Tropical Stock Assessment Packages for Programmable Calculators and Microcomputers

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Fishery biology, particularly the applied aspect of stock assessment, became a truly quantitative science in the mid-1950s, when the Beverton & Holt and Schaefer "workhorse" models for stock assessment were produced. Unfortunately, the computations involved in using either of these models and their variants and successors were generally quite tedious.

In the 1960s and early 1970s, various authors, tempted by the availability of large computers, began to expand on the available models, adding a variable here, a species there. However, the use of large computers as a research tool in fisheries remained, as a whole, limited to a few centers of excellence, and many of the earlier leads were not pursued.

In the mid-1970s, a new type of hardware became available which changed all that: microcomputers and programmable calculators.

Microcomputers

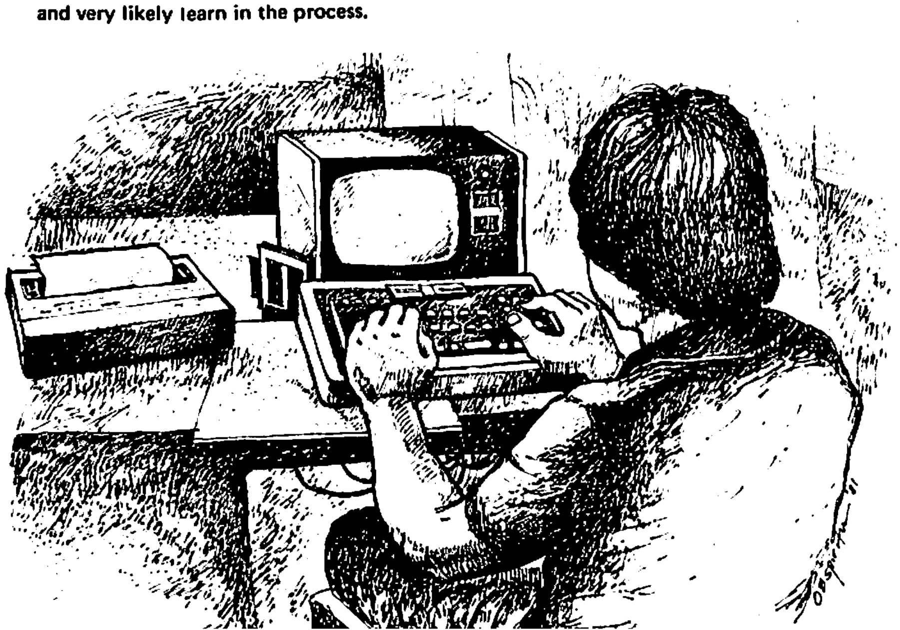
In spite of a wide range of available brands and models, the present lines of microcomputers are essentially similar, with most capacities ranging from 2 to about 60 kilobytes, and prices ranging from about US$500 to 5,000 (including bottom-line peripherals such as cassette drive). The relative uniformity of performance of the major models in the market is based on the fact that they tend to be built around the same microprocessors; more importantly (for the users), the overwhelming majority of microcomputers are programmable in the easy-to-learn BASIC.

Manufacturer-supplied software for microcomputers is generally limited to business applications and bloodthirsty "games," while scientific programs are generally limited to standard statistical methods such as can be performed, and with almost equal ease, with programmable calculators.

Programmable Calculators

As opposed to the situation prevailing with microcomputers, the bulk of sales of programmable calculators is essentially attributable to two firms (Texas Instruments and Hewlett-Packard). This situation has led to a wide range of software being available to the users, both in terms of manufacturer- and user-contributed programs.

With a microcomputer, a fishery biologist has all the opportunities to "play" with the data—and very likely learn in the process.



But this software, which covers the fields of statistics and the engineering sciences quite well, is very limited as far as fishery applications are concerned. Nevertheless, what are the applications to which these modern, inexpensive machines can be addressed? One answer is: stock assessment.

Tropical Stock Assessment

Two equally erroneous notions have almost succeeded in totally paralyzing fisheries research in the predominantly tropical waters of developing countries:

> The notion that the good old methods developed for the North Sea can be applied in tropical waters, things being essentially the same everywhere.
>
> The notion that the good old methods developed for the North Sea cannot be applied in tropical waters, things being essentially different in the tropics.

The problem can be tackled on the basis of the assumption that accounting for the differences between tropical and temperate systems is basically a question of adjusting one's scales (smaller fish, "faster" time scale and reduced seasonal phenomena in the tropics). The "trick" with tropical fishes, then, is to turn what appears to be a liability (i.e., the fact that they do not exhibit properties possessed by temperate fishes), into an asset.

For example, the feature that many demersal stocks in tropical waters consist of annual fishes, allows one to follow the growth and decay of a cohort within a period of 12 months, which further allows one, when there are well-defined spawning seasons (as is often the case), to:

- determine growth from length-frequency data without encountering any of the problems facing application of this method to long-lived temperate fishes (see below)
- neglect time-lag effects when fitting Schaefer-type models to catch and effort data
- estimate absolute recruit numbers from a division of yield-per-recruit into the catch

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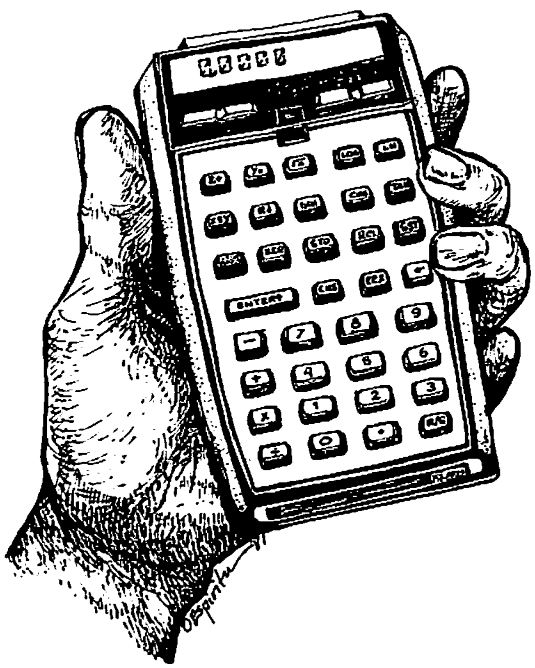
- estimate the age, in days, of individual fish

and other nice things which cannot be done when working with cods or other temperate fishes.

Also, the extremely large number of species often encountered in tropical, especially demersal, fisheries and which many authors have generally considered to represent but a huge problem, may be viewed as a beautiful set of replicates from which not only one but several sets of parameter estimates can be obtained, e.g., to assess



Smaller is beautiful: There is no point using a microcomputer to process data which a programmable calculator can handle.

the impact of fishing on a multispecies stock.

The question now is: How does all this link up with the electronic gadgetry discussed above? Tentative answers follow and an attempt is made to show how the gadgetry could help.

Use of Calculators

The potential user of a tropical stock assessment package is generally young, rather inexperienced, trained in description rather than analysis, underpaid (and therefore often unmotivated) and most often, overwhelmed by responsibilities (qualified, highly skilled scientists are in developing countries quickly promoted out of their research jobs–an acute case of the Peter Principle). Finally, our typical potential user has no back-up library to speak of, and no mathematically oriented colleague to consult (often due to extreme compartmentalization between and within research institutions).

From this, we derive the following prerequisites for a useful package of calculator programs:

- the package must pertain directly to tropical fish and relate in a tropical context;
- the package must be versatile because the user cannot be expected to modify or adapt it;
- the package must be self-explanatory and fully documented because the user generally cannot be expected to have access to anything but, say, a few old copies of the *California Fish and Game*;
- because of biological properties inherent to tropical fishes (relative ease at using length-frequency data, difficulties with routine ageing), the program package should include as many length-structured models as possible.

The relatively low prices of microcomputers and the ease in handling them are major reasons why they could become widely used for tropical stock assessment.

I have attempted to write a program package for programmable calculators with all these things in mind, and the result is a series of programs, implemented on HP 67/97 calculators, and which can be easily implemented on an HP 41C, or a TI 59 (see Table 1). These programs are fully documented in a manual, copies of which should be available in about 6 months.

Use of Microcomputers

The relatively low prices of microcomputers and the ease in handling them are major reasons why microcomputers could become widely used for stock assessment in tropical countries.

To make the most out of such microcomputers, however, the following should be considered:

- there is no point purchasing and programming microcomputers to perform tasks which can be handled just as well by programmable calculators;
- software must be available which is designed to perform jobs likely to be important when tropical fishes and fisheries are considered.

There are a number of applications in which the abilities of a microcomputer can be put to good use in areas important for tropical stock assessment, e.g., the detailed analysis of length-frequency data, the analysis of trawl survey data, and the simulation of multispecies systems.

Analysis of length-frequency data

As mentioned above, length-frequency data and their analysis are extremely important in tropical fishery biology. However, the analytical methods used until recently were essentially refinements of the approach pioneered in 1892 by Petersen.

Recently, a radical departure from these methods was proposed; the result is a series of computer programs (ELEFAN or Electronic LEngth Frequency ANalysis), which extract different sets of information from length-frequency samples:

ELEFAN I–Extracts von Bertalanffy growth parameter values and seasonal growth patterns from one, or a set of, length-frequency samples [See ICLARM Newsletter, July 1980, p. 13-15 or Meeresforschung 28(4)].

Important properties of the approach used in ELEFAN I are that *no* assumptions are made concerning the age-structure (e.g., the number of year classes) of the data set investigated, and that the goodness of fit is estimated by means of a parameter analogous to a coefficient of determination. *to page 13*

Applications of ELEFAN I and II to length-frequency data of the shrimp *Penaeus kerathurus* (females) from Cadiz, Spain (L/F data of Rodriguez 1977, Invest. Pesq. 41: 603-635). ***Right***: Seasonally oscillating growth curve, as estimated by ELEFAN I. The parameters estimated are L_{∞} = 21 cm, K = 0.8, as well as two other parameters which characterize the growth oscillations. *Page 13, right, top*: Length-converted catch curve. The slope of the right side of such a curve provides an estimate of total mortality, here Z = 1.96. *Right, below*: Recruitment pattern of *P. kerathurus* females. The shape of the recruitment pattern suggests one major recruitment event per year (in spring), and possibly a second, minor recruitment event, occurring about 6 months later. Both figures on the right were obtained by means of ELEFAN II from the length-frequency data also used by ELEFAN I. Important with all three applications of the program is that *no* subjective inputs were used, i.e., any researcher working with the same data set could reproduce the same results.

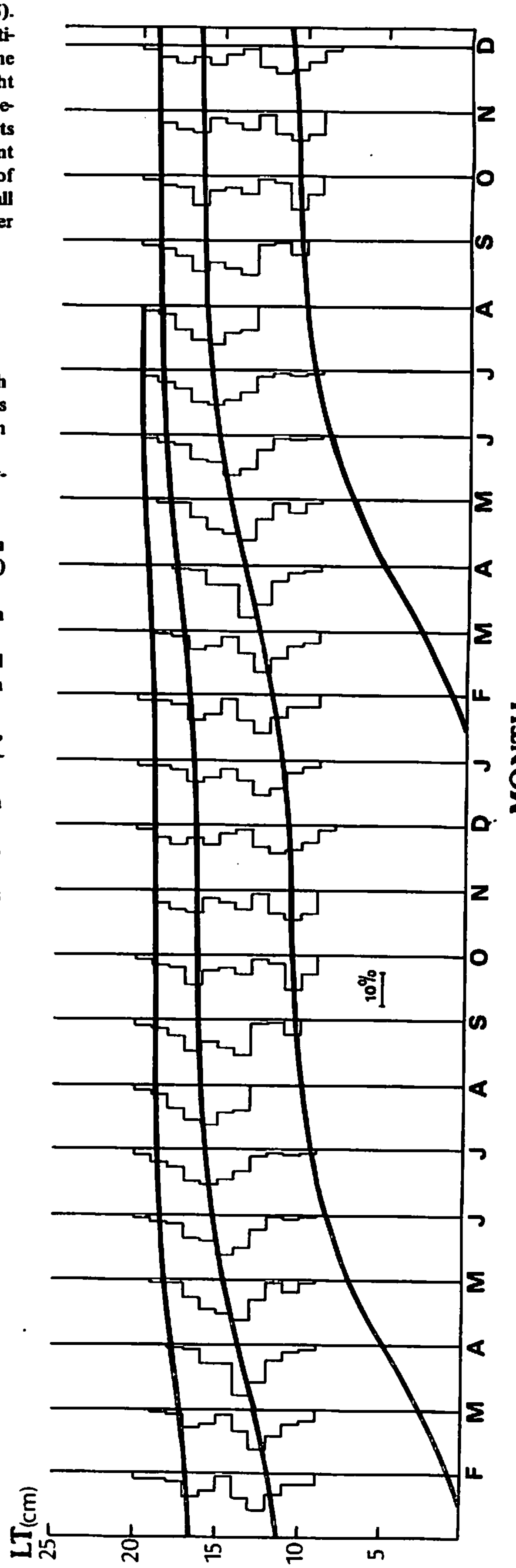


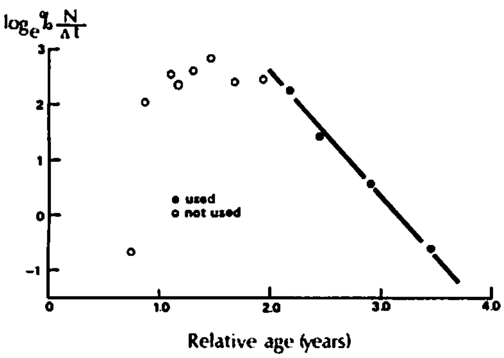
Table 1. Contents of the Calculator Program Package

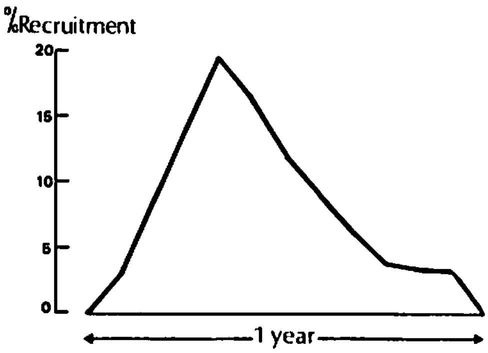
Code	Program name*	Applications
FB 1	Length-weight relationships	Calculates the relationship between the length and weight of fish, including condition factors
FB 2	Trawl mesh selection	Estimates mean length at first capture from trawl selection experiment data
FB 3	von Bertalanffy Plot	Estimates growth parameters of fish given certain types of size-at-age data
FB 4	Ford-Walford Plot	Same as above
FB 5	Gulland Holt Plot	Estimates growth parameters of fish from growth-increment data (e.g., tagging data)
FB 6	Munro Plot	Same as above
FB 7	Fitting seasonally oscillating growth data	Estimates growth parameters of fish when growth oscillates seasonally
FB 8	Estimating d, D and t_o	Estimates various parameters of the special and generalized von Bertalanffy growth formula (VBGF)
FB 9	Generalized VBGF: solution	Solves the generalized VBGF for age, length, weight, growth rates, etc., given the appropriate inputs
FB 10	Total mortality from mean size I	Estimates total mortality (Z) from the mean size of fish in the catch
FB 11	Total mortality from mean size II	Similar to I above, but with variance of Z also estimated
FB 12	Data for catch curve	Bias-free conversion of size frequency samples to catch curves
FB 13	Independent estimate of M	Estimates natural mortality rates from growth parameters and temperature
FB 14	F & M from tagging data	Estimates fishing and natural mortalities from returns of tagging experiments
FB 15	Population sizes (Petersen's method)	Estimates population sizes and their variance using four versions of Petersen's equation
FB 16	Leslie's equation	Estimates original population size in intensively fished stocks
FB 17	VPA and cohort analysis	Estimates population sizes and fishing mortality from catch-at-age data
FB 18	Jones' length cohort analysis	Estimates population sizes and fishing mortality from catch-at-length data
FB 19	VPA with catch-at-length data	Similar to method above, but result unbiased
FB 20	Yield-per-recruit (special VBGF)	Estimation of yield-per-recruit and optimum ages (or sizes) at first capture, using classical method
FB 21	Yield-per-recruit via incomplete β function	Same as above, but usable when exponent of length-weight relationship differs from 3
FB 22	Conversion factor "k"	Estimates the fraction (in weight) of a stock below any age t_k.
FB 23	Stock recruitment curve of Beverton and Holt	Establishes a curve relating stock of spawners to the subsequent quantity of young fishes available to the fishery
FB 24	Ricker's stock recruitment curves	Same as above, but using different shapes for the curve
FB 25	Schaefer and Fox Model	Estimating MSY and optimum effort from catch and effort data
FB 26	Logistic growth curve	Fitting of a population growth curve
FB 27	Yields from two interacting species	Demonstrates the effect of technological and biological interaction on multispecies yields.

*The complete *Fishery Biology* package fits on 22 HP 67/97 program cards

ELEFAN II—Derives a catch curve from length-frequency data and a set of growth parameter values, estimates total mortality (Z), and by subtraction from an independent estimate of natural mortality (M), yields fishing mortality (F).

The program also derives the seasonality of recruitment. Seasonality of growth must be taken into account when deriving recruitment patterns; this part of the program is therefore best implemented following the use of ELEFAN I (see Fig. 1).





ELEFAN III—This program, which was developed in cooperation with J. Pope of Lowestoft (U.K.), uses a length-weight relationship, length-frequency data, and matching bulk catch data to estimate catches in number, by length class. It then runs two different types of Virtual Population Analysis on the catch-at-length data. Results are estimates of population sizes at sea, including estimates of absolute recruitment, as well as an F matrix.

Analysis of trawl survey data

The late 50s and early 60s saw, in Southeast Asia, the onset of trawling on a large scale, first in the Philippines and the Gulf of Thailand, then in the neighboring countries, e.g., Malaysia and Indonesia. The development of these trawl fisheries was in several cases paralleled by extensive series of research trawl surveys, particularly in the Gulf of Thailand, the results of which have been used to assess the impact of the fishery on the stocks.

However, the large amount of data gathered during such surveys has generally been vastly underutilized, mainly because most models presently used in tropical stock assessment simply cannot handle the huge volume of data gathered during such surveys.

Possibly the best approach is to use microcomputers for storing and analyzing such data, major reasons being:

- *costs*: once a microcomputer has been bought, it costs almost nothing to run it day and night.
- *training effects*: a fishery biologist who has no opportunity to "play" with the data (because they are analyzed at a distant computer center) is very unlikely to learn from the analysis.

Aware of these favorable properties of microcomputers, ICLARM has recently commissioned a program package for the filing and analysis of trawl survey data, to be implemented on a microcomputer (diskette) system.

Apart from allowing interactive manipulation of catch and oceanographic data, the program will identify community structure and diversity as well as other indices used in theoretical ecology.

Simulation of multispecies system

Finally, microcomputer programs can be used to simulate the behavior of tropical multispecies stocks under exploitation. This was demonstrated quite elegantly by Larkin and Gazey who produced a simulation of the Gulf of Thailand trawl fishery, and used it at our stock assessment conference last January (see ICLARM Newsletter, January 1981, p. 14), to test the validity of descriptions given elsewhere on interactions between the various fish stocks in that Gulf. Larkin and Gazey suggest that this approach may be helpful even when the data base is scanty (data are then replaced by "outrageous" assumptions), because it allows the detection of gaps both in the data sets and in our understanding of the system in question.

As far as fishery research is concerned, microcomputers and programmable calculators thus seem to represent good examples of appropriate technology, and so might be safely used by those who feel that "small is beautiful." o

The ideas presented in this article incorporate concepts already developed in the following papers:

Gaschütz, G., D. Pauly and N. David. 1980. A versatile BASIC program for fitting weight and seasonally oscillating length-growth data. I.C.E.S. CM 1980/D:6 Statistics Cttee. 14 p.

Pauly, D. n.d. A new methodology for rapidly acquiring basic information on tropical fish stocks: growth, mortality and stock-recruitment relationships, p. 154-172. *In* S.B. Saila and P.M. Roedel (eds.) Stock assessment for tropical small-scale fisheries: proceedings of an international workshop held September 19-21, 1979, at the University of Rhode Island, Kingston, R.I. International Center for Marine Research Development, University of Rhode Island.

Pauly, D. 1980. A selection of simple methods for the assessment of tropical fish stocks. FAO Fish. Circ. No. 729 (FIRM/C729). FAO, Rome. 54 p.

Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. J. du Conseil 39(3): 175-192.

Pauly, D. 1980. The use of a pseudo catch curve for the estimation of mortality rates in *Leiognathus splendens* (Pisces: Leiognathidae) in western Indonesian waters. Meeresforsch. 28(1): 56-60.

Pauly, D. and N. David. 1981. ELEFAN I, a BASIC program for the objective extraction of growth parameter from length-frequency data. Meeresforsch. 28(4): 205-211.

Pauly, D. 1981. The relationships between gill surface and growth performance in fishes: a generalization of von Bertalanffy's Theory of Growth. Meeresforsch. 28(4): 251-282.