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SIMPLE METHOD FOR CALCULATION OF COMPOUND PERIODICAL GROWTH RATES IN ANIMALS AND PLANTS

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ABSTRACT

A simple method for the calculation and adoption of a new growth parameter called 'Compound Periodical Growth Rate' (CPGR) for the analysis of growth rates in animals and plants has been suggested. The CPGR is analogous to compound annual growth rate (CAGR) used in business circles for the analysis of growth trends in financial investments. An illustrative computational mechanism, based on initial and final growth values in the silkworm, *Bombyx mori* is suggested for the computation of CPGR. The new parameter has potential applications in experimental biology for analyzing growth rates in body weight, cell count, metabolism, enzyme activity and the rate of accumulation of metabolites in cells and helps in drawing meaningful, reliable and accurate interpretations of trends in growth rates. The CPGR is not only verifiable mathematically, but also used to forecast future trends in all growth related investigations

Keywords: Animal growth, compound periodical growth rate, plant growth.

No of Tables : 1 Number of References:14

INTRODUCTION

Growth is an inherent property of all living organisms and involves several micro and macro changes in the body (Lawrence 1980; Mangel and Stamps 2001). The micro level growth changes manifest at cellular level in the form of increase in the cell size and number, biochemical composition, metabolic rate, immune function, physiological status and mature function, while the macro changes express at the body level in the form of biomass accumulation, somatic development and increase in body size, shape and form. In most cases, growth ceases at maturity, but continues in some organisms throughout the life, strictly under the control of intrinsic and extrinsic factors. Growth manifests differentially in different parts of the body, a feature commonly termed allometry, heterogony, or heteruxesis (Investopedia 2012). The pioneering reports of Walford (1946) and Linder (1953) suggested computational methods for the analysis of growth trends in animals and plants. Subsequently, correlational allometric studies on selected growth indicators such as body mass (M), surface area (A), metabolic rate (B), biomass production (G), body length (L), light harvesting capacity (H) and stem diameter (D) formed the basis for future investigations (Schmidt-Nelson 1984; Niklas and Enquist 2001;Damuth 2001; Perez-Claros 2005). They demonstrated that the growth indicators B, G, S, H and L are directly proportional to the body mass (M) and they scale nonlinearly as ¾ exponent of M (i.e., B, G, S and H α $M^{3/4}$), while L as ¼ exponent of M (i.e., L α $M^{1/4}$) and M as 8/3 exponent of stem diameter, D (M α $D^{8/3}$). The same allometric scaling relationships were suggested equally for both plants and animals, keeping in view, the existence of common physiological and energy-harvesting mechanisms in all living cells (Niklas 1984; Niklas and Enquist 2001).

In all allometric studies, it is customary to express the growth rates in terms of percent changes using multivariate statistical tools (Brown and Donnelly 1988; Hong Nhan et al. 2007). The periodical percent changes, so obtained are often converted to another compound parameter called 'Arithmetic Mean Return' (AMR), which does not reflect the time-dependent growth trends accurately and hence lead to incorrect interpretations. This problem becomes all the more complicated while analyzing the growth rates of two groups of organisms reared under different treatment or environmental conditions. In business management, similar problem arose while interpreting the growth trends in financial investments and the same was resolved by calculating a parameter called 'compound annual growth rate' or CAGR (Investopedia, 2012). I suggest that biologists could adopt this parameter by rechristening it as 'compound periodical growth rate' (CPGR), as growth trends in many living organisms run on short durations of time such as a days or weeks or months, but not necessarily be on annual basis depending on their life span and environmental conditions. Like CAGR, the CPGR is an imaginary number that describes the rate at which an organism grows when it is allowed to grow at a steady rate and helps investigators to draw meaningful conclusions from their findings.

COMPUTATION OF COMPOUND PERIODICAL GROWTH RATE

Like compound annual growth rate (CAGR) in financial investments, compound periodical growth rate (CPGR) can be calculated as the ratio of the ending value to the beginning value raised to the power of 1/n-1 (n = number of periods) and then subtracting 1 from the resulting number. In other words, if we have a growth value for first period and a corresponding figure for the last period, we can calculate CPGR using the following simple formula or by using the online CAGR calculators (Eg. CalculateGrowth 2012; Investopedia CAGR calculator, 2012).

$$\text{CPGR} = (\text{End Value} / \text{Start Value})^{1/n-1} - 1$$

In this equation, the end value refers to growth after specified period, the start value to growth at the beginning of the experiment and 'n' to the time component which is split into number of sub periods such as days / weeks / months / years etc., depending on the life span of the organism and environment in which it lives. The value, so obtained is generally expressed in percentage form by multiplying it with 100.

Illustration: Calculation of CPGRs for two groups of silkworm (*Bombyx mori*) larvae reared under two different conditions during fifth instar development as shown in table 1.

Table 1. *Growth in the body weight of the silkworm, Bombyx mori during fifth instar development in the control and experimental groups.*

Day of fifth instar	1	2	3	4	5	6	7	AMR	CPGR
Body weight (g) of silkworm larvae reared in control group	0.75	1.00 (33.33)	1.25 (25.00)	1.50 (20.00)	2.00 (33.33)	2.40 (20.00)	2.50 (4.17)	19.31%	0.2222 or 22.22%
Body weight (g) of silkworm larvae reared in treatment group	0.75	1.25 (66.67)	1.50 (20.00)	1.80 (20.00)	2.25 (25.00)	2.50 (11.11)	2.75 (10.00)	25.46%	0.2418 or 24.18%

Figures in parentheses represent percent changes, calculated by taking the previous day body weight as the base value in each case. AMR: Arithmetic Mean Return; CPGR: Compound Periodical Growth Rate.

Note: In the silkworm, the fifth instar larval stage lasts for 7 days and the changes in the mean body weight of larvae, expressed in grams, are taken as basis for calculation of CPGR .

End value = 2.50 for control group and 2.75 for experimental group.

Start value = 0.75 for both control and experimental groups.

'n'= Number of periods = 7 (The 7-day fifth instar stage is divided day-wise into 7 sub periods)

Hence; n – 1 = 7-1 = 6;

By substituting these values in the above equation, we get CPGR, both in absolute and percentage terms as shown below;

CPGR for control group = $(2.50 / 0.75)^{1/6}$ -1 = 0.2222 or 22.22%.

CPGR for experimental group = $(2.75 / 0.75)^{1/6}$ -1= 0.2418 or 24.18%.

Verification of CPGR

The correctness of CPGR can be verified mathematically. If we multiply the initial value by (1 + CPGR) six times (because n – 1 = 6 in the above case) we will get exactly the final value again. This is;

Final Value = Start value x $(1+\text{CPGR})^n$

Final value of control group

= 0.75 x $(1+0.2222)^6$

= 0.75 x (1.2222) x (1.2222) x (1.2222) x (1.2222) (1.2222) x (1.2222) x (1.2222)

= 2.499 or 2.50

Final value of experimental group

= 0.75 x $(1+0.2418)^6$

= 0.75 x (1.2418) x (1.2418) x (1.2418) x (1.2418) (1.2418) x (1.2418) x (1.2418)

= 2.751 or 2.75

Comparison of CPGR and Arithmetic Mean Return

The CPGR can be compared with commonly derived parameter called 'Arithmetic Mean Return' (AMR), which would be the sum of periodical percent changes (compared with the previous period) divided by number of periods. For instance, the AMR for the silkworm growth can be calculated as shown below.

AMR of control group

=(33.33% + 25%+20 % +33.33%+ 4.17%)/6

= 19.31%

AMR of experimental group

= (66.67% + 20%+20 % +25%+ 11.11+ 10%)/6

= 25.46%

Thus, while CPGR for the control group is 22.22%, the AMR is 19.31. Similarly, while the CPGR for experimental group is 24.18, its AMR is 25.46. In contrast to CPGR, we cannot obtain final growth value from AMR by multiplying the initial growth value (0.75 (1 + AMR)^6, unless all periodical growth rates are one and the same

Applications of CPGR

Since, the calculation of CPGR is based on single start time value and a single end time value, it can be widely applied in experimental biology for calculating and communicating average returns of growth, rate of accumulation of metabolites in cells, metabolic rates, enzyme activities, individual specific, species-specific, tissue-specific growth rates and allometric growth rates in different parts of the body. This is the best method for comparative analysis of growth rates of two groups of animals or plants reared under different treatment conditions. It can be widely used in forecasting future values based on the CPGR of a data series (We can find future growth rates by multiplying the last datum of the series by (1 + CPGR) as many times as periods required). The CPGR has its own limitations. Though, it cannot be applied to compute physical growth rates in mature terrestrial animals, it can be conveniently used to compute physiological and metabolic growth trends at the cellular level in all animals and plants, Further, the CPGR has more potential for expressing growth patterns of animals having shorter life spans such as insects and their larval forms. Nevertheless, the application of CPGR to living organisms would facilitate meaningful, reliable and accurate interpretations of growth-related research findings.

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