MINISTRY OF ECOLOGY AND NATURAL RESOURCES OF UKRAINE

STATE ECOLOGY INSPECTION OF THE BLACK SEA

UKRAINIAN SCIENTIFIC CENTER OF MARINE ECOLOGY

ODESSA BRANCH INSTITUTE OF BIOLOGY OF SOUTHERN SEAS
OF NATIONAL ACADEMY OF SCIENCE OF UKRAINE

SHIPPING SAFETY INSPECTION
OF MINISTRY OF TRANSPORT OF UKRAINE

EUROPEAN UNION FOR COASTAL CONSERVATION

ECOLOGICAL SAFETY DEPARTMENT
OF THE CITY EXECUTIVE COMITTEE OF ODESSA

STATE CENTRE FOR SCIENTIFIC
AND ECONOMIC INFORMATION OF ODESSA

International symposium

THE BLACK SEA ECOLOGICAL PROBLEMS

Black Sea Strategic Action Plan Implementations
(1996 - 2000)

Odessa
SCSEIO
2000

ББК 26.221 (922.8)
Э40
УДК 551.46.9:628.5(262.5)

Друкується за рішенням **Редакційно-видавничої Ради** при Одеському ЦНТЕ1. Протокол № 6 від 24. 10. 2000 р.

Екологічні проблеми Чорного моря: 36. наук. ст. / ОЦНТЕІ; - Одеса: ОЦНТЕІ, 2000. - 405с.

Цей збірник наукових доповідей присвячень основним підсумкам виконання Стратегічного плану дій по реабілітації і охороні Чорного моря (1996-2000 pp.), підсумкового документа першого етапу виконання Міжнародної Чорноморської Екологічної Програми ООН. У цьому зв'язку надруковані матеріали відображають основні розділи Програми, а саме: швидке реагування при надзвичайних ситуаціях, моніторинг забруднення і стандарти якості навколишнього середовища, захист біологічної різноманітності, розробка загальної методології управління прибережною зоною моря, рибальство, освіта і громадська поінформованість в природоохоронній області. В статтях представлені результати раніше не надруковані результати наукових досліджень. Подані дані, їх інтерпретація і закінчення належать авторам повідомлень і ні в коєму разі не можуть бути приписані членам організаційного комітету, які склали даний збірник.

Збірник призначень для широкого кола спеціалістів у галузі біології і екології моря, океанографії, техногенної безпеки і охорони природи.

Відповідальні редактори: канд. біол. наук Б.Г. Олександров
канд. хім. наук Б.М. Кац
докт. геол.-мин. наук Т.А. Сафранов

The Black Sea ecological problems: Collected papers / SCSEIO, Odessa: SCSEIO, 2000.- 405 p.

Present issue is devoted to the main results of Strategic Action Plan for the Rehabilitation and Protection (SAPRP) of the Black Sea (1996-2000) implementation. The SAPRP is a resulting document of the Black Sea Environmental Program (GEF/UN/UNDP) first step. The published materials have been reflected by the main Program sections: emergency response, pollution monitoring and environmental quality standards, protection of biodiversity, integrated coastal zone management, fisheries, environmental education and public awareness. These papers are the results of scientific research haven't been unpublished earlier. The findings, interpretations and conclusions expressed in papers, are in own property of the authors and should not battributed in any manner to the members of organization committee, which prepared this issue.

The issue was design for specialists in the field of marine biology and ecology, oceanology, technogenic safety and environmental protection.

Э 1903040000

] БК 26.221(922.8)
' ДК 551.46.9:628.5(262.5)

ISBN 966-7635-08-2

A NEW APPROACH TO ANALYSIS OF THE GROWTH DATA: SHORT-TERM PARAMETERIZATION OF THE GROWTH EQUATION

V.N. Zolotarev

Odessa Branch Institute of Biology of Southern Seas, National Academy of Sciences of Ukraine

Analysis of the animal growth data is often used in revealing organism response to environmental changes. The size-age relations in animals have been usually expressed by the several growth curves, from which von Bertalanffy curve, Gompertz curve and Brody exponential curve are most frequently used, and the methods calculating for parameters of the growth equations from the data have been described (Walford, 1946; Allen, 1966; Rafail, 1973; Ricker, 1975; Shnute, Fournier, 1980).

The growth equation coefficients established by traditional methods have been usually interpreted as the population characteristics that averaged for the growing period studied. However, in many cases it is necessary to reveal the growth parameters for the short time space, for instance for individual annual or seasonal increments. In this paper, some approaches to estimation of the short-term growth parameters are represented for the von Bertalanffy curve that is well known and most frequently used.

The von Bertalanffy growth equation is usually represented in following form:

$$L_t = L_\infty(1-e^{-K(t-t_0)}) \qquad (1)$$

where *L,* is the length at time *t,* L^x means the asymptotic size, t^0 is a constant representing time when *L,* - O, *K* is a constant defining the rate at which the asymptotic length is approached.

For short-term parameterization the following version of the von Bertalanffy growth model is suitable:

$$L_i = L_1 + (L_M - L_1)\frac{1-k^{i-1}}{1-k^{M-1}}\ ; \quad i = 1, 2, \dots, M \qquad (2)$$

In this equation M is number of the age classes, i represents the number (from 1 to M), L_i is the length at age t_i ($t_i = t_x + i - 1$, where t_x is the age of the first age class), L_1 and L_M are the first and final lengths at ages t_x and t_M respectively; k is the fraction at which the distance between two successive lengths shrinks each year (Shnute, Fournier, 1980).

The generalized form of equation (2) is proposed for unequally spaced data (Ratkowsky, 1986). It may be represented as follows:

$$L_i = L_1 + \left(L_M - L_1\right)\frac{1-k^{B(M-1)}}{1-k^{M-1}} \qquad (3)$$

where $B = (t_i - t_1)/(t_M - t_1)$, M is the number of data points. The generalization (3) collapses to the equation (2) when time intervals represent equally spaced data.

The equation (1) and (2)-(3) are actually two expressions for the same von Bertalanffy growth curve with different sets of parameters. The first uses L_∞, K, t_0, while the second involves L_1, L_M, k, and each set of parameters can be transformed to another (Shnute, Fournier, 1980; Ratkowsky, 1986).

The parameters of the equations (2) and (3) are more appropriate to short-term transformation of the growth curve. In many cases the first the first and last means of the body length are known, as well as at least one further L_i for the some age t_i. The values of L_1, L_M and L_i can be substituted into (2) or (3) and these equations can be solved for k.

The authors of parameterizations (2) and (3) suppose that it is not possible to express analytically a general solution for k in above-mentioned equation, but an initial estimate of k may be obtained by the trial-and-error method (Shnute, Fournier, 1980; Ratkowsky, 1986). However, after simple transformation, equation (2) can be represented as follows:

$$k = \left[1 - A(1-k^{M-1})\right]^{\frac{1}{i-1}} \qquad (4)$$

where $A = (L_i - L_1)/(L_M - L_1)$. This equation has one positive solution for k. If $(L_M - L_i)/(M - i) < (L_i - L_1)/(i - 1)$, $k < 1$, that corresponds to a slowing in the growth rate from one year to the next.

New parameterization (4) can be solved for k by the iterative method calculating its successive approaches:

$$k_{n+1} = \left[1 - A(1-k_n^{M-1})\right]^{\frac{1}{i-1}}; \quad n = 0, 1, 2, \ldots$$

The iterative calculations are carried out till the difference between k_n and k_{n+1} will not exceed required accuracy of the estimation for k. To transform parameters of (2) to parameters of (1) the following relations can be applied (Shnute, Fournier, 1980):

$$L_\infty = \frac{L_M - L_1 k^{M-1}}{L_1 - k^{M-1}} \qquad (5)$$

$$K = -\ln k \qquad (6)$$

$$t_0 = t_1 - \frac{1}{\ln k}\ln\left(\frac{L_M - L_1}{L_M - L_1 k^{M-1}}\right) \qquad (7)$$

Similarly, a new transformation of the equation (3) is

$$k = \left[1 - A\left(1 - k^{M-1}\right)\right]^{\frac{1}{B(M-1)}} \qquad (8)$$

where $B = (t_i - t_1)/(t_M - t_1)$. The equation (8) is solved by the iterative method as in the case of (4). The transformation of the parameters of (8) to parameters of (1) is given by (5) for L_∞ and by the following relations for K and t_0 (Ratkowsky, 1986):

$$K = \frac{M-1}{t_1 - t_M}\ln k$$

$$t_0 = t_1 - \frac{t_M - t_1}{(M-1)\ln k}\ln\left(\frac{L_M - L_1}{L_M - L_1 k^{M-1}}\right)$$

New parameterization of the von Bertalanffy curve can be applied for the different relations of initial *{L\),* maximal *(LM)* and intermediate **(I,-)** lengths. However, when the distance between *L,* and L^M is the annual increment, the coefficient *κ* estimated by the equation (4) or **(8)** will arrange calculated values of increments for each year in such a fashion that observed and calculated increments will be equal to the last year. In means that estimation of the growth characteristics from data of the last year by the proposed method is the way to short-term parameterization of the growth curve for observed annual increments.

If the data of annual growth rate are available, there is another manner to obtain short-term estimates of the growth parameters. The equation for the annual increments changing with time is derived from (1), as follows:

/,=/^{0}e-" (9)

where /, is the annual increment at the age *t* (from initial age t^x to maximal age /„), l^0 represents the initial length, A" is a parameter of the von Bertalanffy growth curve. The logarithmic form of (9) is a linear equation:

In/ • *\nlQ-Kt*

where coefficient K represents the slope of the straight line, /^{0} is y-intercept. For short-term parameterization of the growth equation the straight line must pass over two points, one representing the last year increment In /„ at maximal age t^m, another being the midpoint of age interval from t^x to r^m_i and of length interval from In l^x to In $l^{M\sim}$]- In this case, the slope of straight line is as follows:

$$K = \frac{2}{M}\left(\frac{1}{M-1}\sum_{i=x}^{m-1}\ln l_i - \ln l_m\right) \qquad (10)$$

where M is the number of annual increments $(M = t_m - t_x - 1)$. The parameters L_∞ and t^0 are calculated from (5) and (7), substituting $k = e^{-K}$.

A new approach is especially perspective in studying organisms that show periodical microstructural variations in hard parts (e.g. shells of mollusks, scales and otoliths of fishes). Proper interpretation of skeletal periodicity permits assessment of growth rate during selected time space. Such information may then be used to estimate ontogenetic parameters of the growth equations. The data obtained on the basis of sclerochronological methods and new calculation procedures seem to be useful for monitoring biological effects of contamination at the individual and population levels. In particular, analysis of short-term growth characteristics may be applied in Mussel Population Watch (Zolotarev, Shurova, 1998), since distinct annual shell growth bands were found in many species of *Mytilus* from many coastal regions (Lutz, Rhoads, 1980; Shurova, Zolotarev, 1988; Zolotarev, 1989).

References

1. *Allen K.R. A method of fitting growth curves of the von Bertalanffy type to observed data//J. Fish. Res. Board Canada. -1966. - V. 23, N2.-P. 163-179.*
2. *Lutz R.A., Rhoads D.C. Growth patterns within the molluscan shell. An overview // Skeletal Growth of Aquatic Organisms. - Plenum Publishing Corporation, 1980. -p. 203-254.*
3. *Ratkowsky D.A. Statistical properties of alternative parameterizations of the von Bertalanffy growth curve // Can. J. Fish. Aquat. Sci. - 1986. - 43. - P. 742-747.*
4. *Ricker W.E. Computation and interpretation of biological statistics of fish populations//Bull, Fish. Res. Board. Canada. -1975. - V. 191. - P. 1-382.*
5. *Rafail S.Z. A simple and precise method for fitting a Von Bertalanffy growth curve//Mar. Biol- 1973. - V. 19. - P. 354-358.*
6. *Shnute J., Fournier D. A new approach to length-frequency analysis: growth structure//Can. J. Fish. Aquat. Sci. -1980. - V. 37, N9. -P. 1337-1351.*

7. *Shurova N.M., Zolotarev V.N. Seasonal growth layers in the shells of the Black Sea mussels //Biologiya Morya. -1988. -Nl.-P. 18-22 (in Russian).*
8. *Walford L.A. A new graphic method of descibing the growth of animals // Biol. Bull. -1946. - V. 90. - P. 141-147.*
9. *Zolotarev V.N. Sclerochronology of marine bivalve molluscs. - Kiev: Naukova Dumka, 1989. - 112 pp. (in Russian).*
10. *Zolotarev V.N., Shurova N.M. The mussel population watch as a tool for monitoring of the biological effects in contaminated coastal waters // Littoral'98. Proc. of the Fourth Inern. Conf. "Sustainable waterfront and coastal developments in Europe: socieconomics, technical and environmental aspects". Barcelona, Spain, 1988. - P. 117-120.*