x^2}{n}\right]^2}{\left[\Sigma x^2 - (\Sigma x)^2/n\right]\left[\Sigma x^4 - (\Sigma x^2)^2/n\right] - \left[\Sigma x^3 - \frac{(\Sigma x)(\Sigma x^2)}{n}\right]^2}$$

$$\left[(\Sigma x^2 - (\Sigma x)^2/n)\right]\left[\Sigma x^2 y - (\Sigma x^2)(\Sigma y)/n\right] - \left[\Sigma x^3 - \frac{\Sigma x \Sigma x^2}{n}\right]$$

$$b = \frac{\left(\Sigma xy - \frac{\Sigma x \Sigma y}{n}\right)}{\left[(\Sigma x^2 - (\Sigma x)^2/n)\right]\left[\Sigma x^4 - (\Sigma x^2)/n\right] - \left[\Sigma x^3 - \frac{(\Sigma x)(\Sigma x^2)}{n}\right]^2}$$

$$c = \frac{\Sigma y - na - b\Sigma x}{\Sigma x^2}$$

The growth rate in this case is

$$\frac{a + b(x+1) + c\,(x+1)^2}{a + bx + cx^2} - 1$$

This will depend upon the values of b and c.

For examining the relationship between body weight and shank length one of the technique used was coefficient of correlation. For predicting body weight from shank length linear equation of the form $y = a + bx$ and exponential equation of the form $y = ab^x$ were fitted with y as body weight and x as shank length.

3.2. Comparison of growth curves

In order to compare the relative efficiency of various growth curve models and to select the most suitable curve the following two methods were used.

3.2.1. Coefficient of determination (r^2)

It is calculated as the square of the correlation coefficient between the observed and predicted values. A large value of r^2 indicates best fit of the curve.

3.2.2. Standard error of the estimate (s)

The standard error of the estimate is worked out by the formula

$s = \sqrt{\frac{\sum(y_i - \hat{y}_i)^2}{n-2}}$ where 'y_i' is the observed value and '$\hat{y}_i$' is the estimated value and 'n' is the number of observations. A small value of 's' indicates goodness of fit of the curve.

Rao (1958) suggested a method for comparing rates of growth. This in fact is a covariance analysis. The concomitant variable is the initial shank length of the birds. For successive periods we calculate the increase in shank length. Let 'y_i' be the increase in shank length of the birds in a group at time 'i' and 'g_i' is the mean value of 'y_i' for that group. Compute the regression of 'y_i' on 'g_i' for each of the four groups in the form

$$y_i = b g_i$$

The method of least squares then gives $b = \frac{\sum y_i g_i}{\sum g_i^2}$

It is evident that if these coefficients are equal the rates of growth of the different groups also will be equal. But these 'b' values may be influenced by the initial value. Therefore we perform a covariance analysis in which the initial shank length as the concomitant variable.

A number of methods have been enumerated for representing the pattern of growth of shank length for birds, cut the relation between body weight and shank length and also for testing the differences in the rates of growth of the same. If all of them lead to same result any one of the methods will be appropriate for the future analysis of the available data. If there is a discrepancy, the methods are to be scrutinised for their appropriateness for any given situation.

Results

RESULTS

The present investigation was to assess the growth pattern of shank length in two breeds of ducklings ie. Desi and White pekin and to compare the rate of growth of shank length at different age groups of these ducklings by fitting suitable mathematical models. It was also aimed to find a prediction equation for predicting the body weight through shank length of the six groups of ducklings viz. Desi males, Desi females, Desi ducklings without considering sex, White pekin males, White pekin females and White pekin ducklings without considering sex on the basis of data taken upto 12 weeks of age.

4.1. Shank length

The average shank lengths of the four groups of ducklings and that of WP duckling and Desi duckling without considering sex during the first seven days from day old, along with their standard errors were worked out and was given in table 1.

At day old age, Desi females had the highest average shank length of 25.10 mm with a standard error of 0.1893 mm. It was followed by Desi males with an average shank length of 25.04 mm with a standard error of 0.1774 mm. The average shank length of WP females was 23.75 mm with a standard error 0.1946 mm. The least average shank length of 22.65 mm was observed for WF males with a standard error 0.1323 mm. The analysis of variance of the initial shank length of four groups were worked out and given in table 3.

There was only a slight increase in shank length from day old to 7 days of age. The average increase in shank length till the end of seven days was 1.57 mm for Desi males, 1.88 mm for Desi females, 1.46 mm for WF females and 1.08 mm for WF males.

The average shank length in 'mm' of the four groups upto twelve weeks along with their standard error were given in table 2. The order in mean shank length as observed at day old was not disturbed during first week. At the end of the first week the maximum shank length was 24.9 mm for Desi females which was followed by Desi males with an average shank length of 24.61 mm. The average shank lengths for the other two groups were 24.21 mm for WF females and 23.73 for WF males.

At the end of second week, Desi females attained the highest average shank length of 31.18 mm. The second highest average shank length of 30.43 mm was for Desi males which was followed by WF females with a mean shank length of 28.09 mm. The least average shank length of 27.10 mm was for WF males.

The order of magnitude of average shank lengths of four groups was the same at the end of second week. The average shank length in the third week was 37.86 mm for Desi females, 35.96 mm for Desi males, 35.68 mm for WP females and 31.62 mm for WP males. The average increase in the shank length from day old to the end of third week was 14.78 mm for Desi females, 11.95 mm for Desi males, 12.55 mm for WP females and 8.97 mm for WP males.

Analysis of variance of mean shank lengths of the four groups at the fourth week of age was given in table 4. The mean shank length for the four groups were 45.02 mm for Desi females, 43.68 mm for Desi males, 41.02 mm for WP females and 36.58 mm for WP males. The order of magnitude of these averages were the same as in third week. It is interesting to note that this order was maintained till the end of ninth week except at fifth week.

Just as in the previous weeks, the shank length of each duckling continued to increase during fifth week. The mean shank length at the fifth week were 52.36 mm for Desi females, 53.18 mm for Desi males, 45.94 mm for WP females and 40.85 mm for WP males.

Sixth week onwards, the pattern of difference observed in the average shank length was similar to those observed in fourth week. The highest mean shank length of 55.3 mm was observed for Desi females followed by 54.56 mm for Desi males. During this period also the least shank length was observed for WP males. The average shank length for WP males was 44.67 mm and that for WP females was 49.92 mm.

The mean shank length during seventh week were 57.46 mm for Desi females, 56.39 mm for Desi males, 46.46 mm for WP males and 54.52 mm for WP females. At the seventh week lao the highest shank length was observed for Desi males and least shank length was observed for WP males.

At the end of 6th week, the average shank length for four groups in the order of magnitude were 58.22 mm for Desi females, 58.18 mm for Desi males, 56.11 mm for WP females and 51.[illegible]1 mm for WP males. The analysis of variance of shank length at the end of 8th week was given in table 5.

The mean shank length at the end of ninth week were 5[illegible].7[illegible] mm for Desi females, 58.68 mm for Desi males, 57.[illegible]1 mm for WP females and 53.90 mm for WP males. The order of magnitude was not changed during this week. The highest shank length was observed for Desi ducklings than WP ducklings. The order of magnitude of mean shank length observed at 9th week was disturbed during 10th week onwards. At this period the maximum average shank length of 59.61 mm was observed for Desi males which was closely followed by Desi females with an average shank length of 59.38 mm. The least average shank length of 55.25 mm was observed for WP males. The average shank length for WP females was 58.08 mm during this period.

During the eleventh week and twelfth week also the order of magnitude was the same. Ath the eleventh week, maximum mean shank length was 59.89 mm for Desi males followed by a mean shank length of 59.68 mm for Desi females. The mean shank length for other two groups were 56.65 mm for WP males and 59.08 mm for WP females.

At the twelfth week the maximum average shank length was observed as 60.61 mm for Desi males. The average shank length for the other groups were 60.06 mm for Desi females, 58.29 mm for WP males and 59.73 mm for WP females. The analysis of variance of shank length at the 12th week of age was given in table 6.

The overall increments in shank length during 12th week of age were 37.57 mm for Desi males, 36.96 mm for Desi females, 35.64 mm for WP males and 36.98 mm for WP females. The increase in shank length from 8th week owmards was very slow.

4.2. The functional Relations

Shank length was found to increase with age and therefore linear prediction equation of the form $y = a + bx$ was fitted for predicting shank length (y) from age (x) for each bird. The values of the parameters 'a' and 'b' for each duckling in Desi males and Desi females were given in table 7. The values of the parameters 'a' and 'b' for each duckling in WP males and WP females were given in table 8.

The analysis of variance of linear growth rate was as given in Table 9. No significant difference was observed between the rates of growth of the four groups ie. Desi males, Desi females, WP males and WP females.

Linear prediction equation was also fitted to the average shank length of each group. The value of parameters 'a' and 'b' of each group, square of the correlation coefficient (r^2) (coefficient of determination) between the observed and the expected shank length and standard error of the estimate of each group were presented in table 10. The values of r^2 were 0.8782 for Desi males, 0.8522 for Desi females, 0.9729 for WP males and 0.9240 for WP females. The value of standard error of estimate ranged between 2.2155 and 5.6077, the the least standard error for WP males and the highest for Desi males.

The bird wise square of coefficient of correlation (r^2) (coefficient of determination) between the observed and the expected shank lengths at different ages were high. Coefficient of determination calculated for each bird in the four groups were given in table 11. The maximum value of r^2 observed was 0.9944 and the least value was 0.7553. The standard error of the estimate (s) were also calculated for each duckling in each group and it was presented in table 12. The value of 's' varies between 0.8383 and 7.6031.

The second equation fitted with 'y' as shank length and 'x' as age, was the exponential curve which is of the form

$$y = ab^x$$

The values of the parameters 'a' and 'b' calculated for Desi males and Desi female ducklings were given in table 13 and that calculated for WP males and WP females were given in table 14. The values of 'b' ranged between 1.078 to 1.0937 for Desi males, 1.0772 to 1.0975 for Desi females, 1.0666 to 1.0991 for WP males and 1.0758 to 1.1009 for WP females. Exponential curve was fitted for the average shank lengths and the parameters were presented in table 15. The values of 'b', the growth rate, for Desi males, Desi females, Desi ducklings irrespective of sex, WP males, WP females and WP ducklings irrespective of sex were respectively 1.0864, 1.0835, 1.0846, 1.0878, 1.0876 and 1.0878. The analysis of variance of the 'b' values were given in table 16.

The square of the correlation coefficients (r^2) (coefficient of determination) between the observed and the expected shank length were calculated for each duckling in the four groups and was presented in table 17. Standard error of the estimate were also calculated for each duckling in each group and was presented in table 18. The coefficient of determination and standard error of the estimate were also calculated for the average shank lengths of each group and was presented in table 15. The values of r^2 for Desi male, Desi females, WP males and WP females were respectively 0.8848, 0.8679, 0.9581 and 0.9169 (Table 15) and the values of standard errors were 7.3981, 7.7599, 4.1229 and 6.1615 respectively.

The third equation fitted to shank length was modified exponential, of the form $y = k+ab^x$. The values of the parameters fitted for each duckling of Desi males, Desi females, WP males and WP females were presented in tables 19, 20, 21 and 22 respectively. The data obtained from one duckling each in WP males and WP females were not suitable for fitting this curve because 'b' values become equal to one. The same curve was fitted to the average shank length of each group and the values of the parameters obtained were given in table 23. The 'b' values for Desi males was 0.7612, for Desi females was 0.7260, for WP males was 0.9179 and that of WP females was 0.8343.

As the growth rate of this curve depends on the 'b' values, the analysis of variance of 'b' values of the four groups was performed and was given in table 24.

Using modified exponential curve, expected shank lengths of each duckling in each group at different ages were computed and the square of the coefficient of correlation (r^2) (coefficient of determination) of each duckling in the four groups were also computed and was presented in table 25. The standard error of the estimate computed for each duckling were given in table 26. Coefficient of determination and standard error of the estimate were also computed for the averages of each group and were presented in table 23. It was noted that for each duckling, expected and observed shank lengths were highly correlated. The coefficient of determination computed for Desi males was 0.9432, for Desi females was 0.9344, for WP males was 0.9364 and for WP females was 0.9712. The standard error of estimate were highest for Desi females (4.0959) and least for WP males (1.5667).

The fourth curve fitted to the shank length was Gompertz curve of the form $y = ka^{b^x}$. The values of the parameters 'a', 'b' and 'k' for each duckling of Desi males, Desi females, WP males and WP females were given in tables 27, 28, 29 and 30. For each duckling of the four groups the 'b' values and 'a' values were less than one. As the growth rate of Gompertz curve depends on the volume of '$a^{b'}$', the analysis of variance of '$a^{b'}$' values were performed and was presented in table 31. This curve was also fitted for the averages of shank length of each group and the parameters, 'k', 'a' and 'b' were given in table 32.

The square of the correlation coefficient (r^2) (coefficient of determination) for each duckling was computed and were presented in table 33. The values of r^2 ranged between 0.9403 to 0.9834 for Desi males, 0.9003 to 0.9851 for Desi females, 0.9397 to 0.9972 for WP males and 0.9465 to 0.9944 for WP females. Standard error of the estimate of each bird were computed for each group and were presented in table 34. The coefficient of determination and standard error of the estimate were also computed for the average shank length of the four groups and were given in table 32.

Fifth curve fitted was logistic curve of the form $y = a/[1 + 10^{b+cx}]$. The values of the parameters 'a', 'b' and 'c' computed for the four groups, viz. Desi males, Desi females, WP males and WP females were given in tables, 35, 36, 37 and 38 respectively. The square of correlation coefficient (r^2) (coefficient of determination) was computed for each duckling and was presented in table 39. The values of r^2 ranged between 0.9385 to 0.9880 for Desi males, 0.8815 to 0.9862 for Desi females, 0.9676 to 0.9974 for WP males and 0.9637 to 0.9911 for WP females. The standard error of the estimate were also computed and given in table 40. This curve was again fitted for the average of shank length for each group and the parameters were given in table 41 along with coefficient of determination and standard error of the estimate.

The sixth curve fitted was Von-Bertalanffy equation of the form $y = A(1-be^{-kt}$ where 't' is the age and 'b' and 'k' are the parameters to be determined. A, the mature shank length was obtained from the Kerala Agricultural University Duck Farm, Mannuthy as A = 66 mm for Desi ducks and 67 mm for WP ducks. The values of the parameters 'b' and 'k' for Desi males and Desi females were computed for each ducklin and were given in table 42 and that of WP males and WP females were given in table 43. This curve was also fitted for the average shank length of each group and the parameters were given in table 44 along with the square of the correlation coefficient (r^2) (coefficient of determination) and standard error of the estimate.

Since the growth rate depends on the values of be^{-kt} analysis of variance (Table 45) was performed with the values of be^{-kt} for each group. The values of r^2 was determined for each duckling and were given in table 46. Standard error of the estimate for each duckling in each group were also calculated and reported in table 47.

The second degree equation of the form y = a + b[illegible] was also fitted for the four groups. The values of the parameters 'a', 'b' and 'c' of each duckling ... [illegible] females, [illegible] males and [illegible] females were given in tables [illegible], 48, 49, 50 and 51 respectively. The square of the correlation coefficient (r^2) (coefficient of determination) was computed for each duckling of the four groups and were given in table [illegible] and the standard error of the estimate computed for duckling of the four groups were given in table 53. This equation was also fitted for the average shank length [illegible] group and the coefficient of determination (r^2) and standard error of the estimate were computed. The values of [illegible] 'a', 'b' and 'c', values of (r^2) and (s)'s of the curve fitted [illegible] the averages were given in table 54.

4.3. Body weight

The data for the body weight of the four groups of duckling viz. [illegible] males, [illegible] females, [illegible] males and [illegible] [illegible] were also collected. The mean body weight along with standard error of these four groups were given in table 55. The correlation between the shank length and body weights of these four groups of birds were worked out for each duckling over a period of 12 weeks and were given in table 56. From this table it could be inferred that there was high correlation between the shank length and the body weight. The correlation coefficient ranged from 0.8375 to 0.9112 for Desi male, 0.8533 to 0.9619 for Desi female, 0.8467 to 0.9808 for WP male and 0.6793 to 0.9940 for WP female. Similarly the correlation coefficient between the mean body weight and mean shank length over a period of 12 weeks were worked out for each group and was presented in table 57. This table also showed high order correlation between shank length and body weight with a value 0.8775 for Desi males, 0.9072 for Desi females, 0.8973 for Desi duckling without considering sex, 0.9367 for WP males, 0.9166 for WP females and 0.9269 for WP duckling without considering sex.

4.4. Functional relations to predict body weight from shank length

The linear equation of the form y = a + bx was used to predict the body weight (y) from shank length (x) of each duckling. The values of the coefficients 'a' and 'b' of Desi males and Desi females were presented in table 58 and that of WP males and WP females were presented in table 59. This equation was also fitted to predict average body weights (y) of each group from average shank length (x) and the values of the parameters 'a' and 'b' were given in table 60.

The expected body weight for each duckling of the four groups were computed through this linear relationship and square of the correlation coefficient (r^2) (coefficient of determination) between observed and expected body weights were computed for each duckling and were given in table 61. The standard error of the estimate were also worked out for each duckling in each group and were presented in table 62. The values of 'r^2' and 's' were also computed for the averages of each group and presented in table 60.

The exponential equation was also fitted for predicting the body weights by using shank length over a period of 12 weeks for each duckling of the four groups. The parameters 'a' and 'b' of this equation for each duckling of Desi males and Desi females were given in table 63 and that of WP males and WP females were given in table 64. This equation was also used for predicting average body weight of each group from average shank length and the square of the correlation coefficient (r^2) (coefficient of determination) and standard error of the estimate were worked out for each group. The values of the parameters 'a' and 'b' and the values of r' and s' of the estimates for all groups were used for predicting the body weight were given in table 65. A high correlation was observed between the observed and the expected body [illegible] the values of r^2 when exponential curve was fitted for predicting body weight of each duckling of four groups are given in table 67. The respective standard error of the estimate of each duckling were worked out and presented in table 6[illegible].

4.5. [illegible] Method

The growth parameter 'b' as explained by [illegible] (1[illegible]) [illegible] shank length was estimated for each duckling over a period of 12 weeks for the four groups viz. desi males, desi females, [illegible] males, [illegible] females and were presented in table 6[illegible]. The analysis of covariance of these 'b' values by their initial shank length of the corresponding ducklings as concomitant with [illegible] was attempted first. But it was found that the regression coefficient was not significant. Hence the analysis of variance of 'b' values to find out the between group differences were worked out on the basis of these 'b' values and were given in table 69.

4.6. Graphical Representation

As the Gompertz and logistic growth forms were found to be the best fit to the data, these curves were drawn for average data of shank length for all groups as [illegible] in the expected value on the y-axis and age on x-axis. The observed values were also plotted against age on x-axis for each group. For the sake of comparison the two curves ie. logistic and Gompertz of each group were drawn on the same graph along with the observed value. The curves drawn for the six groups viz. Desi males, Desi females, WI males, WI females, Desi duckling irrespective of sex and WI ducklings irrespective of sex were presented in Fig.1, 2, 3, 4, 5 and 6 respectively.

Fig-1 GOMPERTZ & LOGISTIC CURVES FITTED TO DESI MALES

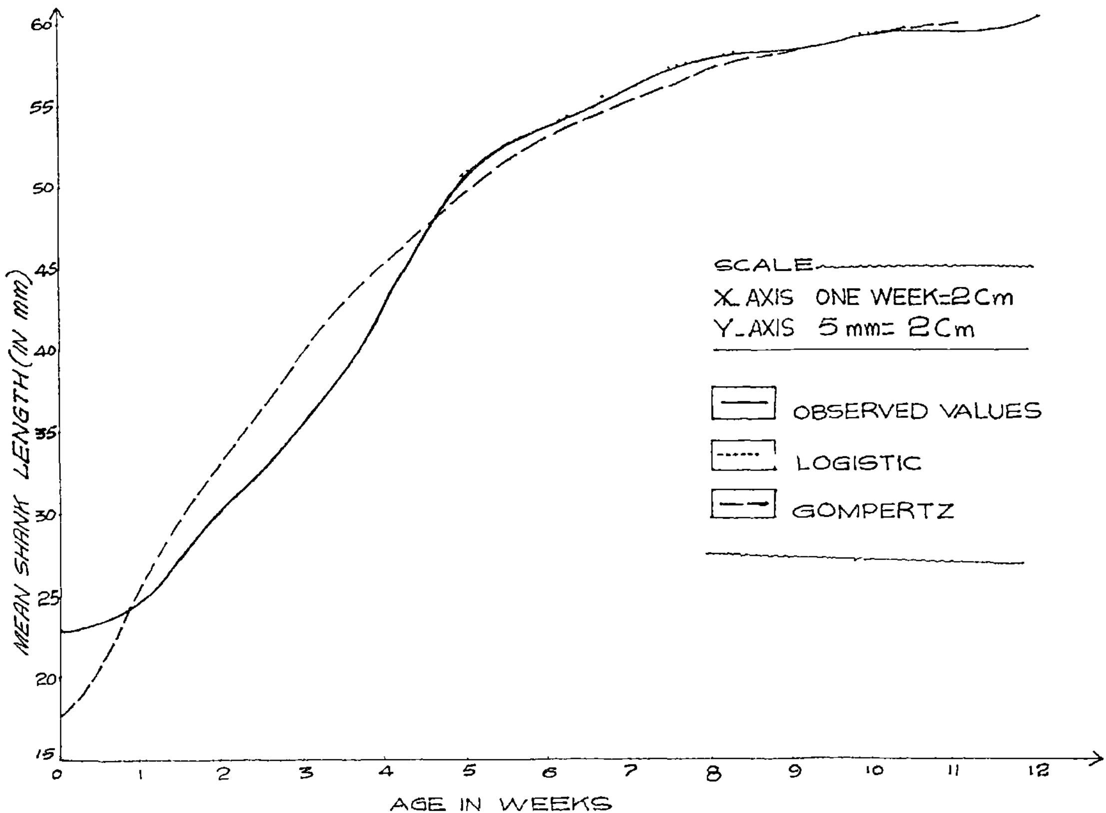


Fig. 2 GOMPERTZ & LOGISTIC CURVES FITTED TO DESI FEMALES

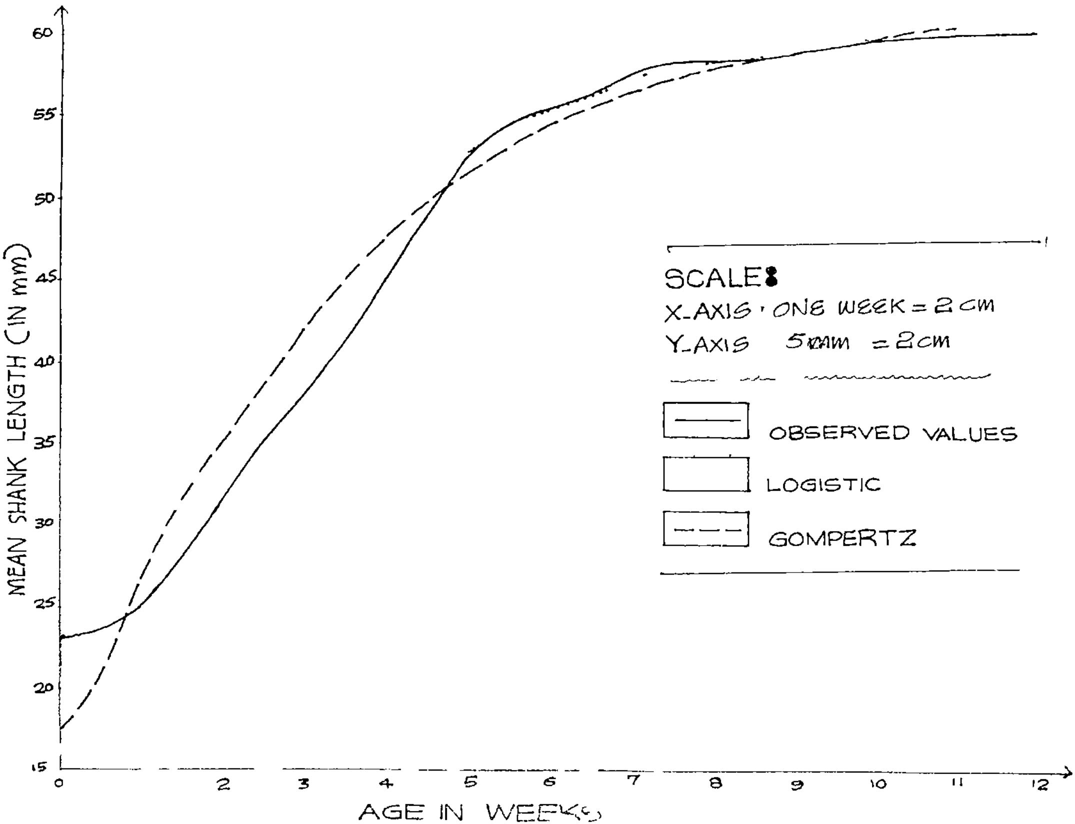


Fig 3 GOMPERTZ AND LOGISTIC CURVES FITTED TO DESI DUCKLINGS IRRESPECTIVE OF SEX

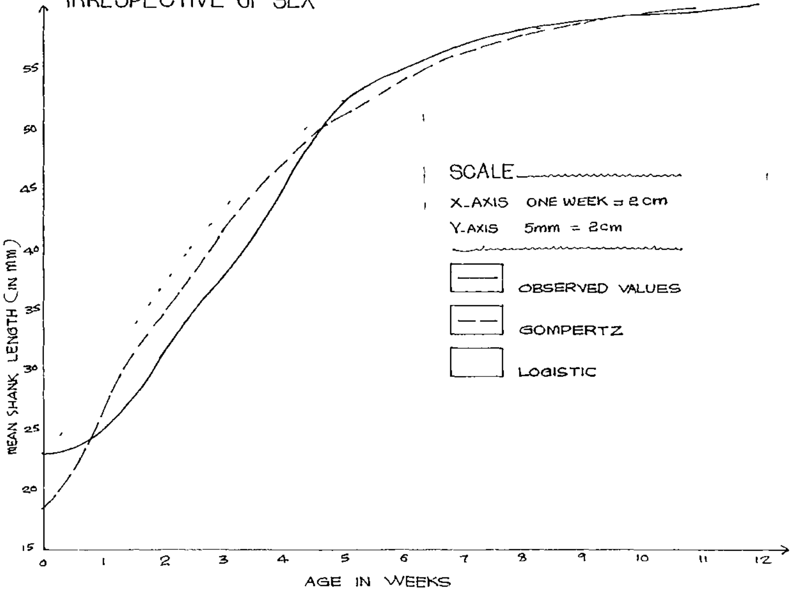


Fig 4 GOMPERTZ AND LOGISTIC CURVES FITTED TO WP MALES

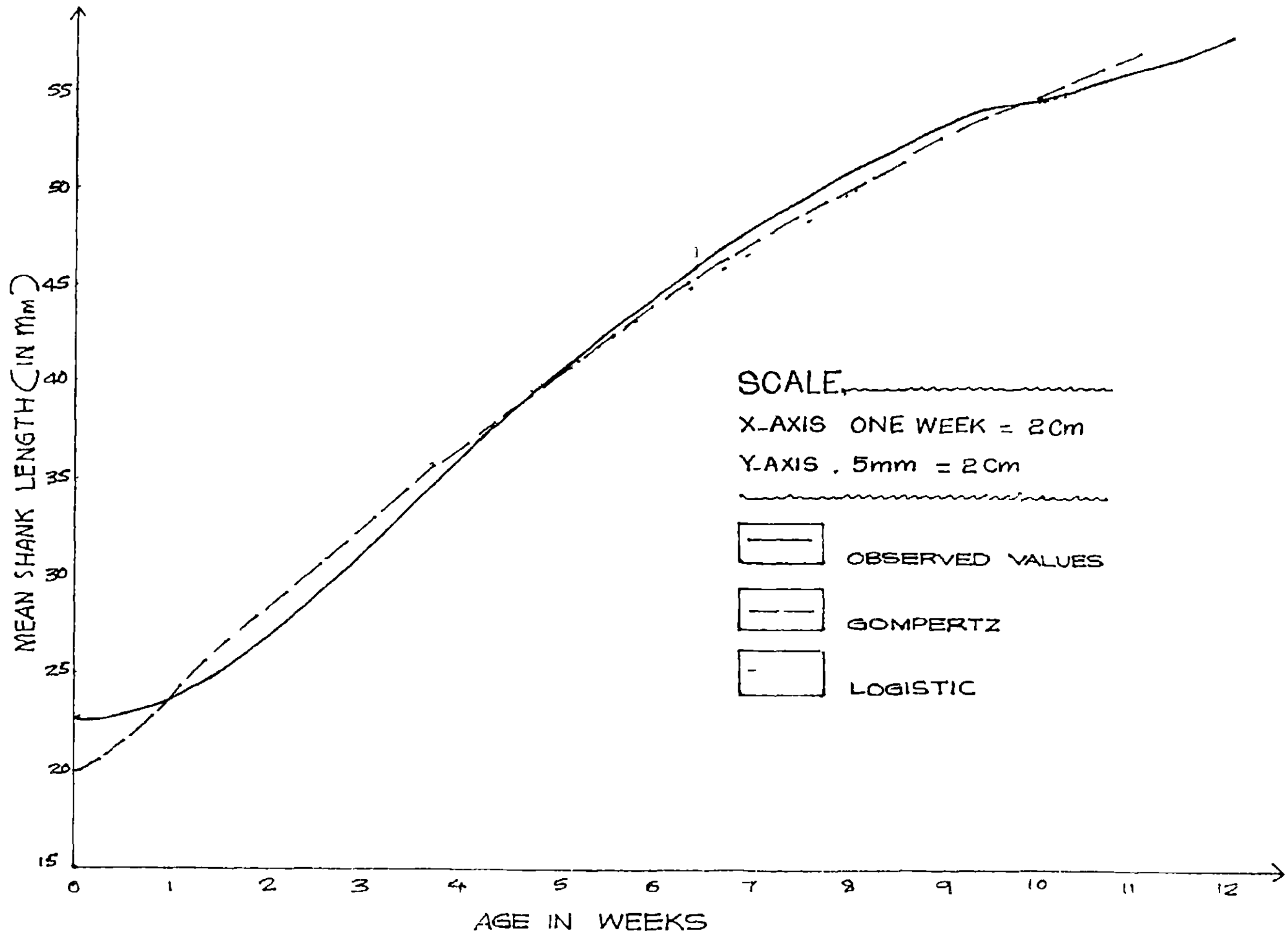


Fig. 5. GOMPERTZ & LOGISTIC CURVES FITTED TO WP FEMALES

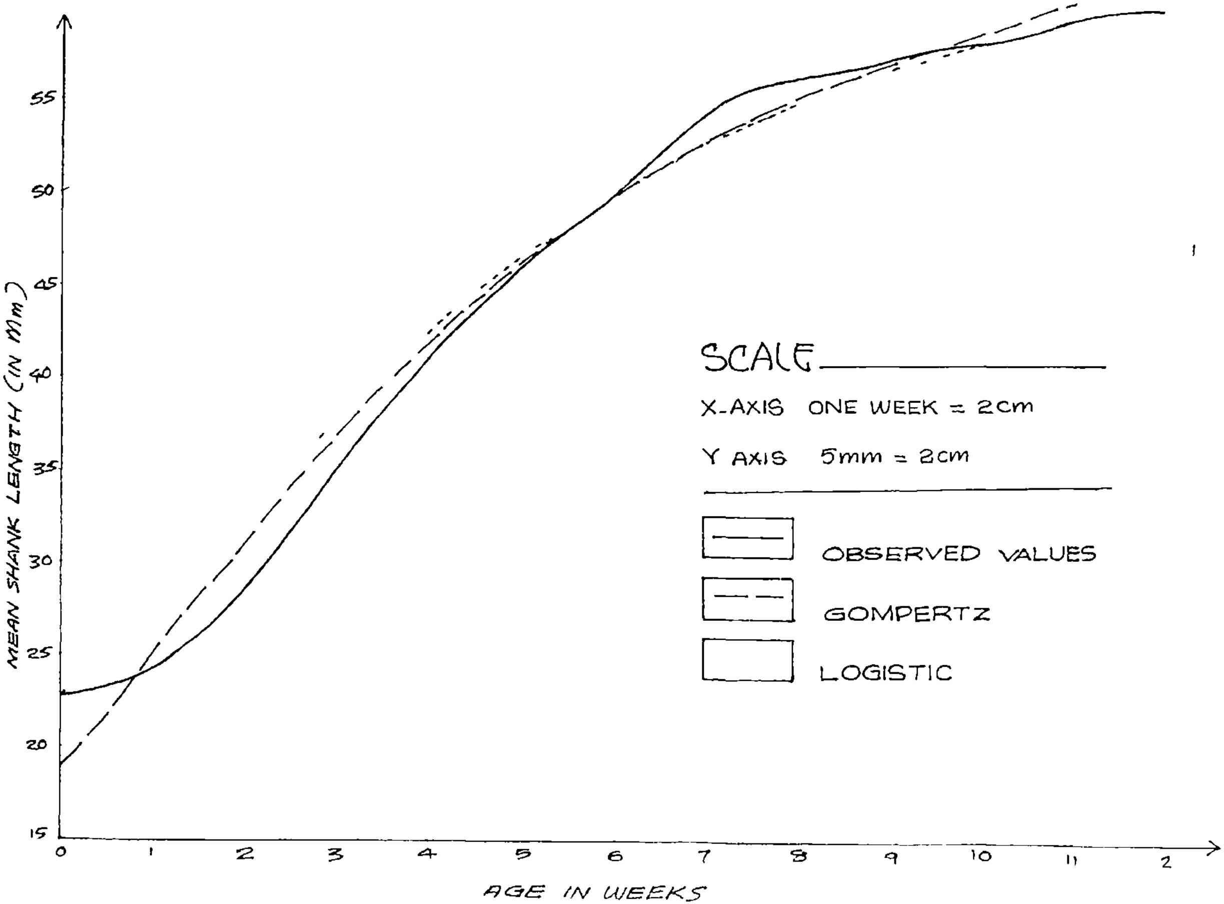
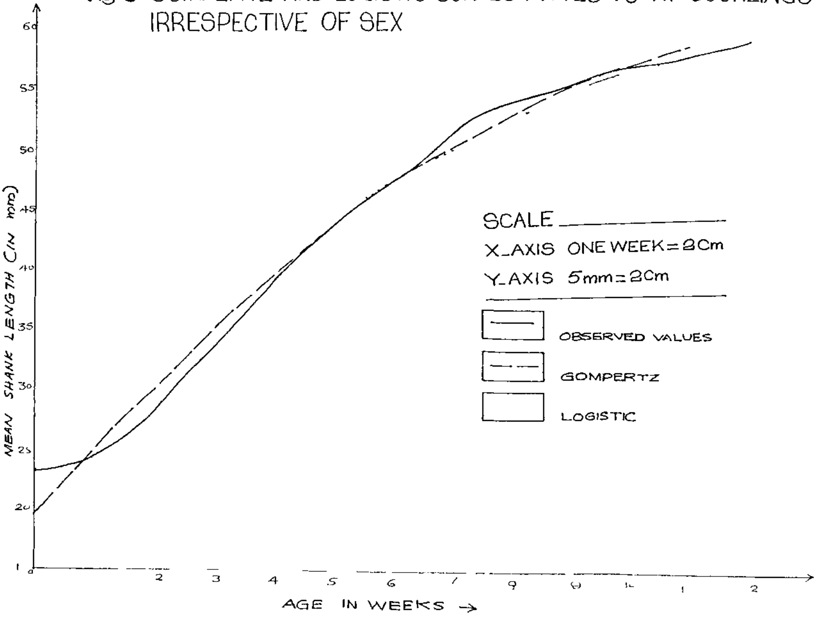


Fig 6 GOMPERTZ AND LOGISTIC CURVES FITTED TO WP DUCKLINGS IRRESPECTIVE OF SEX



Tables

Table 1. Mean and standard error of shank length (in mm) upto the first seven days

Groups					
WP male	WP female	Desi male	Desi female	WP ducks without conside-ring sex	Desi ducks without considering sex
22.65±0.1323	22.75±0.1946	23.04±0.1774	23.10±0.1893	22.70±0.1167	23.08±0.1356
22.85±0.1202	22.83±0.1624	22.89±0.1672	23.26±0.1531	22.86±0.1001	23.13±0.1172
23.08±0.1292	23.27±0.1865	23.25±0.1636	23.52±0.1719	23.17±0.1131	23.42±0.1253
23.21±0.1115	23.44±0.1867	23.29±0.1869	23.64±0.1595	23.33±0.1089	23.51±0.1239
23.25±0.1233	23.75±0.2005	23.75±0.2013	23.98±0.1645	23.55±0.1199	23.90±0.1275
23.69±0.1470	24.02±0.2084	24.11±0.1829	24.48±0.1791	23.86±0.1283	24.35±0.1339
23.73±0.1499	24.21±0.2256	24.61±0.2295	24.90±0.2255	23.97±0.1382	24.79±0.1630

Table 2. Mean and standard error of shank length (in mm) at weekly intervals

Week	Groups			
	WP male	WP female	Desi male	Desi female
ay old	22.65±0.1323	22.75±0.1946	23.04±0.1774	23.10±0.1893
1	23.73±0.1499	24.21±0.2256	24.61±0.2295	24.90±0.2255
2	27.10±0.3552	28.69±0.5936	30.43±0.6064	31.18±0.4949
3	31.62±0.6929	35.08±0.8388	35.96±0.7290	37.88±0.7710
4	36.58±1.0083	41.02±1.2492	43.68±1.2004	45.02±1.1148
5	40.83±1.1780	45.94±1.4492	53.18±1.2275	52.36±1.0895
6	44.67±1.2378	49.92±1.4068	54.36±1.2699	55.30±0.9802
7	48.46±1.3728	54.52±1.3169	56.39±1.1532	57.46±0.7847
8	51.21±1.2941	56.11±1.1729	58.18±1.0581	58.22±0.6947
9	53.90±1.0806	57.21±0.9508	58.68±0.9252	58.72±0.5531
10	55.25±1.0289	58.08±0.9920	59.61±0.8819	59.38±0.5592
11	56.65±1.0014	59.08±0.7374	59.89±0.7917	59.68±0.5211
12	58.29±0.9592	59.73±0.9815	60.61±0.6249	60.06±0.5052

Table 3. Analysis of variance for initial shank length between the four groups

Source	DF	SS	MS	F
Between groups	3	3.2930	1.0977	1.51 NS
within groups	87	63.2422	0.7269	

NS indicates Non significance

Table 4. Analysis of variance for the fourth week shank length between the four groups

Source	DF	SS	MS	F
Between groups	3	1007.063	335.6875	10.88 **
Within groups	87	2683.125	30.8405	

** Indicates significance at 1% level

SD matrix for comparison between group means

	Desi male	Desi female	WP male	WP female	Means
Desi male		3.6835	3.6580	3.6580	43.6786
Desi female			3.0909	3.0909	45.0200
WP male				3.0605	36.5769
WP female					41.0192

Table 5. Analysis of variance of eighth week shank length

Source	DF	SS	MS	F
Between groups	3	772.3125	257.4375	9.04 **
Within groups	87	2476.0940	28.4609	

** Indicates significance at 1% level

CD matrix for comparison between group means

	Desi male	Desi female	WP male	WP female	Means
Desi male		3.5385	3.5140	3.5140	58.1786
Desi female			2.9693	2.9693	58.2200
WP male				2.9400	51.2115
WP female					56.1154

Table 6. Analysis of variance of twelfth week shank length

Source	DF	SS	MS	F
Between groups	3	64.3437	21.4479	1.52 NS
Within groups	87	1226.9690	14.1031	

NS indicates Non significance

Table 7. Parameters of the linear equation y = a + bx fitted to the shank length data of the individual Desi ducklings

Birds	Desi male		Desi female	
	a	b	a	b
1.	24.8791	3.2829	22.8022	3.4945
2.	28.6813	3.2582	23.1209	3.8132
3.	29.5165	3.7857	26.3626	3.0549
4.	24.7582	3.1236	33.1923	3.2692
5.	29.5824	3.4286	30.7033	3.3764
6.	25.3352	3.4313	28.0329	3.3791
7.	24.6264	2.8764	27.8956	3.4341
8.	27.2143	3.5027	23.7308	3.1538
9.	26.9341	3.4725	32.0989	3.3489
10.	27.3187	3.7418	29.8407	3.2445
11.	27.0824	3.3709	26.2582	3.0659
12.	25.4341	3.4725	28.6868	3.3407
13.	27.5769	3.5000	29.8517	3.1786
14.	28.5165	3.5165	30.6264	3.2995
15.			28.6648	3.4533
16.			30.3242	3.2857
17.			27.6374	3.1566
18.			27.0934	2.9973
19.			26.8846	3.0192
20.			25.8022	3.0907
21.			31.5934	3.3626
22.			26.1374	3.6374
23.			26.2312	3.1374
24.			30.5275	3.4698
25.			27.8681	3.6951

Table 8. Parameters of the linear equation y = a+bx fitted to the shank length data of the individual WP ducklings

Birds	WP male		WP female	
	a	b	a	b
1.	25.0550	2.9203	29.0440	3.3324
2.	24.9451	3.6758	27.1484	3.5907
3.	22.1539	2.1538	26.9780	3.4780
4.	21.0275	2.8929	27.4945	3.3791
5.	22.1264	2.8571	23.9120	3.9121
6.	21.2088	3.5934	20.9561	2.5522
7.	21.9890	3.4121	26.9835	3.5412
8.	22.4286	3.0055	19.4725	3.2225
9.	27.2088	3.6511	23.9670	3.6401
10.	23.9451	3.9066	23.1868	3.7060
11.	25.2363	3.9286	22.0769	2.5962
12.	22.2528	3.2335	28.1374	3.1951
13.	23.6648	3.9148	27.9835	3.4451
14.	19.6044	3.0852	21.9890	3.1236
15.	24.8956	3.2995	24.4506	3.7005
16.	25.5879	3.7610	25.6099	3.7060
17.	19.7692	3.4038	24.4396	3.6896
18.	20.5549	2.6896	28.6868	3.4176
19.	24.0330	3.3984	24.7253	3.8022
20.	24.1264	3.5687	20.6044	3.0852
21.	23.3517	3.7363	28.3022	3.3214
22.	20.9066	2.7143	23.1593	3.0632
23.	20.3187	2.9918	27.5109	3.5110
24.	22.0550	2.4973	19.6484	3.3984
25.	23.0275	3.4313	26.3022	3.6676
26.	20.5769	3.2500	31.3297	3.3681

Table 9. Analysis of variance of the linear growth rate (b value)

Source	DF	SS	MS	F
Between group	3	0.3421	0.114	1.07 NS
Within group	87	9.2240	0.106	

NS Indicates non significance

Table 10. The parameters, coefficient of determination (r^2) and standard error of the estimate(s) of the shank length when the linear equation $y = a + bx$ was fitted for the average shank length

Groups	a	b	r^2	s	Fitted equation
Desi male	26.9628	3.4116	0.8782	5.1678	$y = 26.9628 + 3.4116\ x$
Desi female	28.0811	3.3103	0.8522	5.6077	$y = 28.0811 + 3.3103\ x$
Desi ducks	27.6782	3.3471	0.8621	5.4457	$y = 27.6782 + 3.3471\ x$
WP male	22.7722	3.2680	0.9729	2.2155	$y = 22.7722 + 3.2680\ x$
WP female	25.1600	3.4008	0.9240	3.9666	$y = 25.1600 + 3.4008\ x$
WP ducks	23.9867	3.3286	0.9504	3.0930	$y = 23.9867 + 3.3286\ x$

Table 11. Square of the coefficient of correlation (r^2) between the observed and the expected shank lengths of the four groups of birds when linear equation was fitted.

Birds	Groups			
	Desi male	Desi female	WP male	WP female
1.	0.9253	0.9240	0.9502	0.9014
2.	0.8698	0.9409	0.9292	0.8404
3.	0.8124	0.8729	0.9589	0.8643
4.	0.8987	0.7553	0.9909	0.8546
5.	0.8360	0.7939	0.9889	0.9049
6.	0.9255	0.8563	0.9738	0.9856
7.	0.9434	0.8225	0.9650	0.8488
8.	0.8416	0.9326	0.9944	0.9716
9.	0.8749	0.7718	0.8995	0.9225
10.	0.8362	0.7874	0.9167	0.9192
11	0.9008	0.8854	0.8742	0.9773
12.	0.9015	0.8259	0.9644	0.8477
13.	0.8460	0.8164	0.9516	0.8086
14.	0.8109	0.7842	0.9798	0.9655
15.		0.8506	0.9737	0.9452
16.		0.7555	0.9148	0.9060
17.		0.8562	0.9825	0.8972
18.		0.8769	0.9871	0.8604
19.		0.9237	0.9447	0.8958
20.		0.9399	0.9116	0.9873
21.		0.7785	0.9506	0.9121
22.		0.8338	0.9721	0.9677
23.		0.8864	0.9868	0.8503
24.		0.7849	0.9932	0.9791
25.		0.8355	0.9568	0.8834
26.			0.9682	0.8003

Table 12. Standard error of the estimate (s) of the shank length when the linear equation was fitted.

Birds	Groups			
	Desi male	Desi female	WP male	WP female
1.	3.7941	4.0766	2.7181	4.4835
2.	5.1272	3.8864	4.1272	6.3659
3.	7.4006	4.7407	1.8120	5.6052
4.	4.2663	7.5683	1.1276	5.6700
5.	6.1774	6.9964	1.2282	5.1581
6.	3.9608	5.6295	2.3973	1.2545
7.	2.8651	6.4892	2.6427	6.0790
8.	6.1814	3.4494	0.9158	2.2413
9.	5.3399	7.4077	4.9628	4.2927
10.	6.7364	6.8582	4.7909	4.4690
11.	4.5501	4.4864	6.0629	1.6099
12.	4.6678	6.2391	2.5274	5.5090
13.	6.9054	6.1320	3.5913	6.8167
14.		7.0395	1.8029	2.4031
15.		6.3438	2.2043	3.6228
16.		7.6031	4.6690	4.8567
17.		5.2610	1.8485	5.0801
18.		4.5669	1.2515	5.6006
19.		3.5282	3.3445	5.2752
20.		3.1794	4.5214	1.4224
21.		7.2949	3.4660	4.1942
22.		6.6044	1.8687	2.2764
23.		4.5691	1.4076	5.9917
24.		7.3887	0.8383	2.0192
25.		6.6695	2.9652	5.4201
26.			2.3941	6.8428

Table 13. Parameters of the Exponential curve $y = ab^x$ fitted to the shank length data of the individual desi ducklings

Birds	Desi male		Desi female	
	a	b	a	b
1.	25.8636	1.0860	24.0931	1.0940
2.	28.8594	1.0810	24.7672	1.0975
3.	29.3121	1.0902	26.8148	1.0806
4.	25.6076	1.0836	32.1809	1.0775
5.	29.4732	1.0835	30.1613	1.0821
6.	26.3847	1.0875	28.2664	1.0843
7.	25.6240	1.0780	27.7366	1.0875
8.	27.2597	1.0894	24.7073	1.0863
9.	27.5154	1.0868	31.2725	1.0801
10.	27.3330	1.0937	29.2618	1.0817
11.	27.6524	1.0847	26.7283	1.0810
12.	26.2864	1.0890	28.6227	1.0835
13.	27.6927	1.0881	29.6444	1.0788
14.	28.1437	1.0886	30.1633	1.0805
15.			28.5328	1.0860
16.			29.5258	1.0823
17.			27.8226	1.0812
18.			27.5061	1.0781
19.			27.6668	1.0772
20.			26.8288	1.0797
21.			30.7763	1.0813
22.			26.1817	1.0946
23.			26.9356	1.0814
24.			29.8597	1.0847
25.			27.7739	1.0920

Table 14. Parameters of the Exponential curve $y = ab^x$ fitted to the shank length data of the individual WP ducklings

	WP male		WP female	
Birds	a	b	a	b
1.	25.9642	1.0785	29.4158	1.0807
2.	26.1052	1.0927	26.9885	1.0923
3.	23.1270	1.0666	27.3034	1.0881
4.	22.8924	1.0822	27.6315	1.0860
5.	23.8219	1.0796	24.8911	1.1009
6.	23.3401	1.0956	22.3689	1.0770
7.	23.7835	1.0916	27.1121	1.0903
8.	24.1983	1.0818	21.8636	1.0907
9.	27.8363	1.0894	25.2001	1.0941
10.	25.2138	1.0990	24.6865	1.0959
11.	25.9013	1.0991	23.4064	1.0758
12.	23.7945	1.0886	28.2343	1.0812
13.	25.5833	1.0964	27.8062	1.0875
14.	21.6571	1.0895	23.5912	1.0865
15.	26.3640	1.0836	25.9577	1.0925
16.	26.5622	1.0936	26.5877	1.0924
17.	22.2477	1.0935	25.4021	1.0952
18.	22.3963	1.0786	28.9364	1.0835
19.	25.3029	1.0889	25.5807	1.0972
20.	25.1353	1.0935	22.8844	1.0851
21.	24.9335	1.0957	28.9582	1.0307
22.	22.8384	1.0776	24.6976	1.0825
23.	22.2901	1.0858	27.6605	1.0883
24.	23.5512	1.0723	22.1460	1.0936
25.	24.4252	1.0916	26.8232	1.0924
26.	22.3768	1.0921	30.7995	1.0807

Table 15. The parameters, coefficient of determination (r^2) and standard error of the estimate (s) of the shank length when the exponential equation $y = ab^x$ was fitted for the average shank length

Groups	a	b	r^2	s	Fitted equation
Desi male	27.3986	1.0864	0.8848	7.3981	$y = 27.3986 \times (1.0864)^x$
Desi female	28.1867	1.0835	0.8679	7.7599	$y = 28.1867 \times (1.0835)^x$
Desi ducks	27.9025	1.0846	0.8743	7.6276	$y = 27.9025 \times (1.0846)^x$
WP male	24.3492	1.0878	0.9581	4.1229	$y = 24.3492 \times (1.0878)^x$
WP female	26.1035	1.0876	0.9169	6.1615	$y = 26.1035 \times (1.0876)^x$
WP ducks	25.2423	1.0878	0.9380	5.1559	$y = 25.2423 \times (1.0878)^x$

Table 16. Analysis of variance for 'b' values (growth rate) of the four groups when exponential equation was fitted

Source	DF	SS	MS	F
Between group	3	.00029	.000097	2.24 NS
Within group	87	.0037	.000043	

NS Indicates Non significance

Table 17. The square of the coefficient of correlation (r^2) between the observed and the expected shank length when the Exponential equation was fitted.

Birds	Groups			
	Desi male	Desi female	WP male	WP female
1.	0.8512	0.8425	0.8922	0.8192
2.	0.7782	0.8617	0.8429	0.7289
3.	0.7010	0.7853	0.9241	0.7621
4.	0.8202	0.6509	0.9733	0.7530
5.	0.7328	0.6844	0.9649	0.8056
6.	0.8459	0.7582	0.9276	0.9563
7.	0.8828	0.7129	0.9088	0.7424
8.	0.7340	0.8564	0.9684	0.9564
9.	0.7809	0.6638	0.8080	0.8348
10.	0.7214	0.6808	0.8240	0.8361
11.	0.8131	0.7972	0.7717	0.9415
12.	0.8133	0.7222	0.9054	0.7501
13.	0.7415	0.7177	0.8829	0.6986
14.	0.6999	0.6808	0.9536	0.9161
15.		0.7261	0.9258	0.8711
16.		0.6464	0.8265	0.8179
17.		0.7642	0.9610	0.7996
18.		0.7903	0.9833	0.7683
19.		0.8515	0.8716	0.7966
20.		0.8768	0.8205	0.9852
21.		0.6728	0.8755	0.8323
22.		0.7192	0.9778	0.9202
23.		0.8018	0.9658	0.7455
24.		0.6757	0.9837	0.9577
25.		0.7258	0.8883	0.7843
26.			0.9158	0.6952

Table 18. Standard error of the estimate (s) of the shank length when the Exponential equation was fitted

Birds	Groups			
	Desi male	Desi female	WP male	WP female
1.	5.7066	6.2681	4.2586	6.5227
2.	7.1629	6.3841	6.6304	9.0394
3.	10.0645	6.5231	2.5241	7.9744
4.	5.9944	9.6755	2.0117	7.9394
5.	8.4620	9.2921	2.2827	8.0431
6.	6.0835	7.8069	4.2325	2.2765
7.	4.3455	8.8823	4.5223	8.5630
8.	8.6377	5.3819	2.3109	2.8297
9.	7.5344	9.6440	7.4082	6.7246
10.	9.5266	9.0065	7.5270	6.7675
11.	6.7031	6.3456	8.8535	2.6864
12.	6.8700	8.4219	4.3796	7.5237
13.	8.4618	8.0909	5.9610	9.1732
14.	9.4027	9.1191	2.8375	3.9428
15.		8.6763	3.9484	5.9532
16.		9.7844	7.2020	7.2554
17.		7.1767	2.8599	7.6286
18.		6.3066	1.4487	7.7001
19.		5.2049	5.4526	7.9862
20.		4.8104	6.9295	1.5730
21.		9.5338	5.9307	6.1819
22.		9.3044	1.6711	3.7497
23.		6.3772	2.3583	8.4084
24.		9.7656	1.3463	2.9638
25.		9.3385	5.1385	7.9752
26.			4.1238	9.0659

Table 19. The parameters of the Modified exponential curve $y = k + ab^x$ fitted to the data of shank length of the individual Desi male ducklings

Birds	k	a	b
1	62.6320	-47.0517	0.8146
2	62.8750	-47.0122	0.7598
3	66.8163	-59.5770	0.6862
4	59.4097	-45.2424	0.7921
5	64.0651	-51.7338	0.7159
6	67.4122	-51.8285	0.8344
7	65.4694	-45.5626	0.8795
8	62.3566	-52.7750	0.7157
9	64.9828	-50.9963	0.7797
10	65.1784	-56.3087	0.7207
11	65.2500	-46.5251	0.8034
12	64.3762	-50.2009	0.7969
13	63.4009	-51.9926	0.7334
14	61.7640	-56.0377	0.6476

Table 20. The parameters of the Modified Exponential curve $y = k + ab^x$ fitted to the data of shank length of the individual Desi female ducklings

Birds	k	a	b
1.	68.1039	-53.3894	0.8511
2.	82.0565	-65.6425	0.8897
3.	58.5339	-43.9432	0.7633
4.	63.3318	-55.9274	0.5925
5.	63.8521	-52.5828	0.6862
6.	62.1009	-49.4627	0.7287
7.	62.2269	-51.4140	0.7133
8.	61.2813	-45.7426	0.8265
9.	63.1933	-56.3064	0.6067
10.	60.6669	-52.4327	0.6452
11.	61.4286	-45.0590	0.8034
12.	62.1853	-50.3728	0.7134
13.	60.4927	-49.6868	0.6713
14.	61.7691	-54.7441	0.6296
15.	62.0125	-52.8143	0.6815
16.	60.4306	-59.4351	0.5623
17.	58.9990	-46.2603	0.7178
18.	59.7908	-43.3116	0.7809
19.	65.8172	-45.9173	0.8498
20.	81.1960	-59.0388	0.9152
21.	62.8614	-56.1727	0.6119
22.	62.1258	-54.8862	0.7046
23.	60.5601	-45.3426	0.7821
24.	62.9273	-57.8864	0.6169
25.	63.4898	-56.4385	0.6814

Table 21. Parameters of the Modified exponential curve $y = k + ab^x$ fitted to the data of shank length of the individual WP male ducklings

Birds	k	a	b
1.	66.8560	-45.7918	0.8850
2.	75.8402	-58.4709	0.8675
3.	271.7917	-250.7355	0.9901
4.	410.1250	-388.5805	0.9921
5.	145.1513	-126.8053	0.9628
6.	117.7228	-98.6589	0.9525
7.	247.5208	-226.0196	0.9851
8.	65.8403	-51.1861	0.7747
9.	71.7969	-57.9418	0.8340
10.	65.0350	-57.9885	0.7315
11.	92.7258	-74.1660	0.9336
12.	94.4167	-75.8300	0.9147
13.	304.6500	-286.0099	0.9880
14.	76.2944	-55.4345	0.9001
15.	68.6574	-54.7831	0.8077
16.	-50.2361	70.6764	1.0407
17.	-53.7841	74.6693	1.0317
18.	73.1066	-55.4835	0.8777
19.	68.1605	-53.3723	0.8347
20.	87.2892	-69.5821	0.9065
21.	9.8428	13.6004	1.1108
22.	-163.2708	183.7256	1.0154
23.	-169.2813	191.4348	1.0124
24.	71.3938	-54.2203	0.8771
25.	123.7829	-105.8806	0.9589

Table 22. Parameters of the Modified exponential curve $y = k + ab^x$ fitted to the data of shank length of the individual WP female ducklings

Birds	k	a	b
1.	70.7516	-49.5398	0.8422
2.	62.1495	-53.7359	0.6975
3.	64.6250	-51.1909	0.7708
4.	62.3983	-49.4901	0.7440
5.	66.4803	-55.5130	0.7871
6.	949.0000	-928.5561	0.9971
7.	62.9349	-53.0483	0.7256
8.	-16.4074	37.1193	1.0652
9.	78.5556	-61.3620	0.8833
10.	82.9354	-66.2775	0.8951
11.	60.6454	-47.3852	0.7296
12.	62.1989	-52.7459	0.7009
13.	140.0089	-119.7247	0.9657
14.	79.1806	-61.3620	0.8833
15.	65.0884	-52.8046	0.7743
16.	69.6077	-55.1331	0.8301
17.	64.1060	-49.3370	0.7525
18.	66.7959	-54.5751	0.7922
19.	-4.3542	26.7823	1.0785
20.	66.5785	-48.3166	0.8099
21.	96.2450	-75.9535	0.9422
22.	63.9832	-51.6944	0.7457
23.	-18.2285	39.0783	1.0657
24.	64.4084	-52.5198	0.7569
25.	63.2626	-53.4095	0.6510

Table 23. The parameters, coefficient of determination (r^2) and standard er of estimate (s) of the shank length when the Modified exponential $y = k + ab^x$ was fitted to the average shank length

roups	k	a	b	r^2	s	Fitted equa
esi male	62.9767	-49.5592	0.7612	0.9432	3.8037	y = 62.9767-49.
esi female	61.4871	-48.8996	0.7260	0.9344	4.0959	y = 61.4871-48.
esi ducks	61.9723	-49.0557	0.7391	0.9381	3.9761	y = 61.9723-49.
P male	82.7114	-63.8741	0.9179	0.9864	1.5667	y = 82.7114-63.
P female	66.8004	-50.2967	0.8343	0.9712	2.5190	y = 66.8004-50.
P ducks	71.0621	-53.2808	0.8748	0.9801	1.9855	y = 71.0621-53.

Table 24. Analysis of variance of 'b' values (growth parameters) of the four groups when the modified exponential curve was fitted

Source	DF	SS	MS	F
Between group	3	0.5847	0.1949	19.78**
Within group	85	0.8373	0.0099	

** Indicates significance at 1% level

CD matrix for comparison between group means

	Desi male	Desi female	WP male	WP female	Means
Desi male		0.06583	0.06583	0.06583	0.7629
Desi female			0.05578	0.05578	0.7210
WP male				0.05578	0.9274
WP female					0.6355

Table 25. Square of the correlation coefficient (r^2) between the observed and the expected shank length when the modified exponential curve was fitted.

Birds	Groups			
	Desi male	Desi female	WP male	WP female
1.	0.9507	0.9527	0.9820	0.9808
2.	0.9603	0.9701	0.9785	0.9268
3.	0.8908	0.9297	0.9706	0.9474
4.	0.9200	0.8814	0.9904	0.9423
5.	0.9370	0.9294	0.9809	0.9419
6.	0.9632	0.9269	0.9808	0.9921
7.	0.9730	0.9217	0.9686	0.9221
8.	0.9210	0.9649	0.9538	0.9753
9.	0.9334	0.8884	0.9525	0.9727
10.	0.9204	0.8980	0.8954	0.9572
11.	0.9691	0.9618	0.9854	0.9336
12.	0.9411	0.9193	0.9727	0.8989
13.	0.9272	0.9030	0.9807	0.9864
14.	0.8849	0.8554	0.9867	0.9722
15.		0.9063	0.9544	0.9268
16.		0.8117	0.9819	0.9553
17.		0.9212	0.9875	0.9305
18.		0.9510	0.9772	0.9434
19.		0.9760	0.9600	0.9943
20.		0 9747	0.9791	0.9709
21.		0.8904	0.9660	0.9793
22.		0.9031	0.9857	0.9359
23.		0.9324	0.9919	0.9852
24.		0.8711	0.9787	0.9382
25.		0.8926	0.9816	0.9125

Table 26. Standard error of the estimate of the shank length when the modified exponential curve was fitted

Birds	Groups			
	Desi male	Desi female	WP male	WP female
1.	3.1874	3.2884	1.5857	1.5857
2.	3.0283	2.8125	2.3209	2.3209
3.	6.4780	3.7221	1.5294	1.5294
4.	3.9953	6.3460	1.0942	4.2103
5.	4.2864	4.6152	2.0703	0.8996
6.	2.8682	4.3526	1.9471	4.8443
7.	1.9404	4.6883	0.6739	2.0138
8.	4.8704	2.5603	3.4942	2.5834
9.	4.1660	6.2227	3.7125	3.3087
10.	5.1881	5.5314	4.1046	3.9842
11.	2.6424	2.7260	1.6399	5.4726
12.	3.7894	4.6731	2.6891	1.7819
13.	4.5627	5.1098	1.7012	2.6083
14.	6.2653	6.8274	1.5027	4.5417
15.		5.3232	3.6316	3.4511
16.		8.3977	1.8013	4.1836
17.		4.2394	1.1835	4.0546
18.		3.0250	2.1906	0.8983
19.		2.0433	3.1358	2.5522
20.		6.1652	2.2835	1.8047
21.		5.5846	1,8816	4.2311
22.		3.7154	1.3877	1.6559
23.		6.8489	0.8602	4.2047
24.		5.9130	2.0661	5.2368
25			1.8252	

Table 27. Parameters of the Gompertz curve $y = ka^{b^x}$ fitted to the data of shank length of the individual Desi male ducklings.

Birds	k	a	b
1	60.3832	0.3049	0.7488
2	61.7924	0.3130	0.6994
3	66.2974	0.2375	0.6281
4	58.0318	0.3656	0.7338
5	63.3917	0.2811	0.6573
6	64.3347	0.2991	0.7675
7	61.2401	0.3446	0.8202
8	61.6601	0.2564	0.6551
9	63.5007	0.2859	0.7168
10	64.3827	0.2419	0.6581
11	63.2389	0.3085	0.7382
12	62.5802	0.2861	0.7335
13	62.5649	0.2689	0.6730
14	61.4708	0.2366	0.5940

Table 28. Parameters of the Gompertz curve $y = ka^{b^x}$ fitted to the data of shank length ofthe individual Desi female ducklings

Birds	k	a	b
1.	64.2417	0.2732	0.7824
2.	73.1318	0.2561	0.8122
3.	57.6650	0.3162	0.7092
4.	63.2104	0.2604	0.5461
5.	63.3779	0.2749	0.6298
6.	61.4438	0.2891	0.6741
7.	61.6339	0.2675	0.6562
8.	58.7454	0.3066	0.7607
9.	63.0538	0.2557	0.5608
10.	60.4303	0.2626	0.5956
11.	59.6986	0.3187	0.7417
12.	61.6314	0.2822	0.6592
13.	60.1719	0.2864	0.6208
14.	61.5758	0.2573	0.5815
15.	61.5961	0.2620	0.6267
16.	60.3565	0.2215	0.5193
17.	58.4600	0.3007	0.6656
18.	58.7046	0.3317	0.7262
19.	62.6300	0.3440	0.7875
20.	70.6059	0.3224	0.8474
21.	62.6740	0.2505	0.5612
22,	51.5686	0.2367	0.6469
23.	59.4091	0.3151	0.7267
24.	62.7340	0.2373	0.5664
25.	63.0085	0.2374	0.6225

Table 29. The parameters of the Gompertz curve $y = ka^{b^x}$ fitted to the data of shank length of the individual WP male ducklings.

Birds	k	a	b
1.	61.1972	0.3527	0.8168
2.	69.9264	0.2788	0.7925
3.	85.7565	0.2487	0.9265
4.	106.1308	0.1986	0.9254
5.	97.0098	0.2257	0.9189
6.	85.0881	0.2272	0.8721
7.	81.6768	0.2452	0.8720
8.	90.1140	0.2425	0.9066
9.	64.4007	0.2879	0.7110
10.	68.1106	0.2551	0.7606
11.	63.9939	0.2253	0.6642
12.	72.3606	0.2705	0.8531
13.	80.0478	0.2549	0.8381
14.	93.0005	0.2075	0.9078
15.	67.81105	0.3223	0.8296
16.	65.9237	0.2676	0.7335
17.	317.9074	0.0657	0.9567
18.	192.0440	0.1100	0.9543
19.	66.7848	0.2913	0.8046
20.	64.8324	0.2700	0.7640
21.	74.3159	0.2601	0.8237
22.	4.7715	4.9054	1.0383
23.	143.2568	0.1453	0.9396
24.	114.6839	0.1942	0.8033
25.	65.1767	0.2898	0.7442
26.	80.0722	0.2356	0.8771

Table 30. The parameters of the Gompertz curve $y = ka^{b^x}$ fitted to the shank length data of the individual WP female ducklings

Birds	k	a	b
1.	67.1462	0.3337	0.7723
2.	61.5631	0.2445	0.6357
3.	63.2266	0.2788	0.7059
4.	61.4728	0.2835	0.6831
5.	64.4307	0.2435	0.7156
6.	98.0009	0.2115	0.9272
7.	62.0988	0.2552	0.6624
8.	21479.64	0.00098	0.9856
9.	71.0567	0.2697	0.8079
10.	73.7797	0.2559	0.8204
11.	103.48	0.2084	0.9280
12.	59.9613	0.2981	0.6734
13.	61.6777	0.2590	0.6451
14.	85.2252	0.2447	0.8933
15.	71.6340	0.2776	0.8086
16.	63.6272	9.2695	0.7106
17.	66.5336	0.2670	0.7612
18.	63.0561	0.2980	0.6960
19.	64.8522	0.2565	0.7241
20.	335212.3	0.000067	0.9907
21.	64.3143	0.3234	0.7439
22.	75.1125	0.2823	0.8723
23.	63.0028	0.2732	0.6842
24.	2230.698	0.0095	0.9769
25.	63.1913	0.2654	0.6920
26.	62.9954	0.2723	0.6002

Table 51. Analysis of variance of 'a^b' values (growth rate) of the four groups when the Gompertz equation was fitted

Source	DF	MS	MS	F
Between group	3	0.3154	0.1051	0.38 NS
Within group	87	23.9413	0.2752	

NS Indicates Non significance

Table 32. The parameters, coefficient of determination (r^2) standard error of the estimate (s) of shank length when the Gompertz curve $y = ka^{b^x}$ was fitted to the average shank length

ɪps	k	a	b	r^2	s	Fitted equations
ɪ male	61.8298	0.2871	0.6997	0.9711	2.5663	$y = 61.8298 \times (0.2871)^{(0.6997)^x}$
ɪ female	60.8011	0.2887	0.6690	0.9680	2.6772	$y = 60.8011 \times (0.2887)^{(0.6690)^x}$
ɪ ducks	61.1420	0.2885	0.6805	0.9694	2.6261	$y = 61.1420 \times (0.2885)^{(0.6805)^x}$
male	69.6167	0.2872	0.8427	0.9918	1.1947	$y = 69.6167 \times (0.2872)^{(0.8427)^x}$
female	63.6909	0.2981	0.7656	0.9850	1.7671	$y = 63.6909 \times (0.2981)^{(0.7656)^x}$
ducks	65.2615	0.2991	0.8029	0.9891	1.4412	$y = 65.2615 \times (0.2991)^{(0.8029)^x}$

Table 33. Square of the correlation coefficient (r^2) between the observed and the expected shank length of the four groups when the Gompertz curve was fitted.

Birds	Desi male	Desi female	WP male	WP female
1.	0.9697	0.9704	0.9837	0.9830
2.	0.9796	0.9820	0.9883	0.9684
3.	0.9403	0.9595	0.9723	0.9739
4.	0.9492	0.9438	0.9910	0.9716
5.	0.9700	0.9664	0.9918	0.9703
6.	0.9789	0.9622	0.9842	0.9932
7.	0.9792	0.9614	0.9857	0.9616
8.	0.9616	0.9796	0.9972	0.9741
9.	0.9618	0.9476	0.9771	0.9824
10.	0.9625	0.9501	0.9737	0.9702
11.	0.9834	0.9787	0.9397	0.9881
12.	0.9668	0.9590	0.9898	0.9666
13.	0.9634	0.9496	0.9816	0.9465
14.	0.9451	0.9228	0.9841	0.9822
15.		0.9544	0.9911	0.9828
16.		0.9003	0.9743	0.9584
17.		0.9567	0.9823	0.9750
18.		0.9726	0.9884	0.9573
19.		0.9851	0.9866	0.9693
20.		0.9771	0.9774	0.9944
21.		0.9477	0.9862	0.9840
22.		0.9528	0.9628	0.9846
23.		0.9603	0.9868	0.9678
24.		0.9365	0.9921	0.9848
25.		0.9518	0.9873	0.9693
26.			0.9863	0.9599

Table 34. Standard error of the estimate (s) of the shank length of the four groups when the Gompertz curve was fitted.

Birds	Desi male	Desi female	WP male	WP female
1.	2.4047	2.5405	1.5119	1.8689
2.	2.0637	2.1441	1.6820	2.9061
3.	4.3509	2.7028	1.4824	2.5209
4.	3.0529	3.8346	1.0577	2.5599
5.	2.7396	2.9326	1.0128	2.8756
6.	2.1125	2.9400	1.8569	0.8387
7.	1.6963	3.1029	1.6676	3.1627
8.	3.1423	2.1136	0.6237	2.0689
9.	3.0076	3.7384	2.3665	2.0514
10.	3.3213	3.4758	2.6913	2.7261
11.	1.8759	1.9686	4.2885	1.1490
12.	2.7349	3.1161	1.3521	2.6549
13.	3.0388	3.3509	2.1973	3.7143
14.	3.8727	4.4351	1.5428	1.7003
15.		3.3973	1.2158	2.0109
16.		5.1773	2.6002	3.2441
17.		2.9467	1.7777	2.5374
18.		2.1884	1.1343	3.1379
19.		1.5652	1.6441	2.8773
20.		1.9471	2.2977	0.8968
21.		3.7440	1.8269	1.8218
22.		3.6072	1.9861	1.5451
23.		2.7365	1.3365	2.8425
24.		4.2261	0.8507	1.6868
25.		3.7177	1.5761	2.8095
26.			1.5611	3.1982

Table 35. The parameters of the Logistic curve $y = a/[1+10^{b+cx}]$ fitted to the data of shank length of the individual Desi male ducklings

Birds	a	b	c
1	62.1560	0.2161	-0.1384
2	61.5316	0.2391	-0.1891
3	63.1653	0.2632	-0.2382
4	56.7145	0.1503	-0.1704
5	62.2573	0.2173	-0.[illegible]16[illegible]
6	61.3667	0.2072	-0.1541
7	59.5588	0.2167	-0.1178
8	61.3829	0.2529	-0.2046
9	62.1420	0.2012	-0.1607
10	62.6719	0.2669	-0.2356
11	61.0865	0.2281	-0.1721
12	60.8231	0.2009	-0.1720
13	61.1480	0.2197	-0.2362
14	62.0394	0.2601	-0.2881

Table 36. Parameters of Logistic curve $y = a/[1+10^{b+cx}]$ fitted to the data of shank length of the individual desi female ducklings

Birds	a	b	c
1.	59.7505	0.2502	-0.1600
2.	64.9321	0.2755	-0.1334
3.	57.6706	0.1626	-0.1743
4.	63.5707	0.2027	-0.2630
5.	62.0423	0.2298	-0.2830
6.	61.2603	0.2210	-0.2159
7.	60.0447	0.2224	-0.2792
8.	57.4762	0.2236	-0.1502
9.	63.0023	0.2404	-0.3892
10.	60.0447	0.2224	-0.2792
11.	56.5512	0.1640	-0.1809
12.	60.11501	0.1926	-0.2425
13.	60.2963	0.1796	-0.2072
14.	61.5273	0.1647	-0.2932
15.	62.2477	0.2321	-0.2192
16.	61.0105	0.2182	-0.3320
17.	58.7966	0.1921	-0.2073
18.	56.4527	0.1469	-0.1862
19.	58.7629	0.1457	-0.1503
20.	65.4356	0.2372	-0.0941
21.	63.0650	0.2410	-0.2689
22.	61.1270	0.2812	-0.2469
23.	57.5653	0.1457	-0.1791
24.	63.0962	0.2414	-0.2548
25.	64.3434	0.2694	-0.2117

Table 37. Parameters of the Logistic curve $y=a/[1+10^{b+cx}]$ fitted to the data of shank length of the individual WP male ducklings

Birds	a	b	c
1.	63.0390	0.2557	-0.1060
2.	63.9730	0.2656	-0.1469
3.	51.4286	0.1091	-0.0795
4.	104.8673	0.5514	-0.0495
5.	69.9765	0.2962	-0.0702
6.	73.0311	0.3514	-0.0845
7.	63.6252	0.2471	-0.1050
8.	77.3378	0.3734	-0.0672
9.	66.7958	0.2654	-0.1520
10.	65.7442	0.2837	-0.1540
11.	66.1531	0.3174	-0.1724
12.	61.2064	0.2509	-0.1068
13.	68.8797	0.2718	-0.1158
14.	71.9626	0.3562	-0.0695
15.	73.0387	0.3103	-0.0945
16.	67.2247	0.2839	-0.1458
17.	81.0000	0.4284	-0.7140
18.	108.2914	0.5692	-0.0459
19.	62.3825	0.2336	-0.1229
20.	60.7239	0.2456	-0.1803
21.	68.4559	0.3102	-0.1109
22.	126.6539	0.6539	-0.0449
23.	65.7507	0.2986	-0.0839
24.	81.9133	0.4085	-0.0541
25.	63.2195	0.2727	-0.1286
26.	64.8752	0.3048	-0.0876

Table 38. Parameters of the Logistic curve $y = a/[1+10^{b+cx}]$ fitted to the data of shank length of the individual WP female ducklings

Birds	a	b	c
1.	64.0285	0.2373	-0.1528
2.	62.9866	0.3009	-0.2008
3.	60.4375	0.2116	-0.1957
4.	60.4201	0.2267	-0.1985
5.	66.4423	0.3352	-0.1658
6.	63.9835	0.2958	-0.0675
7.	61.4902	0.2388	-0.1945
8.	84.5272	0.4273	-0.0600
9.	61.6139	0.2554	-0.1521
10.	62.0536	0.2299	-0.1413
11.	62.5000	0.2499	-0.0709
12.	58.8088	0.1768	-0.2045
13.	60.3496	0.2106	-0.2038
14.	61.2485	0.2669	-0.1010
15.	67.2538	0.2699	-0.1249
16.	65.3854	0.2655	-0.1608
17.	60.6027	0.2442	-0.1869
18.	64.2407	0.2101	-0.1596
19.	65.1910	0.3080	-0.1472
20.	511.8588	1.3275	-0.0355
21.	63.6084	0.1887	-0.1479
22.	64.03169	0.2222	-0.0888
23.	61.6206	0.2251	-0.1848
24.	91.3861	0.4859	-0.0596
25.	64.3719	0.2697	-0.1777
26.	63.0674	0.2263	-0.2664

Table 39. Square of the correlation coefficient (r^2) between the observed and the expected shank length of the four groups when the Logistic curve was fitted.

Birds	Desi male	Desi female	WP male	WP female
1	0.9807	0.9702	0.9813	0.9843
2	0.9865	0.9844	0.9910	0.9868
3	0.9515	0.9715	0.9748	0.9758
4	0.9531	0.9723	0.9896	0.9809
5	0.9788	0.9500	0.9924	0.9831
6	0.9821	0.9676	0.9838	0.9911
7	0.9846	0.9268	0.9860	0.9776
8	0.9777	0.9862	0.9962	0.9770
9	0.9743	0.8813	0.9869	0.9817
10	0.9618	0.9503	0.9814	0.9687
11	0.9880	0.9772	0.9676	0.9871
12	0.9715	0.9503	0.9898	0.9746
13	0.9540	0.9749	0.9829	0.9637
14	0.9385	0.9086	0.9844	0.9824
15		0.9744	0.9882	0.9883
16		0.8994	0.9838	0.9772
17		0.9682	0.9974	0.9648
18		0.9721	0.9907	0.9710
19		0.9854	0.9900	0.9791
20		0.9739	0.9719	0.9881
21		0.9695	0.9874	0.9905
22		0.9508	0.9798	0.9863
23		0.9619	0.9871	0.9794
24		0.9643	0.9938	0.9827
25		0.9762	0.9916	0.9835
26			0.9848	0.9667

Table 40. Standard error of the estimate (s) of shank length of the four groups when the logistic curve was fitted

Birds	Desi males	Desi females	WP males	WP females
1	2.9585	3.6042	1.6855	1.8477
2	2.4241	2.8042	2.0980	2.4779
3	4.6559	3.2741	1.7551	3.3719
4	4.1294	3.4747	1.4805	2.8453
5	3.0599	4.5536	1.4029	3.2448
6	2.8891	3.8015	2.5183	1.4686
7	1.6780	5.6541	2.9473	3.2448
8	3.1742	2.1989	1.9434	2.7171
9	3.1486	6.8669	2.2273	2.8094
10	4.4575	4.4090	3.3469	3.7931
11	2.3044	2.8633	2.6343	1.7803
12	3.7519	4.5259	1.9103	3.1735
13	4.7660	2.9622	2.9639	3.8404
14	5.6334	6.2187	2.1827	2.0295
15		3.5624	1.8378	2.2672
16		6.4348	2.6059	3.3496
17		3.4804	1.9105	4.0421
18		2.9634	1.3482	2.9114
19		2.3092	2.0417	2.7152
20		2.6802	3.9096	2.1982
21		3.6546	2.2434	1.8925
22		5.0084	1.7244	2.0549
23		2.3812	2.1677	3.0022
24		4.0165	0.8446	2.6574
25		3.7122	2.1288	3.0691
26			2.3779	3.9262

Table 41. The parameters, coefficient of determination (r^2), standard error of estimate (s) of shank length when the logistic curve $y = a/[1+10^{b+cx}]$ was fitted to the average shank length.

ups	a	b	c	r^2	s	Fitted equations
i male	61.1875	0.2189	-0.1867	0.9804	3.0715	$y = 61.1875/\ 1+10^{(0.2189-0.1867x)}$
i female	60.3733	0.2078	-0.2075	0.9776	3.1872	$y = 60.3733/\ 1+10^{(0.2078-0.2075x)}$
i ducks	60.6578	0.2117	-0.1993	0.9789	3.1245	$y = 60.6578/\ 1+10^{(0.2668-0.1993x)}$
male	64.5134	0.2668	-0.1032	0.9948	1.4441	$y = 64.5134/\ 1+10^{(0.2668-0.1032x)}$
female	61.6621	0.2331	-0.1436	0.9910	1.9576	$y = 61.6621/\ 1+10^{(0.2331-0.1436x)}$
ducks	62.1595	0.2401	-0.1238	0.9933	1.5755	$y = 62.1595/\ 1+10^{(0.2401-0.1238x)}$

Table 43. Parameters of Von-Bertalanffy equation $y = A(1-be^{-kt})$ fitted to the data of shank length of individual WP ducklings where A = 67 mm

Birds	WP male		WP female	
	b	k	b	k
1	0.6944	0.1256	0.6973	0.2078
2	0.7868	0.2109	0.6829	0.2058
3	0.6943	0.0684	0.6800	0.1899
4	0.7644	0.1107	0.6575	0.1794
5	0.7446	0.1119	0.8618	0.2432
6	0.8486	0.1751	0.7319	0.0865
7	0.7886	0.1546	0.6793	0.1966
8	0.7590	0.1259	0.8162	0.1291
9	0.7954	0.2468	0.7704	0.1906
10	0.8518	0.2402	0.7904	0.1930
11	0.8476	0.2658	0.7167	0.0919
12	0.7580	0.1374	0.6291	0.1613
13	0.9583	0.2660	0.6258	0.1896
14	0.7931	0.1171	0.7548	0.1280
15	0.7914	0.1778	0.8307	0.2184
16	0.8452	0.2467	0.7971	0.2272
17	0.8423	0.1479	0.7545	0.1981
18	0.7583	0.0967	0.6775	0.2082
19	0.7496	0.1637	0.7892	0.2238
20	0.7473	0.1790	0.8052	0.1281
21	0.8361	0.2083	0.6975	0.1951
22	0.7627	0.1017	0.7354	0.1290
23	0.7797	0.1143	0.6714	0.1999
24	0.7237	0.0893	0.8398	0.1461
25	0.7746	0.1620	0.7500	0.2206
26	0.7815	0.1302	0.5949	0.2259

Table 44. The parameters, coefficient of determination (r^2) and standard error of estimate (s) of shank length when Von-Bertalanffy equation was fitted for the averages.

Groups	b	k	r^2	s	Fitted equation
Desi male (A = 66)	0.6906	0.1959	0.9668	2.8496	$y = 66(1-0.6906 \times e^{-0.1959\ t})$
Desi female (A = 66)	0.6475	0.1888	0.9654	3.1867	$y = 66(1-0.6475 \times e^{-0.1888\ t})$
Desi ducks (A = 66)	0.6629	0.1914	0.9667	3.0219	$y = 66(1-0.6629 \times e^{-0.1914\ t})$
WP male (A = 67)	0.7632	0.1453	0.9732	2.3746	$y = 67(1-0.7632 \times e^{-0.1453\ t})$
WP female (A = 67)	0.7249	0.1698	0.9760	2.2351	$y = 67(1-0.7249 \times e^{-0.1698\ t})$
WP ducks (A = 67)	0.7426	0.1559	0.9774	2.1234	$y = 67(1-0.7426 \times e^{-0.1559\ t})$

Table 42. Parameters of Von-Bertalanffy equation $y = A(1-be^{-kt})$ fitted to the data of shank length of the individual desi ducklings

where A = 66 mm

Birds	Desi male		Desi female	
	b	k	b	k
1	0.7278	0.1661	0.7655	0.1706
2	0.6562	0.1938	0.8713	0.2338
3	0.8261	0.3910	0.6510	0.1435
4	0.6898	0.1426	0.5481	0.2630
5	0.6518	0.2350	0.5970	0.2398
6	0.7452	0.1903	0.6606	0.2013
7	0.6896	0.1240	0.6376	0.2011
8	0.6714	0.2068	0.7161	0.1409
9	0.7004	0.2072	0.5635	0.2567
10	0.7113	0.2632	0.5806	0.1905
11	0.7065	0.1971	0.6568	0.1445
12	0.7298	0.1919	0.6252	0.1976
13	0.6759	0.2141	0.5953	0.1861
14	0.6457	0.2260	0.5786	0.2143
15			0.6566	0.2215
16			0.5544	0.1991
17			0.6396	0.1640
18			0.6388	0.1431
19			0.6666	0.1500
20			0.7003	0.1535
21			0.6015	0.2554
22			0.6845	0.2120
23			0.6653	0.1536
24			0.6179	0.2570
25			0.7421	0.2709

Table 45. Analysis of variance of be^{-k} (growth rate) values of the four groups when Von-Bertalanffy equation was fitted

Source	DF	SS	MS	F
Between group	3	0.2574	0.0858	29.15**
Within group	87	0.2560	0.0029	

** Indicates significance at 1% level

CD matrix for the comparison between group means

	Desi male	Desi female	WP male	WP female	Means
Desi male		0.03598	0.0357	0.0357	0.5085
Desi female			0.0302	0.0302	0.5347
WP male				0.0239	0.6698
WP female					0.6115

Table 46. Square of the correlation coefficient (r^2) between the observed and the expected shank length of the four groups when Von-Bertalanffy equation was fitted.

Birds	Desi male	Desi female	WP male	WP female
1	0.9659	0.9543	0.9839	0.9791
2	0.9750	0.9241	0.9616	0.9663
3	0.8892	0.9555	0.9681	0.9631
4	0.9516	0.9536	0.9552	0.9643
5	0.9655	0.9597	0.9632	0.9441
6	0.9637	0.9621	0.9267	0.9787
7	0.9769	0.9532	0.9531	0.9581
8	0.9587	0.9783	0.9648	0.9096
9	0.9508	0.9589	0.9596	0.9575
10	0.9479	0.9436	0.9330	0.9330
11	0.9760	0.9675	0.9244	0.9771
12	0.9572	0.9530	0.9712	0.9586
13	0.9568	0.9519	0.8868	0.9387
14	0.9541	0.9362	0.9450	0.9636
15		0.9588	0.9602	0.9414
16		0.9242	0.9449	0.9447
17		0.9583	0.9157	0.9529
18		0.9631	0.9444	0.9545
19		0.9787	0.9712	0.9515
20		0.9707	0.9635	0.9178
21		0.9571	0.9477	0.9771
22		0.9505	0.9164	0.9646
23		0.9577	0.9510	0.9598
24		0.9496	0.9668	0.9122
25		0.9486	0.9735	0.9614
26			0.9608	0.9625

Table 47. Standard error of the estimate (s) of shank length of the four groups when Von-Bertalanffy equation was fitted.

Birds	Desi male	Desi female	WP male	WP female
1	2.5767	3.1789	1.5472	2.0696
2	2.4909	5.0867	3.1816	3.4723
3	5.9077	3.0638	1.5975	3.2577
4	3.0120	5.1112	2.7501	3.2896
5	3.3567	4.4526	2.4372	4.3566
6	2.8101	3.2618	4.6149	1.5675
7	1.8330	4.1840	3.2730	3.6352
8	3.6736	1.9693	2.6422	4.3887
9	3.4507	5.0018	3.4364	3.2136
10	4.2267	4.7650	4.6591	4.1448
11	2.2565	2.6376	4.9374	1.6389
12	3.0917	4.0026	2.3498	3.4187
13	3.6115	3.9696	7.4042	4.8175
14	4.2640	5.0242	3.2011	2.5556
15		3.6629	3.5698	4.3157
16		5.8689	4.3646	3.9056
17		3.2145	4.8985	3.4725
18		2.7885	2.8110	3.3298
19		1.8978	2.4568	3.6369
20		2.2395	2.9209	4.2154
21		4.3640	4.0630	2.1457
22		4.2395	3.5396	2.4601
23		2.9492	2.9600	3.5594
24		4.6875	2.0003	4.7269
25		3.8123	2.4654	3.1314
26			2.7633	4.1674

Table 46. The parameters of the second degree equation $y = a + bx + cx^2$ fitted to the data of shank length of the individual [illegible] male ducklings

Birds	a	b	c
1	6.0572	-0.2295	0.7983
2	7.5200	-0.3551	0.8568
3	9.6776	-0.4910	0.9099
4	6.1236	-0.[illegible]500	0.7775
5	8.6[illegible]54	-0.4331	0.8825
6	6.4733	-0.25[illegible]5	0.8194
7	4.9533	-0.1731	0.7594
8	8.5707	-0.4223	0.8439
9	7.6264	-0.3462	0.8444
10	9.2862	-0.4620	0.8651
11	7.1141	-0.3119	0.8413
12	7.0270	-0.2962	0.8[illegible]04
13	8.4351	-0.4111	0.8522
14	9.1628	-0.4705	0.8655

Table 49. Parameters of the second degree equation $y = a + bx + cx^2$ fitted to the data of shank length of the individual Desi female ducklings

Birds	a	b	c
1	6.3297	-0.2363	0.7771
2	6.5165	-0.2253	0.8167
3	6.7772	-0.3102	0.7955
4	9.5629	-0.5244	0.9278
5	9.3494	-0.4978	0.8919
6	7.9825	-0.3836	0.8525
7	8.7987	-0.4471	0.8477
8	5.8392	-0.2238	0.7631
9	9.6036	-0.5212	0.9430
10	8.9238	-0.4733	0.8645
11	6.7403	-0.3062	0.7950
12	8.4835	-0.4286	0.8564
13	8.2405	-0.4218	0.8643
14	8.9728	-0.4728	0.8857
15	8.6411	-0.4323	0.8667
16	9.4416	-0.5130	0.8735
17	7.3614	-0.3504	0.8264
18	6.7285	-0.3109	0.8043
19	5.8694	-0.2375	0.8111
20	5.3714	-0.1901	0.8023
21	9.3566	-0.4995	0.9082
22	8.9780	-0.4451	0.8331
23	6.6499	-0.2927	0.8044
24	9.4968	-0.5022	0.8973
25	9.0627	-0.4473	0.8732

Table 50. Parameters of the second degree equation $y = a + bx + cx^2$ fitted to the data of shank length of the individual WP male ducklings

Birds	a	b	c
1	4.9253	-0.1671	0.7730
2	6.9785	-0.2752	0.8335
3	3.0110	-0.0714	0.6499
4	2.8719	-0.0017	0.7100
5	3.1508	-0.0245	0.7253
6	4.5884	-0.0829	0.7736
7	4.9286	-0.1264	0.7658
8	3.3771	-0.0310	0.7454
9	7.6461	-0.3329	0.8693
10	7.4490	-0.2952	0.8341
11	8.3581	-0.3691	0.8533
12	4.9268	-0.1411	0.7515
13	6.1476	-0.1861	0.8425
14	3.2560	-0.0142	0.6989
15	4.7710	-0.1226	0.8181
16	7.3304	-0.2975	0.8522
17	3.2870	-0.0097	0.7369
18	2.1771	-0.0427	0.6852
19	5.9308	-0.2110	0.7952
20	7.0542	-0.2904	0.8045
21	6.2597	-0.2103	0.8154
22	1.8392	-0.0729	0.6983
23	3.0427	-0.0042	0.7050
24	2.3444	-0.0127	0.6924
25	5.6461	-0.1846	0.7815
26	4.5057	-0.1046	0.7240

Table 51. Parameters of the second degree equation $y = a + bx + cx^2$ fitted to the shank length data of the individual WP female ducklings.

Birds	a	b	c
1	6.9978	-0.3054	0.8775
2	8.8684	-0.4398	0.8493
3	8.0934	-0.3846	0.8412
4	8.0784	-0.3916	0.8408
5	7.8442	-0.3277	0.8301
6	3.0587	-0.0422	0.6693
7	8.4773	-0.4113	0.8444
8	2.8659	-0.2972	0.7153
9	6.8919	-0.2710	0.8108
10	6.6461	-0.2450	0.8049
11	3.4023	-0.0672	0.6931
12	7.7775	-0.3818	0.8364
13	8.9476	-0.4585	0.8492
14	4.4093	-0.1071	0.7393
15	6.3229	-0.2185	0.8328
16	7.2994	-0.2995	0.8469
17	7.5887	-0.3249	0.8188
18	7.7692	-0.3626	0.8720
19	7.8661	-0.3387	0.8341
20	2.3689	-0.0597	0.7278
21	6.7650	-0.2870	0.8638
22	4.3489	-0.1071	0.7566
23	8.4261	-0.4096	0.8522
24	3.2575	-0.0117	0.7342
25	7.9923	-0.3604	0.8496
26	9.1464	-0.4815	0.9056

Table 52. Square of the coefficient of correlation (r^2) between the observed and the expected shank length of the four groups when the second degree equation was fitted.

Birds	Desi male	Desi female	WP male	WP female
1	0.7478	0.7499	0.7889	0.6958
2	0.6461	0.7773	0.7427	0.6043
3	0.5746	0.6593	0.8360	0.6389
4	0.7109	0.4983	0.9216	0.6245
5	0.5968	0.5395	0.9040	0.7090
6	0,7416	0.6293	0.8654	0.8873
7	0.7785	0.5814	0.8342	0.6195
8	0.6081	0.7520	0.9059	0.9184
9	0.6629	0.5146	0.6943	0.7379
10	0.5996	0.5371	0.7312	0.7483
11	0.6936	0.6711	0.6699	0.8640
12	0.7048	0.5868	0.8227	0.6148
13	0.6158	0.5747	0.8052	0.5677
14	0.5684	0.5384	0.9023	0.8393
15		0.5952	0.8417	0.0806
16		0.5028	0.7246	0.7149
17		0.6332	0.9177	0.6967
18		0.6593	0.9445	0.6430
19		0.7334	0.7759	0.6843
20		0.7734	0.7184	0.9508
21		0.5279	0.7899	0.7920
22		0.5994	0.9489	0.8402
23		0.6815	0.9143	0.6200
24		0.5365	0.9316	0.9156
25		0.6028	0.7994	0.6710
26			0.8451	0.5499

Table 53. Standard error of estimate (s) of shank length of the four groups when the second degree equation was fitted

Birds	Desi male	Desi female	WP male	WP female
1	28.3939	26.6702	28.2320	32.3054
2	31.7247	27.4369	28.8557	30.5892
3	33.1401	29.3194	24.7184	30.3404
4	28.0367	35.8128	24.8377	30.6810
5	32.6828	33.5721	25.7787	28.1553
6	28.9640	31.2272	25.6529	24.1343
7	27.7358	31.0746	26.0268	30.4172
8	30.5591	27.0710	26.2289	23.8989
9	30.4023	34.8562	30.9101	27.8978
10	30.9593	32.6334	28.2367	27.3642
11	30.4215	29.2102	29.4627	25.2160
12	29.0438	31.7270	25.9738	31.0557
13	30.9275	32.6308	28.2216	31.1969
14	31.7771	33.5057	23.6287	25.7003
15		31.8704	28.7338	28.5699
16		33.1481	29.5904	29.5571
17		30.6110	24.3091	28.3421
18		29.9222	24.3035	31.9988
19		29.9389	27.7432	28.7579
20		29.1423	27.9107	24.9325
21		34.4613	27.5582	31.6059
22		29.7266	24.8703	26.7709
23		29.4131	24.2404	30.8697
24		33.6021	25.4142	24.2033
25		31.4583	26.8678	30.0229
26			24.4805	34.2007

Table 54. The parameters, coefficient of determination (r^2), standard error of estimate (s) when the second degree equation $y = a + bx + cx^2$ was fitted to the average shank length

roups	a	b	c	r^2	s	Fitted equation
si male	7.6156	-0.3503	0.8384	0.6611	30.2973	$y = 7.6156 - 0.3503x + 0.8384x^2$
si female	7.9631	-0.3877	0.8461	0.6213	31.1555	$y = 7.9631 - 0.3877x + 0.8461x^2$
si ducks	7.8392	-0.3743	0.8434	0.6359	30.8458	$y = 7.8392 - 0.3743x + 0.8434x^2$
male	4.8389	-0.1309	0.7665	0.8361	26.5493	$y = 4.8389 - 0.1309x + 0.7665x^2$
female	6.5975	-0.2664	0.8113	0.7334	28.6971	$y = 6.5975 - 0.2664x + 0.8113x^2$
ducks	5.7368	-0.2006	0.7885	0.7836	27.6172	$y = 5.7368 - 0.2006x + 0.7885x^2$

Table 55. Mean and standard error of the

Weeks	Desi male	Desi female
0	36.6428±0.5704	38.16±0.6026
1	58.5000±2.3008	63.28±1.8371
2	108.3591±5.7880	118.08±6.4057
3	190.4785±12.2795	210.80±15.0442
4	289.4285±21.1864	345.60±26.7933
5	412.2142±30.9867	495.20±36.8022
6	491.0700±35.2196	573.00±42.6947
7	536.0700±33.2874	609.80±39.1977
8	633.8800±38.4135	709.00±44.4700
9	757.8500±45.8085	813.00±44.4259
10	839.2857±56.3175	892.40±44.0673
11	931.7857±48.8623	928.80±41.2667
12	1291.7857±59.7857	1239.40±45.0836

body weight (in g)

Groups	
WP male	WP female
38.6538±0.5318	38.3846±0.6565
49.1153±1.6261	55.3462±0.1825
84.2692±4.2148	105.0769±5.5824
134.1538±9.6694	188.5769±13.8539
202.6923±15.6217	293.8461±25.4454
277.8462±24.3026	431.0385±38.2648
309.1923±26.8709	492.3077±40.7528
468.4651±31.0443	706.1530±58.7461
537.8846±44.4047	811.7308±62.8904
637.3076±52.9834	935.5769±60.8904
781.9307±59.1510	1145.7692±63.7451
964.2307±71.4727	1309.6154±66.9822
1021.7308±79.5385	1401.6154±73.0109

Table 56. Correlation coefficient between the body weight and the shank length of each individual in the four groups.

Birds	Desi male	Desi female	WP male	WP female
1	0.8619	0.8664	0.9065	0.9632
2	0.8816	0.8948	0.8917	0.8357
3	0.8893	0.8791	0.9430	0.9152
4	0.9112	0.9119	0.9517	0.8972
5	0.8440	0.9003	0.9457	0.9273
6	0.8531	0.9619	0.9038	0.9612
7	0.8911	0.9040	0.9117	0.8961
8	0.8750	0.8720	0.9673	0.9940
9	0.8926	0.8856	0.8981	0.8403
10	0.8599	0.8820	0.9093	0.8761
11	0.8375	0.8553	0.9034	0.9405
12	0.8585	0.8932	0.9062	0.6793
13	0.8657	0.9048	0.9014	0.8755
14	0.8793	0.9041	0.9555	0.9848
15		0.9150	0.8467	0.8567
16		0.8892	0.8754	0.8720
17		0.8810	0.9447	0.8956
18		0.8680	0.9808	0.8655
19		0.8646	0.9115	0.9145
20		0.8749	0.9061	0.9908
21		0.9126	0.9087	0.7876
22		0.9481	0.9706	0.9422
23		0.8990	0.9622	0.8158
24		0.9299	0.9571	0.9867
25		0.9273	0.9055	0.7961
26			0.9372	0.8198

Table 57. Correlation coefficient between the mean body weight and the mean shank length

Group	Correlation
Desi male	0.5775
Desi female	0.907[illegible]
Desi ducks (without considering sex)	0.3973
WP male	0.9367
WP female	0.9166
WP ducks (without considering sex)	0.9269

Table 58. Parameters of the linear equation y = a + bx used for predicting the body weight from shank length of the individual Desi ducklings

Birds	Desi male		Desi female	
	a	b	a	b
1	-587.7736	22.5437	-481.5416	19.8946
2	-538.9933	20.5294	-490.1224	19.6448
3	-686.4343	26.8521	-567.0116	22.02091
4	-485.1330	20.0154	-949.5496	33.9536
5	-635.9355	23.3929	-711.3549	27.4319
6	-660.2126	24.8673	-602.9895	22.9584
7	-382.9356	16.1087	-684.2464	27.3849
8	-634.3079	25.2376	-471.4747	19.2519
9	-581.9571	22.5853	-727.5906	27.5308
10	-608.0450	23.9823	-584.5361	23.5304
11	-617.7463	23.2272	-484.7677	19.5021
12	-642.2920	24.7245	-610.6583	23.9125
13	-593.8965	22.9480	-580.2999	22.4197
14	-666.2716	26.1977	-712.1968	27.0886
15			-582.4013	22.9645
16			-623.4576	25.0499
17			-566.1029	22.1971
18			-515.5205	20.2061
19			-600.2158	22.5142
20			-586.7941	21.4108
21			-743.4040	27.8785
22			-546.6430	23.1217
23			-383.1297	16.0915
24			-753.7070	29.4115
25			-758.0690	29.3403

Table 59. Parameters of the linear equation y = a + bx used for predicting the body weight (y) from shank length of the individual WP ducklings

Birds	WP males		WP females	
	a	b	a	b
1	-687.4404	25.9851	-1317.3140	46.8848
2	-757.1681	27.9710	-727.9434	28.3385
3	-459.3548	19.7513	-969.7925	36.8027
4	-445.6050	18.4286	-756.0325	28.6690
5	-445.6189	18.2312	-661.8882	27.4051
6	-648.9308	24.6854	-1320.1260	54.7606
7	-590.1263	23.0338	-178.7497	7.7827
8	-320.2010	14.0829	-933.7267	43.5529
9	-902.6520	32.6601	-445.8411	16.6850
10	-744.9805	28.6132	-820.7296	31.6469
11	-891.4648	35.1553	-1237.7420	48.6918
12	-698.9986	27.6159	-599.6129	24.4744
13	-696.1432	25.3929	-640.8301	26.7480
14	-411.3311	18.0652	-943.3346	33.2451
15	-776.0737	28.1445	-641.3356	27.4368
16	-950.6079	34.4615	-773.4103	28.5005
17	-588.6386	24.0408	-832.4501	32.6620
18	-335.7833	15.1073	-830.2178	29.0130
19	-642.6035	25.2084	-841.3098	34.0502
20	-647.1465	25.9441	-1302.5220	53.1657
21	-567.5840	22.1086	-546.0802	18.0798
22	-347.7150	15.4898	-973.1062	38.4285
23	-406.3027	15.9376	-407.4172	15.7964
24	-448.0470	18.6825	-1043.9980	46.5321
25	-593.6128	23.4744	-499.5846	18.2032
26	-489.1850	20.9989	-1074.6400	36.3617

Table 60. The parameters, coefficient of determination (r^2) and standard error of estimate (s) of body weight when the linear equation y = a + bx was was used for predicting the average body weight (y) from average shank length (x)

Groups	a	b	r^2	s	Fitted equation
Desi male	-606.9035	23.46135	0.76999	189.8795	y = -606.9035 + 23.46135x
Desi female	-623.5968	24.2969	0.8229	164.3872	y = -623.5968 + 24.2969 x
Desi ducks	-617.1625	23.9889	0.8051	173.0666	y = -617.1625 + 23.9889 x
WP male	-629.0318	24.81603	0.8775	124.9796	y = -629.0318 + 24.81603x
WP female	-848.0834	31.9745	0.8402	200.6862	y = -848.0834 + 31.9745 x
WP ducks	-744.8615	28.6596	0.8591	161.2091	y = -744.8615 + 28.6596 x

Table 61. Square of the coefficient of correlation (r^2) between the observed and the expected body weight when the linear equation was used for predicting body weight

Birds	Desi male	Desi female	WP male	WP female
1	0.7430	0.7507	0.8214	0.9277
2	0.7773	0.8006	0.7952	0.6983
3	0.7907	0.7729	0.8892	0.8375
4	0.8302	0.8317	0.9057	0.8050
5	0.7124	0.8105	0.8943	0.8599
6	0.7278	0.7429	0.8169	0.9240
7	0.7941	0.8172	0.8311	0.8031
8	0.7657	0.7607	0.9397	0.9880
9	0.7966	0.7842	0.8065	0.7061
10	0.7396	0.7779	0.8267	0.7675
11	0.7014	0.7281	0.8160	0.8021
12	0.7369	0.7978	0.8212	0.8211
13	0.7495	0.8187	0.8125	0.8310
14	0.7732	0.8174	0.9130	0.8265
15		0.8372	0.7170	0.8163
16		0.7906	0.7664	0.7604
17		0.7762	0.8925	0.8021
18		0.7534	0.9619	0.7457
19		0.7475	0.8308	0.8363
20		0.7655	0.8209	0.9817
21		0.8328	0.8257	0.6203
22		0.8989	0.9420	0.8878
23		0.8082	0.9258	0.6655
24		0.8648	0.9160	0.9734
25		0.8573	0.8260	0.6338
26			0.8784	0.6721

Table 62. Standard error of estimate (s) of body weight predicted from shank length of the four groups using linear equation.

Birds	Desi male	Desi female	WP male	WP female
1	184.0525	169.5548	147.6379	186.8484
2	156.1726	156.7634	220.2200	296.7370
3	235.9844	158.7783	62.3644	246.6724
4	121.3211	233.7113	70.2964	209.7836
5	226.7249	204.4148	73.2312	185.0488
6	220.6382	200.6063	173.1267	164.2458
7	98.8131	199.5025	146.7025	60.2565
8	216.8151	143.5551	45.2672	63.7938
9	172.3102	223.9170	250.4714	165.9602
10	236.8767	187.0217	217.3981	273.8383
11	218.9266	157.9404	285.2776	257.0668
12	219.7351	179.9894	172.5696	162.9256
13	205.3368	150.9701	199.1336	145.9340
14	225.3326	194.0298	70.7159	175.8431
15		156.0698	240.4947	192.5643
16		198.2345	304.3087	253.3808
17		165.3747	116.5319	257.0668
18		150.4899	33.1201	253.9262
19		167.1842	161.7704	246.1828
20		153.6758	184.1844	91.6111
21		193.6684	158.3327	200.1219
22		125.6346	43.0239	173.0761
23		106.2420	62.2315	173.4467
24		185.2311	67.6763	107.2426
25		196.8633	156.9257	219.6352
26			104.9809	388.9637

Table 63. Parameters of the Exponential curve $y = ab^x$ used for predicting the body weight (y) from the shank length (x) of the individual Desi ducklings

Birds	Desi male		Desi female	
	a	b	a	b
1	8.1330	1.0821	9.2443	1.0784
2	8.6372	1.0775	10.4310	1.0731
3	12.9944	1.0712	6.4761	1.0875
4	7.7071	1.0844	7.4100	1.0851
5	8.3098	1.0777	9.6881	1.0788
6	7.9432	1.0827	8.4607	1.0792
7	9.5377	1.0775	8.8560	1.0826
8	8.5457	1.0815	8.2955	1.0818
9	8.7318	1.0788	11.00029	1.0754
10	9.3098	1.0767	10.2942	1.0770
11	9.8717	1.0766	8.7428	1.0797
12	7.9190	1.0830	0.7921	1.0778
13	8.4523	1.0789	8.36178	1.0798
14	8.9654	1.0800	8.9562	1.0802
15			9.0350	1.0781
16			10.0286	1.0778
17			8.4674	1.0812
18			7.8156	1.0822
19			8.5099	1.0814
20			5.4519	1.0886
21			8.5692	1.0804
22			9.9179	1.0781
23			10.1390	1.0736
24			10.6401	1.0781
25			8.3253	1.0826

Table 64. Parameters of the Exponential curve $y = ab^x$ used for predicting the body weight (y) from shank length (x) of the individual WP ducklings

Birds	WP male		WP female	
	a	b	a	b
1	5.8367	1.0949	6.1995	1.0979
2	8.3206	1.0822	11.1949	1.0769
3	3.5861	1.1151	7.7886	1.0901
4	6.2125	1.0910	7.3165	1.0867
5	7.1934	1.0868	11.9560	1.0769
6	6.5525	1.0873	4.0523	1.1332
7	6.8419	1.0872	8.6984	1.0603
8	10.9027	1.0731	13.3704	1.0953
9	8.4564	1.0835	5.8214	1.0792
10	8.1522	1.0831	9.2698	1.0839
11	11.4953	1.0800	3.7229	1.1277
12	7.2423	1.0917	6.0269	1.0787
13	9.0725	1.0772	9.6447	1.0808
14	6.9124	1.0895	8.8424	1.1035
15	8.8003	1.0830	8.1972	1.0760
16	7.9835	1.0855	8.3433	1.0817
17	8.2586	1.0865	9.8644	1.0836
18	7.1889	1.0878	5.4646	1.0888
19	9.0485	1.0829	13.0611	1.0791
20	9.9219	1.0807	8.2226	1.1074
21	10.0199	1.0760	4.8772	1.0800
22	7.1768	1.0874	8.9742	1.0957
23	8.5205	1.0851	9.4572	1.0690
24	6.3167	1.0941	13.9556	1.0929
25	8.3580	1.0835	7.2599	1.0741
26	8.1662	1.0867	4.6099	1.0933

Table 65. The parameters, coefficient of determination (r^2) standard error of the estimate (s) of body weight when the exponential equation was used for predicting average body weight (y) from average shank length (x)

Groups	a	b	r^2	s	Fitted equation
Desi male	8.7468	1.0799	0.8935	130.6848	$y = 8.7468 \times (1.0799)^x$
Desi female	8.7848	1.0809	0.9174	112.3274	$y = 8.7848 \times (1.0809)^x$
Desi ducks	8.7646	1.0806	0.9097	118.0835	$y = 8.7646 \times (1.0806)^x$
WP male	7.4326	1.0887	0.9888	41.0419	$y = 7.4326 \times (1.0887)^x$
WP female	7.1703	1.0908	0.9748	79.7512	$y = 7.1703 \times (1.0908)^x$
WP ducks	7.2159	1.0904	0.9862	51.2465	$y = 7.2159 \times (1.0904)^x$

Table 66. Standard error of estimate (s) of the body weight (g) predicted from shank length (x) of the four groups using Exponential curve.

Birds	Desi male	Desi female	WP male	WP female
1	103.1728	120.4330	74.5530	234.5286
2	104.2309	111.2240	120.4574	215.6903
3	190.5668	113.0730	49.4558	154.2732
4	86.4502	155.3300	31.3891	123.5945
5	178.5432	199.6123	32.4849	109.9601
6	160.2214	157.6440	72.3461	188.5995
7	64.1474	170.2710	76.0989	42.7162
8	167.7864	97.7152	40.1546	315.0262
9	139.4949	188.1528	121.0535	127.6112
10	200.6572	159.5602	108.5551	197.3398
11	156.0587	125.9539	150.8678	94.6555
12	162.3711	146.0909	96.0875	292.5504
13	153.5862	125.0890	98.5214	213.5652
14	165.7065	155.0101	43.5802	285.1041
15		111.3465	209.6738	128.3004
16		167.0119	153.4095	142.7591
17		116.4903	60.0282	179.5139
18		120.7701	43.7584	163.8624
19		118.5478	77.2765	159.2828
20		97.7066	109.5314	409.0414
21		131.5715	82.6499	157.2867
22		95.3724	83.7508	92.9436
23		89.1486	43.4331	147.1697
24		131.2273	33.0327	316.0026
25		97.9819	61.1282	178.3100
26			45.8234	295.3100

Table 67. Square of the coefficient of correlation (r^2) between the observed and the expected body weight when the exponential curve was used to predict body weight.

Birds	Desi male	Desi female	WP male	WP female
1	0.9336	0.8809	0.9546	0.9404
2	0.9024	0.8999	0.9417	0.8614
3	0.8638	0.8914	0.9313	0.9371
4	0.9139	0.9258	0.9857	0.9344
5	0.8288	0.8260	0.9809	0.9539
6	0.8606	0.8436	0.9688	0.9471
7	0.9142	0.8689	0.9549	0.9094
8	0.8601	0.8989	0.9651	0.8897
9	0.8669	0.8479	0.9551	0.8515
10	0.8137	0.8385	0.9568	0.8823
11	0.8604	0.8339	0.9488	0.9788
12	0.8597	0.8671	0.9446	0.6055
13	0.8644	0.8759	0.9559	0.8244
14	0.8789	0.8836	0.9775	0.9178
15		0.9173	0.7866	0.9036
16		0.8518	0.9435	0.9328
17		0.8919	0.9763	0.9035
18		0.8445	0.9639	0.9046
19		0.8798	0.9615	0.9335
20		0.9111	0.9374	0.9008
21		0.9228	0.9528	0.8509
22		0.9446	0.8592	0.9755
23		0.8952	0.9763	0.7831
24		0.9330	0.9796	0.9257
25		0.9647	0.9733	0.8257
26			0.9777	0.8317

Table 68. Initial shank length, y_0, and 'b' values of the four groups of ducklings by Rao's Method.

Birds	Desi male		Desi female		WP male		WP female	
	y_0	b	y_0	b	y_0	b	y_0	b
1	23.5	25.2675	21.5	44.2825	22.5	30.8575	23.5	41.5275
2	23.5	28.1425	22.5	45.7975	22.5	38.4475	21.0	52.4325
3	23.0	36.5050	23.5	44.8775	22.5	20.9775	23.0	47.6050
4	23.5	24.1125	24.5	60.7425	23.0	27.2975	22.5	47.6500
5	23.5	30.5925	23.0	54.3500	23.5	27.2600	21.0	50.6650
6	23.5	25.6200	23.0	50.2025	22.5	34.9500	21.5	26.5175
7	22.5	20.2450	22.5	52.9650	23.0	33.2875	22.5	50.4875
8	22.0	30.7225	21.5	41.6975	23.0	28.2275	23.0	29.4400
9	24.0	27.7800	23.0	58.7300	23.5	40.8125	22.0	44.1775
10	22.0	30.8600	22.5	57.8050	22.5	41.8175	23.0	43.5900
11	23.0	26.5975	23.0	44.6625	21.5	44.0175	22.5	27.4675
12	23.5	27.1150	23.5	54.1950	22.0	32.4025	23.5	45.3425
13	23.0	30.3300	24.0	52.9125	24.0	38.7275	23.0	52.6525
14	22.0	31.8400	25.0	58.0250	22.0	29.0050	21.5	34.1575
15			23.0	56.5000	24.0	33.8950	23.5	43.4325
16			23.0	59.9175	23.0	41.3625	23.0	46.3875
17			23.0	50.7275	22.0	30.9325	22.0	46.9300
18			23.5	43.9100	23.0	24.5925	24.5	49.3075
19			24.5	39.6975	23.0	34.9300	21.5	51.3875
20			24.0	38.7075	22.0	37.6400	23.0	28.8250
21			23.0	60.4025	22.5	38.7125	25.0	42.5175
22			21.0	57.6075	23.0	24.1750	24.0	33.6100
23			24.0	44.1875	22.0	27.6450	23.0	50.0875
24			23.0	62.2700	23.0	23.1125	22.5	32.1575
25			22.5	60.0175	22.0	35.4400	22.5	49.9425
26					21.5	31.2325	23.5	50.1500

Table 69. Analysis of variance of 'b' values obtained by Rao's Method

Source	DF	SS	MS	F
Between group	3	7007.938	2335.979	46.78**
Within group	87	4343.875	49.9296	
Total	90	11351.81		

** Indicates significance at 1% level

CD matrix for comparison between group means

	Desi male	Desi female	WL male	WL female	Means
Desi male		4.6868	4.6543	4.6543	28.2671
Desi female			3.9328	3.9328	51.8088
WL male				3.8941	32.7608
WL female					43.0185

Discussion

V. DISCUSSION

The results of present investigation "Statistical approach on the pattern of development of shank length in ducks" were given in Chapter IV. On the basis of those results the following discussion, conclusion and recommendations are made.

5.1. Shank length

Based on the mean and standard error of shank length for the first seven days of six groups of ducklings viz. Desi male, Desi female, WP male, WP female, Desi duckling without considering sex and WP duckling without considering sex, it could be observed that there was a daily increase in shank length in the three groups, viz. Desi females, WP males and WP females.

Range of increase was 0.04,to 0.44 mm for WP males, 0.08 to 0.44 mm for WP females, 0.04 to 0.5 mm for Desi males and 0.12 to 0.5 mm for Desi females. Standard error for mean shank length was less for WP males and it ranged between 0.1115 to 0.1499. But for the other three groups standard error for mean shank length was less than 0.23 which was comparatively greater than that of WP males.

Based on the mean and standard error of shank length of the four groups of ducklings on weekly basis upto 12 weeks of age, it could be observed that except at fifth week Desi females had higher shank length than all the other three groups upto 9th week of age. The second highest shank length was observed for Desi males followed by WI females. The least average shank length was observed for WI males. But during fifth, tenth, eleventh and twelfth week of age, Desi males had the highest shank length followed by Desi females. During the entire period least shank length was always observed for WI males. Standard error of the shank length was less than 1.5 for all the four groups viz. Desi males, Desi females, WI males and WI females. During the entire period of study, Desi ducklings had higher shank length than WI ducklings. From the eighth week onwards, rate of growth in shank length was very less for all the groups. It was also noted that the mean shank length of females were always higher than that of the males.

Analysis of variance of initial, fourth, eighth and twelfth week shank length of the four groups showed that there was significant difference between the shank length of the four groups on initial day and also on twelfth week of age, whereas data on fourth and eighth week showed highly significant difference between the shank length of the four groups. In fourth week and eighth week, WP males differed significantly from all the other three groups and Desi males were not significantly different from Desi females and WP females. No significant difference was observed between the data on Desi females and WP females during the 8th week, whereas significant difference was observed between these groups during the fourth week.

At the twelfth week of age mean shank length was 6.66 and 6.01 cm respectively for Desi males and Desi females. These figures were comparatively less than the average shank length of Desi ducks reported by Renchi (1979). He observed that the means of shank length at the 12th week of age was 6.44±0.04 and 6.15±0.2 cm in the male and the female Desi ducks respectively.

From the linear growth equation fitted to the individual ducklings, it was found that the coefficient of determination was of the highest order for WP males, with least standard error. When the same equation was fitted on the average basis it was observed that WP males was having the highest coefficient of determination (r^2) (0.9729) with the least standard error of the estimate (2.2155) and Desi females had least coefficient of determination (0.8522) and highest standard error of the estimate (5.6077). In all the four groups the growth rate was higher with the least growth rate of 3.268 for WP males and the highest growth rate of 3.4116 for Desi females.

On the basis of the analysis of variance of the growth rate (b) of the linear equation it was observed that there was no significant difference between the four groups viz. Desi males, Desi females, WP males and WP females (Table 9).

When exponential curve was used for fitting the shank length of the individual ducklings upto 12 weeks of age, a high order coefficient of determination was observed between the observed and the expected shank length in the case of WP males and WP females. But the value of the coefficient of determination was less for Desi males and Desi females than that for WP males and WP females. The same curve fitted to the average data of shank length of the four groups showed that WP males were having the least coefficient of determination (0.9581) with the least standard error of estimate (4.1229) and Desi females were having the least coefficient of determination (0.8679) with the highest standard error of the estimate (7.7599). The average value of growth rate 'b' was highest for WP males and least for Desi females. Since the standard errors of the estimate were high in this case, this curve was not a good fit for the data.

The analysis of variance of the growth rate of the exponential equation (table 16) showed that there was no significant difference between the four groups viz. seed males, seed females, wild males and wild females. Since the standard error of the estimate was very high, the curve was a poor fit for the data.

The results obtained by modified exponential fitted to the data on shank length of individual quails showed that it was suitable for fitting the data of shank length since it showed a high value for the coefficient of determination (r^2).

The same curve fitted for the averages also showed that the coefficient of determination was high for all the four groups. The highest value of the coefficient of determination (0.9964) was for wild males with the lowest standard error of estimate (1.5667) and the least value of coefficient of determination (r^2) (0.9544) was for seed females with the highest standard error of estimate (4.0959).

On the basis of analysis of variance of growth rate it could be found that there was significant difference between the growth rate of the four groups when modified exponential curve was fitted. No significant difference was observed between the growth rates of seed males and seed females. All the other pairs viz. seed males and wild males, Desi males and WP females, Desi females and WP females, Desi females and WP males and WP males and WP females were differed significantly. The average value of 'b' was the highest for WP male and least for Desi female.

The highest coefficient of determination and least standard error of the estimate was observed for all the individuals when the Gompertz equation was fitted for each duckling. The same result was obtained when this curve was fitted for the average shank length of each group. The highest value of the coefficient of determination (0.9918) was observed for WP males with least standard error of the estimate (1.1761) and least value of coefficient of determination (0.9680) was observed for Desi females with highest standard error of the estimate (2.6772).

Analysis of variance of 'a^{b}' values associated with the growth rate (Table 31) showed that there was no significant difference between the growth rate of these four groups. This is in agreement with the result obtained from the analysis of variance of shank length of the four groups at the end of the experiment.

Logistic curve fitted to the data of shank length of the individual ducklings showed that the value of the coefficient of determination (r^2) was very high and the standard error of the estimate was less. The same result was also obtained when this equation was fitted to the average shank length of the six groups. The highest value of coefficient of determination (0.9948) was for WP males with the least standard error of estimate (1.4441) and the least value of coefficient of determination r^2 (0.9776) for Desi males, with the highest standard error of estimate (3.1872).

The results obtained by fitting Von-Bertalanffy equation were also the same. High values of the coefficient of determination was observed between the expected and observed shank length and standard errors of the estimate were also found to be less. The results of the equation fitted for the averages also showed that the value of the coefficient of determination was high and it ranged between 0.9760 (for WP females) and 0.9654 (for Desi females). The value of the standard error of the estimate was less and it ranged between 2.3746 (for WP females) and 3.1867 (for Desi females).

The analysis of variance of the be^{-k} values associated with the growth rate (Table 45) showed that there was significant difference between the growth rate of the four groups. No significant difference was observed between the growth rates of the males and females of Desi ducks. All the other pairs viz. Desi males and WP males, Desi males and WP females, Desi females and WP males, Desi females and WP females and WP males and WP females differed significantly in respect of growth rates.

The results obtained by fitting the second degree equation individually and later by taking average shank length showed that the coefficient of determination was less and the standard error of the estimate was high. The coefficient of determination was high for WP males with a value 0.8361 and less for Desi females with a value 0.6213. The standard error of estimate ranged between 26.5493 (for WP males) and 31.1555 (for Desi females).

5.2. Rao's Method

Based on the analysis of covariance of the growth parameter estimates (b) as explained by Rao (1958), by taking initial shank length (y_0) as the concomitant variable, it was found that there was no significant relationship between the initial shank length and the growth parameters and the regression coefficient (-0.6037) was found to be non significant. Hence the analysis of variance of 'b' values (growth parameters) given in table 69 showed that the four groups were highly significantly different. The CD matrix for the comparison between the groups showed that there was no significant difference between Desi males and WP males. All the other groups viz. Desi females and WP males, Desi females and WP females, Desi females and Desi males, Desi males and WP females and WP males and WP females were highly significantly different.

From the seven curves, ie. linear, exponential, modified exponential, Gompertz, logistic, Von-Bertalanffy and second degree equations fitted for the four groups individually and later by taking average shank length of each group, it was found that the Gompertz curve was consistently superior on the individual bird as well as on the average basis for all the groups of ducklings. Next best was the logistic form of the curve.

The graph of the two best fitted curves – Gompertz, logistic were plotted and were given in Figures 1, 2, 3, 4, 5 and 6 along with the plot of observed mean shank length for all the six group of birds. From these six figures it could be found that the Gompertz curve was more nearer to the observed values. This fact also establishes the appropriateness of Gompertz curve for fitting mathematical model of shank length data in six group of ducks. Hence the general conclusion one can make is that the model suitable for fitting the trend of shank length in the case of ducks irrespective of breed and sex is the Gompertz curve. The second curve of best fit was found to be the logistic curve. This result is also in agreement with the conclusion made by Arai et al.(1994). They showed that the growth pattern was better described by the Gompertz curve than the logistic curve.

5.3. Body weight

Based on the mean and standard error of body weight upto 12 weeks of age, it was observed that the highest mean body weight upto sixth week of age was for Desi females and the least body weight was for WP males. Upto third week of age Desi males had the higher weight than that of WP females. From sixth week onwards WP females were having the highest body weight. In all stages WP females had higher body weight than that of WP male and except for the 11th and 12th week Desi females had higher body weight than that of Desi males.

The correlation between the shank length and body weight were worked out on average observation basis and individual observation basis and it was found that significantly high correlation (Table 57) was found between these two characters. Highest correlation between body weight and shank length (0.9367) was observed for WP males and least (0.8775) for Desi males.

When linear equation was fitted for predicting the body weight from shank length, the value of coefficient of determination was less and ranged between 0.8775 for WP male and 0.7699 for Desifemales. The standard error of estimate was the highest for Desi female and the least for WP males (Table 60).

When exponential equation was fitted for predicting body weight from shank length, the value of the coefficient of determination was high. The highest value (0.988) was for WF male with the least standard error of estimate (41.0419) and the least value of coefficient of determination (0.8935) was for Desi male with the standard error of estimate 136.6848.

From these two curves (linear and exponential) fitted for predicting body weight from shank length it was found that exponential was the best fit for all the six groups. Hence one can reasonably recommend the exponential equation for predicting the body weight through shank length data.

Summary

VI. SUMMARY

In order to examine the pattern of development of shank length in two breeds of ducks ie. Desi and White Pekin and to compare the rate of growth of shank length at the different age groups of these birds, a study was conducted in Kerala Agricultural University Duck Farm, Mannuthy with 81 day old Desi ducklings and 72 day old White pekin ducklings under identical management practices. Body weight in grams and shank length in millimetres of each duckling were recorded at weekly intervals for twelve weeks. In addition to this, body weight and shank length were recorded during the first seven days. At the end of the twelfth week, measurements on 14 males and 25 females of Desi ducklings and 26 males and 26 females of White pekin ducklings were utilised for the study.

The average shank length of the day old ducklings were 23.10 mm for Desi females, 23.[illegible]4 mm for Desi males, 23.75 mm for WP females and 23.65 mm for WP males. There was no significant difference in the day old shank length of the four groups. But significant difference was observed between the mean shank length of the four groups during the fourth and 8th week of age. The increase in shank length from [illegible]th week onwards was very slow. At the end of the experiment it was observed that the difference between sexes as also between breeds in shank length was not significant.

Heterogeneity in the pattern of growth of body weight was observed from the beginning of the study. In all stages WP females had higher body weight than that of WP males and except for 11th and 12th week Desi females had higher body weight than that of Desi males.

High correlation was obtained between the body weight and the shank length of each ducklings. All these correlations were highly significant. These correlations imply that for obtaining highest body weight at a particular period it is desirable to select ducklings with longest shank.

Shank length was found to increase with age. This led to the fitting of linear prediction equations of the form $y = a + bx$. The correlation between the observed and the expected shank length was less and standard error of estimate were comparatively high, thereby indicating that linear equations were not a good fit to shank length as a function of age. The exponential curve $y = ab^x$ and the second degree equation $y = a + bx + cx^2$ were also found to be unsuitable for fitting shank length as a function of age because for these curves also the coefficient of determination were less and the standard error of the estimate were comparatively high.

Gompertz curve of the form $y = ab^{c^x}$ fitted to shank length was found to give good fit to the data. The analysis of variance of growth rates gave the same result as the analysis of variance of shank length at the end of the twelfth week. The square of the correlation coefficient (coefficient of determination) between the observed and the expected shank lengths was very high and standard error of the estimate were less indicating that Gompertz curve was most suitable for expressing shank length as a function of age.

The second best equation fitted to the shank length was logistic form $y = a/(1+10^{b+cx})$. For this curve also coefficient of determination was very high and standard error of the estimate was less.

Modified exponential and Von-Bertalanffy equations were also found to be suitable for the shank length data. The analysis of variance of growth rate of these two curves led to the same result that the growth rate of Desi males and female ducklings were homogeneous. For all the other pairs, the growth rate was heterogeneous.

Graphs were drawn using the best fitted equations viz. logistic and Gompertz, for all the six groups along with a plot of observed values. It was found that the graph drawn for Gompertz was more nearer to the observed values. This results also confirms the above conclusion.

In short, shank length expressed as a function of age in the Gompertz and Logistic form were formed to be good fit for the six groups of ducklings. However the best form of representation of shank length as a function of age was Gompertz form.

For comparing growth rates of the different groups, the growth parameter estimate (b) as suggested by Rao (1958) were also worked out. The analysis of covariance of these 'b' values by taking the initial shank length as concomitant variable showed that there was no relation between 'b' values and initial shank length. Hence this method was not suitable for the comparison of growth rate in the present study.

As there was high correlation between body weight and shank length, body weight can be predicted from shank length. Linear equation of the form $y = a + bx$ and exponential equation of the form $y = ab^x$ were used for predicting body weight from shank length. Among these two curves exponential form was found to be the best fit to the body weight as a function of shank length. The coefficient of determination in this case was very hi[illegible] and standard error of estimates were comparatively l[illegible]. In short, best form of representation of body weight as a function of shank length was exponential.

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STATISTICAL APPROACH ON THE PATTERN OF DEVELOPMENT OF SHANK LENGTH IN DUCKS

By

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ABSTRACT OF A THESIS

Submitted in partial fulfilment of the requirement for the degree

Master of Science in Agricultural Statistics

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1989

ABSTRACT

The present investigation entitled 'Statistic approach on the pattern of development of shank length in ducks' has been undertaken to study the following objectives.

1. To examine the pattern of development of shank length in two breeds of ducks in University Duck Farm, ...

2. To compare them (a) between genetic group (b) between males and females within each genetic group (c) between males of genetic group (d) between females of genetic group and

3. To fit appropriate growth curves for prediction of body weight through shank length at different stages of growth.

For this purpose shank length and body weights of ... males and 25 females of ... ducklings and ... females of White Pekin (WP) ducklings were utilised. The ducklings were reared for twelve weeks in ... University Duck Farm, ... under uniform feeding and identical management practices.

In the day old and the twelfth week of age and ... could be seen in the mean shank length of the genetic groups. But at the fourth and eighth week of age, mean shank ...

of the four groups was not uniform. Upto ninth week of age, Desi females had higher shank length than the other three groups except at the fifth week. But during the fifth, tenth, eleventh and twelfth week of age Desi males had the highest shank length. The least shank length was always observed in [illegible] males. During the entire period, Desi ducklings had higher shank length than [illegible] ducklings. The growth pattern of body weight was not uniform in the four groups except the initial body weight.

High correlation was found between the body weight and shank length. It revealed that shank length can be used as criterion for selection for higher body weight.

The method of comparison of growth rates recommended by Rao (1958) was found unsuitable for the present study.

Among the functional relationships worked out linear, exponential and second degree equations were found to be unsuitable for fitting shank length as a function of age. Modified exponential, logistic, Gomperts and Von-Bertalanffy equations were found to be suitable for fitting shank length over a period of time. Among these four, Gomperts was found to be the best fit. The second best fitted equation was logistic.

Graphs of the best fitted equations i.e. Gomperts and logistic were drawn for all the six groups along with the observed values. This also confirmed above result.

Among the two functional relations ie. linear and exponential used for predicting body weight from shank length, exponential was found to be most suitable.