

Short communication

Modular microcomputer software to estimate fish population parameters, production rates and associated variance

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Abstract – Microcomputer software to estimate fish population parameters, production rates, and associated variances was developed using established procedures. Pop/Pro Modular Statistical Software is a series of portable programs written in English that run on Macintosh® or IBM® (and compatible) computers. Population parameters can be estimated using either a single-census mark-recapture method or a removal method. Production and component parameters can be estimated with either the instantaneous growth rate method or the increment summation method. Output may be stratified by fish length, age or sampling interval and includes variance estimates for all parameters. The software was developed for use with fish data but may be applicable to other taxa.

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Un resumen en español se incluye debrás del texto principal de este artículo.

Introduction

Numerous data on static measures of fish populations appear in the literature and may be of interest for specific applications, but the dynamic measure of production rate is by far the best indicator of a species' ecological success. Le Cren (1969) expressed this view by calling production "the best epitome of the population dynamics and environmental performance" of a population. The methods and terminology for estimating fish production have evolved to a generally accepted convention (Waters 1977; Chapman 1978), and estimates of production are becoming more abundant in the literature. The instantaneous growth rate method is most commonly used for fish, but the increment summation and size-frequency methods are also used.

Many fisheries managers and researchers routinely gather the population abundance, biomass and age structure data required to estimate production but rarely do so, presumably because the computations can be complex and cumbersome. Adding to the difficulty of calculations is the need to estimate the precision of population statistics, i.e., variance for production estimates and component parameters. The use of computers reduces the required effort and potential for calculation error and thus may facilitate and encourage biologists to incorporate production into their assessment of fish populations. Although computer programs

have been developed to estimate production and its variance (Garman & Waters 1983; Newman & Martin 1983; Railsback, Holcomb & Ryon 1989), most are restrictive in method, portability and flexibility. I report the availability of modular microcomputer software that will provide estimates of fish population parameters, production rates and associated variance by several different methods.

The software

Pop/Pro Modular Statistical Software^a is written in English and is available to run on any Apple Macintosh® or IBM® and IBM-compatible machines. These portable programs were developed in the C programming language and represent a total of 18,870 lines of computer source code. No additional software is required, other than a word processing or spreadsheet application to create data input files.

Application

The software is designed for use with electrofishing field data but may be applicable to other data and taxa. Population parameters are estimated for a

^a The software is available at no cost by sending a double-sided, 90-mm disk to the author (indicate computer format: Macintosh or IBM).

single date using either a single-census mark-recapture method or a removal method with constant sampling effort (maximum-likelihood estimate). Production and component parameters are then estimated by the instantaneous growth rate method or the increment summation method. A second method of estimating production using identical data may be desirable for cross-validation purposes.

To minimize a known size bias associated with electrofishing, population estimates are stratified by size group. The data required for a mark-recapture population estimate include lengths of all fish captured in the marking sample and all fish captured in the recapture sample, both recaptured (marked) and unmarked. Removal-method estimates require lengths of all fish collected in each successive removal sample; the number of removal samples may vary from 2 to 16. Data on the weights and ages of all fish, or a subset thereof, are also required to calculate population estimates by age. If only a standing stock estimate is desired, collection of age data may be omitted. The output of the population-estimate modules includes abundance, biomass, mean individual weight and variance for the total population and each age class.

To estimate production, a minimum of two population estimates are required, including the dates of the estimates and abundance, biomass and associated variance, according to age. Output files from the population-estimate modules may be used as input files to calculate production for one or more intervals between successive sampling dates, or alternatively, population-estimate files may be created manually by the user from the results of another method. Production estimates are provided for the total population and each cohort sampled, and include a summary of the interval dates, mean abundance, mean biomass, instantaneous rates of growth and mortality, production and the ratio of production to mean biomass (P/\bar{B}) for each interval. Mean values weighted by interval length are computed for abundance and biomass, and totals among intervals are computed for all other parameters. A summary table including means and totals of all year classes is then finally created. Approximate 95% confidence intervals (± 2 SE) are presented for estimates of total population production, mean abundance and biomass, P/\bar{B} ratio and total instantaneous rates of growth and mortality.

The algorithms

The modules primarily follow the statistical methods of Newman & Martin (1983) with several

exceptions. Population size and its variance are calculated using a modified Petersen estimate (Ricker 1975) or 3 distinct sets of maximum-likelihood estimators, depending on the number of removal passes (Seber 1982; Bohlin et al. 1989). Age-specific estimates are made using the proportion of fish of a given length for each age (Newman & Martin 1983).

Production, component parameters and variance are calculated according to explicit formulae found in Newman & Martin (1983), except that variance of instantaneous growth and mortality rates is estimated by an approximation of the variance of the natural logarithm of a mean, using a Taylor series expansion (the delta method: Seber 1982; Cone & Krueger 1988). This method is simpler than the jackknife estimator suggested by Newman & Martin (1983).

Other features and information

As with any statistical software, the user should understand the procedures and verify a subset of results. Pop/Pro Software has undergone limited testing, but I do not guarantee the accuracy or application of results. The modules contain several traps for problematic, anomalous or inconsistent data; however, the responsibility for data quality lies with the user, and input files should be carefully scrutinized. Users may refer to Waters (1977) and Bohlin et al. (1989) for a review of secondary production methods and field procedures, respectively.

The variance estimates produced by this software are measures of sampling error only and provide no indication of process error (Walters 1986) or systematic error. Users should also understand the assumptions associated with each sampling and estimating method (Ricker 1975; Seber 1982; Newman & Martin 1983).

Several subjective decisions arise when population size and production are estimated. The user is prompted to indicate the number of length units to be included in each size group and is allowed to further combine consecutive size groups if necessary (for example, small sample sizes or more recaptured fish than marked within a size group). Units of results may be converted within the modules, and other changes may be made by altering data sets. The procedures implemented in the modules are designed to give conservative minimum estimates of production, component parameters and variance. For example, if a year class is sampled at only one of two successive sampling dates (such as migration or mortality occurs), its mean standing stock is considered zero. However, the interval production estimate and variance for

newly recruited age-0 fish is computed as the biomass estimate and its variance when the age class is first sampled (Waters 1983). Negative values of growth (weight loss) or mortality (increase in number) for a cohort over an interval are estimated and included in the output, but for intervals of negative growth, production and its variance are assumed to be zero (Waters 1977; Chapman 1978).

It was my intention in developing this software to improve precision and accuracy of estimates and to facilitate the complex process of estimating fish population parameters, production rates and the variance of these estimates. The ability to estimate production rates readily will allow the refinement of methods and guide investigators in decisions regarding spatial and temporal scale in production studies. Downing (1984) put forth 4 ecological goals that may be addressed by studies of secondary production in fresh water: 1) elucidation of energy or material transfer within ecosystems, 2) sound management of aquatic resources, 3) detection of the effects of pollution and 4) formation of theories of biological productivity. If population and production techniques are accessible to more biologists through computer technology, then we will further the potential for contributing to such worthy goals.

Resumen

El fin de este trabajo es presentar programas para estimar parámetros de poblaciones de peces, tasas de producción y sus varianzas asociadas, basados en procedimientos establecidos. Pop/Pro Modular Statistical Software es una serie de programas en BASIC, escritos en inglés, que pueden correr en Macintosh*, IBM* o cualquier otro computador compatible. Su estructura permite obtener los parámetros de población sobre los métodos de marcado-recaptura o sobre los de capturas-sucesivas. A su vez, los parámetros de producción se pueden determinar o bien sobre la Tasa Instantánea de Crecimiento, o bien sobre el método de Incrementos Acumulados. La salida de los datos puede estratificarse sobre las longitudes de los peces, sus edades o sobre intervalos entre muestreos e incluye las varianzas de todos los parámetros. Estos programas aunque están particularmente diseñados para poblaciones de peces pueden ser aplicados a otros grupos taxonómicos.

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