Computer Application for assistance in comparing growth curves of fish stocks

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Abstract

In order to guide marine researchers while comparing fish growth curves, a user-friendly interface was created in Microsoft Excel environment, written in VBA Language. Nominated "Comparison of Growth Curves", it consists of the following three parts: (I) "Adjust to growth models", which, from the length-at-age data, makes adjustments to three of the most well-known growth models - Von Bertalanffy, Logistic and Gompertz - taking advantage from the nonlinear least square method; (II) "Likelihood ratio test", useful to compare statistically, and ~~therefore significantly~~, two apparently similar growth curves, applying the likelihood ratio test; (III) "Punctual comparison", helpful to compare absolute and relative growth rates, average rate of change or even simple length-at-age or age-at-length functions. Meanwhile one has the opportunity to output enlightening graphics along the whole process. The existence of dialog boxes that clarify both the mathematical procedure supporting the study and the interpretation of the results turns the interface into a valuable, and easy to handle, tool. The interface was tested in a few samples and the results suggest that the innovative implementation of a previous careful selection of features will improve the program's potential

Objective

Bearing in mind that mathematical modeling has been heavily used in biology to assist in the study and interpretation of biological processes, in order to clarify the population dynamics and predict their behavior towards the changes in the environment, we objectified to create a user-friendly interface to help marine researchers at the comparison of fish ~~families'~~ growth curves, that:

- ❑ was easy **to use, with** simple procedures so that you do not need to master a large manual to deal with it;
- ❑ produced **relevant results** in a **comparative study of growth curves**, without requiring excessive amount~~s~~ of information.

Steps for using the application

I. Collect individual age and length data ~~sample~~ of two fish populations;
II. For each sample separately: Enter data in the first part of the application;
III. Select the mathematical model to fit the data;
IV. Enter initial parameters values to estimate;
V. Determine the estimated parameters and the adjusted R^2;
VI. Repeat steps (III) and (V) for the other models and select the one that best fits the data (comparing the value of adjusted R^2 or outputting the graph with the inputted data and the curve fitted)
VII. Transport the results to the second and third parts of the application.
VIII. If the two samples follow two different models, the comparison process ends. However, the user can compare in terms of rates, in the third part of the application – "Punctual Comparison".
IX. If the two samples follow the same model and parameter values are close, infer their differences using the second part of the application – "Likelihood ratio test".

Methodology

The application "**Comparison of Growth Curves**" was developed in Microsoft Excel (version 2007), written in the programming language *Visual Basic Applications*. It consists of three sheets visible to the user named: (I) "**Comparison of Growth Curves**", (II) "**Likelihood ratio test**" and (III) "**Punctual comparison**".
Firstly the interface allows the user, in part (I), to adjust its sample of age-at-length data to a mathematical model of growth, among the three most commonly referred in the scientific literature:

Growth Models

Von Bertalanffy Model: $L(t) = L_\infty\left(1-e^{-k(t-t_0)}\right), \quad L_\infty > 0, k > 0, t \in \Re_0^+$

Where: **L(t)** represents the length at the age **t**; represents the maximum asymptotic length that the population reaches; **K** represents a constant growth rate, with unit t^{-1}.

Logistic Model: $L(t) = \dfrac{L_\infty}{\left(1+e^{-k_1(t-T_L)}\right)}, \quad L_\infty > 0, k_1 > 0, t \in \Re_0^+, T_L > 0$

Where: k_1 represents a relative growth rate related to an innate ability to grow (DeSapio, 1978), it's simply the product of a constant growth rate with the maximum asymptotic length, ; T_L is the age at which the velocity of growth is maximum.

Gompertz Model: $L(t) = L_\infty e^{-e^{-k(t-T_G)}}, \quad L_\infty > 0, k > 0, t \in \Re_0^+, T_G > 0$

Where: T_G is the age at which the velocity of growth is maximum.

For each growth models, selected by the user, the application outputs, in part (I), **estimates for the model parameters**, their **standard deviations** and the value of **adjusted R^2**. These values serve as support for the statistical comparison of two growth curves that follow the same model - to be made in part (II) - or to compare biological points of curves that follow different models of growth – to be made in part (III). For this, we introduced a feature in part (I), which will transport the important results to parts (II) and (III) of the application.

Fitting

To determine the values of the fitted models parameters we implemented the **non-linear least squares method**, allowing it to be carried out with or without weights. To minimize the likelihood function the application uses the Excel Solver (an implementation of the iterative Levenberg-Marquardt algorithm).

Comparison Test

To analyze the mathematical difference in the growth processes of two populations whose adjusted growth models are the same was implemented, in part (II), the **likelihood ratio test proposed by Kimura (1981).** In practice, it allows to test the hypothesis that the curves of two populations are mathematical similar against the alternative hypothesis - their independence. However, if the hypothesis of independence is rejected the application also allows to infer at what point each parameter can be considered similar.

To allow a visual analysis of both growth comparison and curve fitting, the application outputs **graphics** representing the length-age data inputted and the respective curve fitted.

We introduced in the application several **"help buttons"** which inform the user about the procedure that must be taken, the meaning of the labels and how the results can be interpreted.

As the graphics provided by the interface are saved as temporary file, in Graphics Interchange Format, at the same place as the application was saved, they can later on be reused.

Graphic Interface of the Application

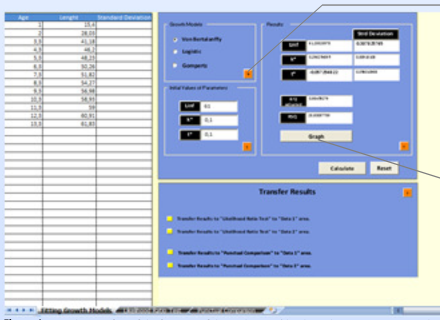

Figure 1 – Graphic interface of the first part of the application (the three sheets representing each part of the application are visible in the bottom of the image).

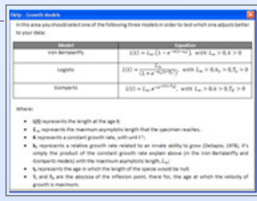

Figure 2 – Dialogue box outputted when the help button, on "Growth Models" area is clicked, describing the models and the interpretation of it´s parameters.

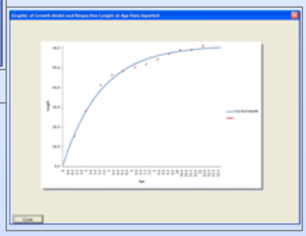

Figure 3 – Graph outputted when the button "Graph" is clicked, representing both data sample inputted and the curve fitted.

Figure 4 – Graphic interface of the second part of the application (in the left bottom one can visualize each result of the statistical test).

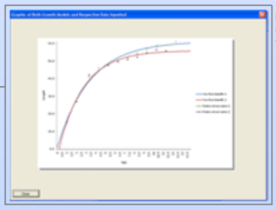

Figure 5 – Graph outputted when the button "Graph" is clicked, representing both data sample inputted and the curve fitted for the two families of fish.

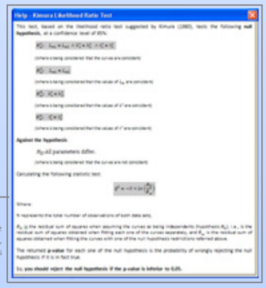

Figure 6 – Dialogue box outputted when the help button, on "Likelihood ratio test" is clicked, describing the statistical test and how results should be interpreted.

Figure 7 – Graphic interface of the third part of the application – "Punctual Comparison".

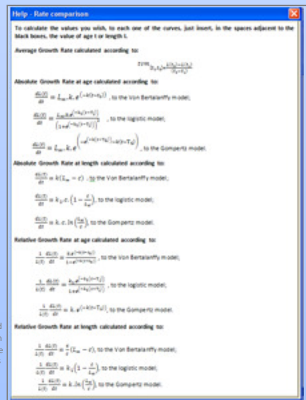

Figure 8 – Dialogue box outputted when the help button, on "Comparison Rates" is clicked, describing the mathematical expression that calculates each rate.

References

- **Cerrato**, R.M. (1990). *Interpretable Statistical Tests for Growth Comparisons Using Parameters in the Von Bertalanffy Equation*. Canadian Journal of Fisheries and Aquatic Sciences, Vol. 47, 1416-1426.
- **De Sapio**, Rodolfo (1978). *Calculus For The Life Sciences*. W. H. Freeman and Company. San Francisco.
- **Francis**, R.I.C. Chris Francis. (1996). *Do Herring grow faster than orange roughy?*. Fishery Bulletin, Vol. 94, 783-786.
- **Haddon**, Malcolm (2001). *Modelling and Quantitative Methods in Fisheres*. Chapman & Hall/CRC. USA.
- **Kimura**, Daniel K. (1980). *Likelihood Methods For The Von Bertalanffy Growth Curve*. Fishery Bulletin, Vol. 77, N.º 4. 765-776. [*on-line*] <http://allenlab.ifas.ufl.edu/courses/Kimura1979.pdf >.
- **Levie**, Robert de (2001). *How to Use Excel in Analytical Chemestry and in General Scientific Data Analysis*. Cambridge University Press. Cambridge.
- **Peres**, Paula (2007). *Excel - Macros e Aplicações*. Edições Sílabo, Lda. Lisboa.
- **Prager**, M. H., S. B. **Saila**, e C. W. **Recksiek** (1989). *FISHPARM: a microcomputer program for parameter estimation of nonlinear models in fishery science, second edition*. Old Dominion University Oceanography Technical Report 87-10.
- **Quin II**, T. J., **Deriso**, R. B. (1999). *Quantitative Fish Dynamics*. Oxford University Press. New York.
- **Wang**, You-Gan, e **Milton**, David A. (2000). *On comparison of growth curves: How do we test whether growth rates differ?*. Fishery Bulletin, Vol. 98, 874-880.

Conclusion

The application "Comparison of Growth Curves" was tested in various samples and the results suggest that the innovative implementation of a careful selection of features will make of this a useful tool, accessible and enlightening in its steps, in the comparison of growth curves of two populations, since the statistical procedures that it implements were not yet available in the programs commonly used by marine researchers. It is especially useful when one aims to statistically compare the parameters of two growth curves that are described by the same mathematical model. When two growth curves follow two different mathematical models, within the three models studied here - Von Bertalanffy, Logistic and Gompertz -, the application can be useful to compare biological points, such as growth rates or lengths at certain ages or ages in certain lengths.

Further Work

As is usual in all applications, this interface can be improved and updated. With that in mind, we are fully aware that there are certain features not included in the application, because they require further clarification and more time for its design. The most relevant, that we would like it to make part of a future version of this application, is the possibility of anticipate the discover of the growth model, from among several models with different numbers of parameters, which best fits the data sample introduced - implementing, for example, of the Akaike's method -, avoiding the need of pre-selecting the model and the careful selection of initial values of the parameter estimates.