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ON IMPROVING OPERATION AND USE OF THE ELEFAN PROGRAMS. PART III. CORRECTING LENGTH-FREQUENCY DATA FOR THE EFFECTS OF GEAR SELECTION AND/OR INCOMPLETE RECRUITMENT

by
Daniel Pauly
ICLARM, P.O.Box 1501, Makati
Metro Manila, Philippines

One important feature of length-frequency data that is usually ignored when data are collected for subsequent estimation of growth and various related parameter estimates is that length-frequency data are necessarily collected with gears that are always selective for certain sizes. This feature often results in length-frequency samples that cannot be used to extract growth and mortality parameter estimates, for example in the case of data sampled by means of a gill net. On the other hand, it is usually possible to extract growth and mortality parameter estimates from length-frequency data obtained using trawls, Danish seines and similar gears. These estimates will usually be biased, however, because of some residual selection and other effects. A method is presented here which allows for a partial correction of such biases, as related to the estimation of growth parameters (L_∞ and K) using the ELEFAN I program.

Before presenting the method, it is necessary, however, to introduce a few concepts related to gear selection and related processes. First we should distinguish between recruitment to a gear (or fishery) and selection by a gear. The first process refers to the fact that the youngest stages of fish (eggs, larvae and early juveniles) usually do not occur over the same grounds as the adults, and that these early stages "recruit" (i.e. migrate), usually upon reaching a certain size, to the fishing grounds (and hence to the gear used in a given fishery). This process is usually represented by a S-shaped curve, with fish of increasing size having an increasing probability of being recruited (Fig. 1).

Selection by a gear refers to the fact that certain fish sizes are better retained than others. In the case of trawls, Danish seines and some other gears, this process is usually represented by a logistic curve, with very small fish being almost uncatchable in the gear, middle-sized fish having a moderate probability of being retained by the gear, while virtually all the larger fish are retained (see Fig. 1).

Since only those fish can be caught that have previously been recruited, what a given gear actually catches is given for each length class by the fraction of the total stock recruited multiplied by the fraction selected (or: probability of being recruited x probability of being selected). The curve obtained as the product of a recruitment and a selection curve is called a "resultant curve" (Gulland 1983, p 127). (In earlier version of the ELEFAN programs and publications based thereon, resultant curves were referred to as "selection patterns").

It has been shown in a previous article (Pauly 1984) how a resultant curve can be derived from a length-converted catch curve and an estimate of natural mortality. The feature of resultant curves of interest here is that they can be used to correct length-frequency data such that improved growth parameter estimates can be obtained. The procedure is as follows:

(i) create a length-frequency data file ("A") using your version of ELEFAN 0,

(ii) estimate preliminary values of L_∞ and K (and of WP and C if growth oscillates seasonally) using ELEFAN I,

(iii) derive a length-converted catch curve, using ELEFAN II, based on file A, and the growth parameters estimated in (ii),

(iv) use the catch curve routine of ELEFAN II to derive a "selection pattern" (i.e. a resultant curve),

(v) in each sample, divide each frequency value in file A by the probability of capture corresponding to the appropriate length.

The new file thus created may be named "ACORR".

(vi) use file ACORR to obtain new growth parameter estimates. (See Fig. 2 for an example).

(vii) use file A and new growth parameter estimates (obtained in vi) to derive a new catch curve with ELEFAN II and go to (iii) for a second pass if necessary).

This iterative procedure - which in most cases won't require more than one pass to markedly improve growth parameter estimates - usually results in an increase and a decrease in the estimates of K and L_∞ respectively. It appears, in fact, that this procedure almost completely compensates for the tendency of ELEFAN I to underestimate K and overestimate L_∞, especially when a version of this program is used which allows L_∞ to be smaller than the largest fish in the data file. (See Pauly 1986; Brey and Pauly 1986).

Three practical aspects of this procedure need brief comments.

1. The division in (v) of the frequencies by the corresponding probabilities of capture and the creation of a new "corrected file" are best implemented as a routine of ELEFAN 0.

2. Care must be taken to provide a lower limit for the probability of capture utilized, such that the highest frequency in file "A", divided by the lowest probability of capture utilized, doesn't lead to a number higher than can be handled by your version of ELEFAN 0. Thus, if your version of ELEFAN 0 uses <u>integers</u> to express the frequencies, the highest number that can be handled will be 32767. This can be achieved by (a) not allowing entry of probabilities say >0.001, and by including an internal error trap which provides an upper limit for the corrected frequency. This procedure will cause a negligible bias only, because ELEFAN I doesn't use the corrected frequencies themselves, but the restructured (corrected) frequencies, which are largely independent of the absolute <u>height</u> of the length-frequency histograms.

3. Not all the samples in file "A" should be used to derive a resultant curve. Rather, as suggested by Yahiaoui et al. (1986), the samples used for such purposes should be those containing the smallest fishes, i.e. those obtained during the recruitment season. This will have the effect of shifting the resultant curve to the left, toward the selection curve proper (note that, however, <u>all</u> available samples should be used to obtain estimates of total mortality estimate in (vii)).

SUMMARY AND CONCLUSION

The technique outlined above to correct length-frequency data for incomplete selection and/or incomplete recruitment based on a length-converted catch curve derived from the data to be corrected appears to have been first proposed by Pauly and Sann Aung (1984), who implemented it with the ELEFAN I and II programs.

This straightforward method, which has been verified by Hampton and Majkowski (in press) has rather beneficial effects on growth parameter estimates, in that it largely eliminates the respective downward and upward biases of K and L_∞ which have been associated with the ELEFAN I program.

This point implies that the overwhelming majority of growth parameter estimates already in the fishery literature - for which such correction have not been performed - should be biased, some of them severely. This problem has, to this author's knowledge, never been addressed previously.

On the other hand, various critiques of the ELEFAN programs have suggested to this author (and especially to others) that the ELEFAN method, because it is computer-based, and because it makes it easy to estimate growth and related parameters from length-frequency data, will contribute to an uncritical attitude among young Third World fishery scientists, to a flood of erroneous analyses, to misleading management advice, maybe even to stock collapse as significant as that of the North Sea herring. Voilà.

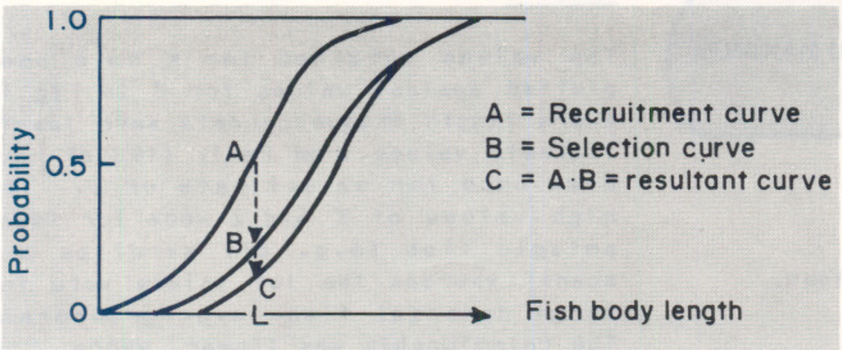
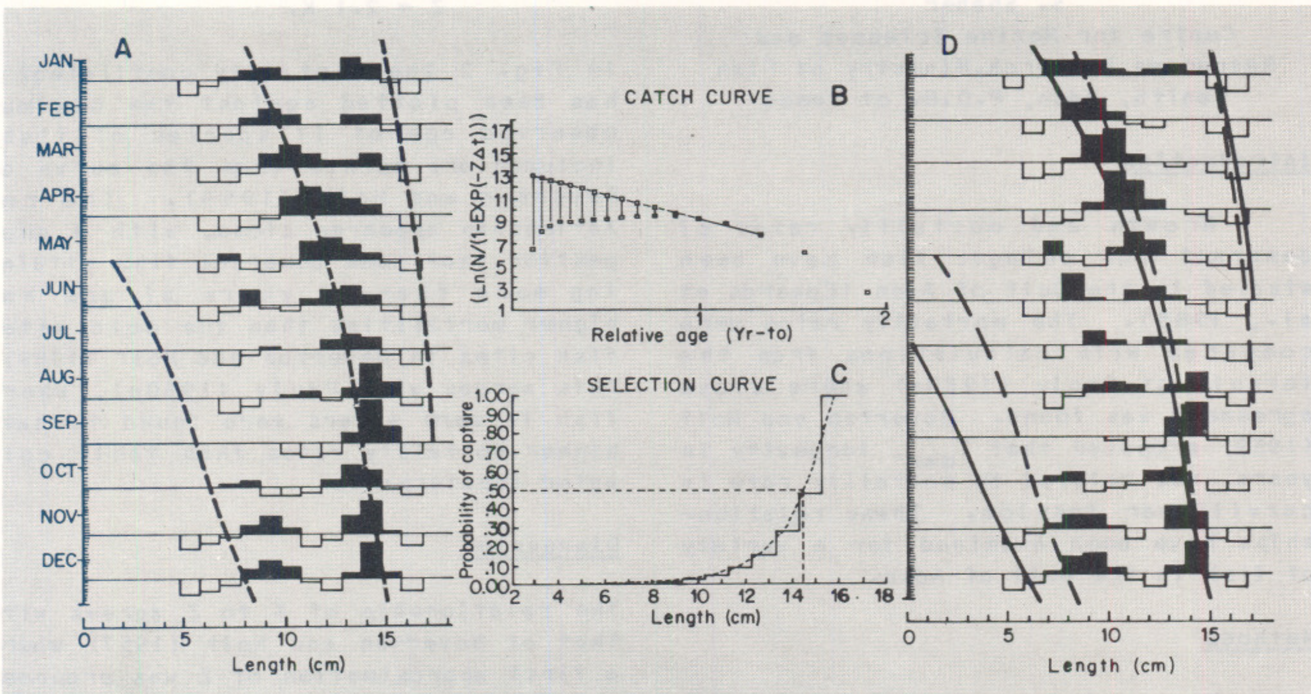


Fig. 1. Definitions and interactions of recruitment, selection and resultant curves. Note that a given C value is simply the product of the A x B values for the corresponding length (L). Fig. 2. *Left:* growth curve for Peruvian anchoveta, as derived from uncorrected data. *Center, upper figure:* catch curve, with backward projection as used to estimate probabilities of resultant curve. *Center, lower figure:* resultant curve, as used to correct original length-frequency data. *Right:* comparison of initial growth curve (dotted line) with second growth curve (solid line). Note steeper growth curve, due to shift of peaks toward the left (see also text).



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RELATIONSHIPS BETWEEN GROWTH, MORTALITY AND MAXIMUM OBSERVED AGE OF FISH IN THE GULF OF ADEN

by
R.R.C. Edwards
UNESCO, P.O. Box 1188, Aden,
P.D.R. of Yemen

and

S. Shaher
Centre for Marine Sciences and Resources Research, Ministry of Fish Wealth, Aden, P.D.R. of Yemen

Introduction

Growth and mortality rates of demersal and pelagic fish have been studied in the Gulf of Aden (Edwards et al., 1985). The mortality rates were compared with calculations from the formula of Pauly (1980a) where close agreement was found. Beverton and Holt (1959) proposed that T_{max}, longevity in years, was related to mortality rate in curvilinear fashion. These relationships have been examined for a variety of fish in the Gulf of Aden.

Methods

Demersal and pelagic fish were trawled during 580 hours from R/V Ibin Magid, Aden, and R/V Dr. Fridtjof Nansen, Bergen. Fish were separated by species, then measured and weighed. Age was determined from sections of vertebrae (Edwards et al., 1985). Mortality rates were calculated from numbers of fish at age in random samples (Pauly, 1980b). This was compared with the formula of Pauly (1980a):

$$\log M = -0.0066 - 0.279 \log L_\infty + 0.6543 \log K + 0.4634 \log T$$

where M is the coefficient of natural mortality and L_∞ and K are growth parameters. The average water temperature, T, is 28°C in the Gulf of Aden. Only data from unfished areas have been used in the results given here.

Results

The values obtained for K have been plotted against values for Z in Fig 1. Where length frequency data were insufficient, values from Pauly (1980a) have been used for an estimate of Z. The high values of K and Z were for small pelagic fish (e.g. oil sardines and scads) whereas the low values were for large demersal fish (e.g. groupers). The relationship was linear, where

$$Z = 2.1\ K.$$

In Fig. 2 the mortality coefficient Z has been plotted against the maximum observed age of 17 species of fish. Included are points from the curve of Beverton and Holt (1959). The relationship appeared close, with a suggestion that some demersal fish attaining more than 10 years of age had higher mortalities than the cold water fish cited in Beverton and Holt (1959). This agrees with Pauly (1980a), where fish in warm waters were found to have higher mortality rates than their cold water counterparts.

Discussion

The relationship of K to Z agrees with that of Beverton and Holt (1957) where a first approximation of Z was proposed as 2K. The small pelagic fish with short life span had high values of Z around 1.0 for a T_{max} of 5 years, whereas larger demersal fish had values of Z between 0.2 and 0.4 for life spans between 12 and 21 years.

The good agreement with Pauly (1980a) in Fig. 1 supports the estimate of mortality using L_∞, K and water temperature. It is also suggested here that the growth factor K alone may be used for a first approximation of Z in the Gulf of Aden, before L_∞ has been accurately determined.

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