# Growth Curve Fitting for Turkish Native Geese

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***Abstract*—** In this review it was aimed to describe the non-parametric permutation test which is successful in many cases where parametric tests are not because of its independency from the distribution. Some properties and usage fields of permutation tests were reviewed for experimental researchers in biological sciences to lead them having more reliable statistical results in their studies.

***Index Terms*—** permutation tests, resampling methods, exact test, biological studies

## I. INTRODUCTION

Animal production has a high importance in Turkey’s economic structure and it is important for a balanced human nutrition [1,2]. To meet the requirement of protein of animal origin from an increasing population, the production of poultry other than chicken, such as turkeys, ducks and geese, is increasing [3]. The size of the geese population of Turkey is about 0.85 million head [4]. Most of the population is raised in Kars, Muş, Ardahan, Batman and Ağrı provinces [5]. Geese production generally depends on the free range backyard type for home consumption. However, a small number of semi-intensive and intensive producers of geese is present [4].

Growth traits are important characteristics for both economic profitability and population dynamics [6]. Growth is an increase in size (height, length, weight) with age and growth curve models provide a visual assessment for growth as a function of time. The models can be used for predicting body weight for a specific age from a dimensional perspective [7].

In this study we aimed to compare Bertalanffy, Brody, Gompertz, Logistic and Negative Exponential models on body weight of Turkish native geese.

## II. MATERIAL AND METHODS

The study was conducted at the Ondokuz Mayıs University Agricultural Faculty’s Experimental Farm between May-September 2014. Turkish native geese (n = 210) were used as animal material in the study. All goslings were transferred to a production house and randomly allocated among 16 pens interspersed within windowed houses, each holding 12–14 goslings.

Live weights were evaluated at 2-week intervals from hatch to slaughter. All weights were measured using a scale with a sensitivity of up to 0.5 g.

For each sex group, the Bertalanffy, Brody, Gompertz, Logistic and Negative Exponential models were fitted to the data of the average growth curve and for the individual growth curves. Parameters were estimated using NLREG. The convergence criterion was used as 1.0E-10. SPSS software was used to analyse the data. To compare the fit, data determination coefficients (adjusted $R^2$) and residual mean standard error (RMSE) were used as goodness of fit criteria. Functions and age and weight of inflection points (IPA and IPW) and maximum increment (MI) of the models were given in Table 1 [8,9]. Interesting functions and their properties are given in Table 1. Inflection points of Brody and Negative Exponential functions were not given because they do not exist [10].

TABLE I: FUNCTION AND INFLECTION POINTS FOR BERTALANFFY, BRODY, GOMPERTZ, LOGISTIC AND NEGATIVE EXPONENTIAL MODELS

| Models | Function | IPA | IPW | MI |
|---|---|---|---|---|
| Bertalanffy | $a * (1 - b * e^{(-k*t)})^3$ | $Ln3(b)/k$ | $8a/27$ | $3k * IPW/2$ |
| Brody | $a * (1 - b * e^{(-k*t)})$ | | | |
| Gompertz | $a * e^{(-b*e^{(-k*t)})}$ | $Ln(b)/k$ | $0.368 * a$ | $k * IPW$ |
| Logistic | $1/a * (1 + b) * e^{(-k*t)}$ | $Ln(b)/k$ | $a/2$ | $k * IPW/2$ |
| Negative Exponential | $a - a * e^{(-k*t)}$ | | | |

a: Asymptotic or predicted final mature weight
b: Scaling parameter (constant of integration)
k: Instantaneous growth rate (per time unit) parameter
t: Age at the inflection point
e: 2.718281
IPA: Inflection Point Age
IPW: Inflection Point Weight
MI: Maximum Increment

## III. RESULTS

Estimates of parameters and goodness-of-fit criteria are given in Table 3 for Bertalanffy, Brody, Gompertz, Logistic and Negative Exponential models. For Brody and Negative Exponential models IPA, IPW and MI were not estimated because a greater than zero second derivation of the functions could not be satisfied for any value of time [10].

Concerning the mature weight the predicted value (parameter a) of Negative exponential was the maximum both in males and females (6366 and 5159) whereas the Logistic produced minimum predicted values for both males and females (4905 and 4067). The greatest scaling parameter (b) was observed from the Gompertz model and the lowest from the Bertalanffy. The greatest growth rate per time unit (k) was observed from the Logistic model and the lowest from the

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Negative Exponential. In regard to the age at the inflection point, higher values were estimated for the Logistic model in both sexes, 33.59 and 32.9 days for males and females, respectively. Lowest values were estimated for the Bertalanffy model as 22.5 and 21.6 days for males and females, respectively. The highest value of weight at the inflection point (IPW) was found for the Logistic model for both sexes. The greatest maximum increment value was observed for the Bertalanffy model for males and for the Logistic model for females; the lowest values were observed from the Gompertz model for both sexes. Predicted average and observed growth curves are given in Fig 1.

When the curve from the Bertalanffy model was examined, the estimated values were closer to the observed ones until the age of 56 days. After that time estimations were higher or lower than the observed ones. For the late growth, Bertalanffy estimations were found closer to observed weights for females than males. Estimations from the Brody model were generally higher than observations for both sexes during the growth period. Estimations from the Gompertz model were closer to the observed ones until the age of 56 days. Between 56 and 98 days of age estimates from the Gompertz model were higher than observation values but lower than observations after 98 days of age for both sexes. Higher and lower estimated values than observations often occurred for the Logistic model. Predicted values from the Negative Exponential model was found as the worst according to how close estimations were to observed values and this was due to of over-estimations. The curves obtained from the Bertalanffy and Gompertz models were more similar than others curves. This might be so because both models originate from Richards’s model [10].

## IV. Discussion And Conclusion

The Gompertz and Bertalanffy models were found more reliable than Brody, Logistic and Negative Exponential models according to their coefficient of determination. The Gompertz model was found as the best model to describe the growth of geese because RMSE values of the Gompertz model were lower than those of the Bertalanffy model. However, all models except the Negative Exponential model adequately predicted growth curve parameters as mentioned by Osei-Amponsah et al. [11] and Gao et al. [12]. S-shaped or sigmoid growth curves such as Gompertz, Bertalanffy and Logistic models were found more suitable to describe goose growth. This idea was described with the study of Shukla et al. [13] and interpreted for chickens by Osei-Amponsah et al. [11]. It was easily attributed to sigmoid nature of growth of poultry. Atil et al. [8] implied that up to age at the inflection point, growth for males and females were similar. In the present study growth of the two sexes did not differ. This might be attributed to a characteristic of the genotype. Similar results were observed for mule ducks in a study of Vitezica et al. [14].

Body weight and growth rates are economically important features for goose production. According to the present results, a Gompertz model can be suggested for examining goose growth [11,12] because the sigmoid shape of growth gives the best fit.

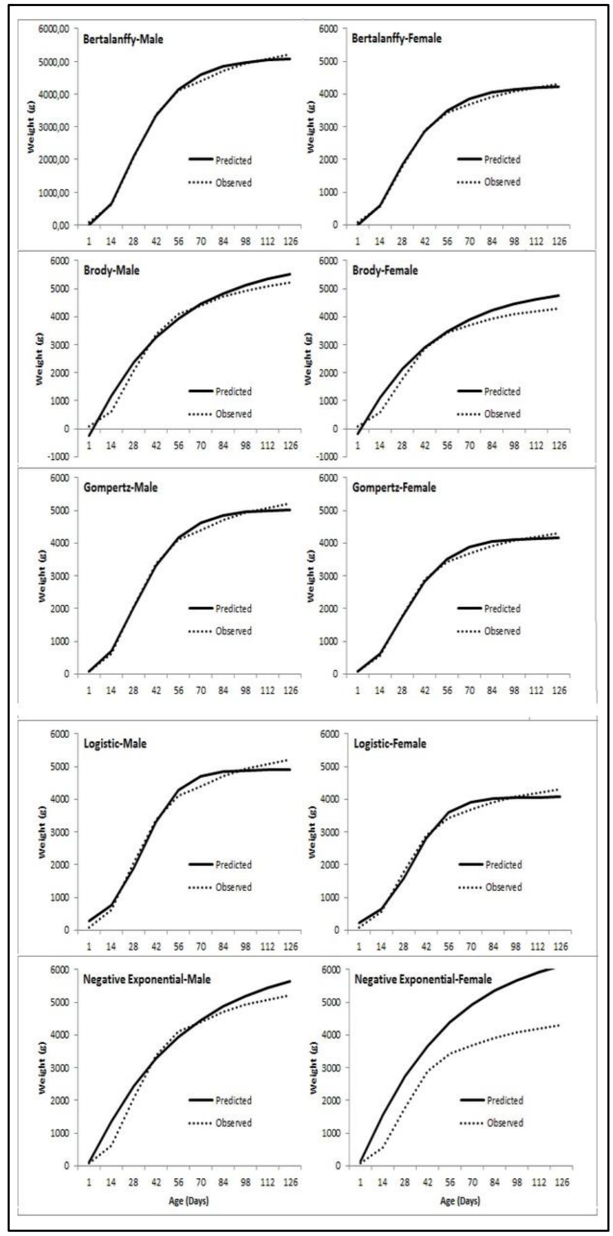


Fig. 1 Predicted average and observed growth curves for Bertalanffy, Brody, Gompertz, Logistic and Negative Exponential models.

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