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Graphical Representations of ELEFAN I Response Surfaces*

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Abstract

Graphical representations of the response surface of the ELEFAN I software for estimation of the von Bertalanffy growth parameters L_∞ and K are given, based on length-frequency data on *Engraulis ringens, Upeneus moluccensis* and *Sarda chiliensis*.

These 3D plots of a goodness-of-fit index *vs.* L_∞ and K, obtained using a CRAY XMP/48 supercomputer, illustrate several problems associated with parameter estimation using ELEFAN I and point to possible solutions.

Introduction

The method for the estimation of growth parameters (especially L_∞ and K) implemented in successive versions of the original ELEFAN I program of Pauly and David (1981) implies the comparison of numerous growth curves (defined by a distinct pair of L_∞, K values) in terms of how well they fit the length-frequency data at hand.

The goodness-of-fit index used for these comparisons is the ratio of two numbers:

(i) ESP, the explained sum of peaks, i.e., the sum of the scores or "points" associated with those peaks in a set of length-frequency (L/F) data that are hit by a given growth curve, and

(ii) ASP, the sum of all scores (i.e., peaks) "available" in that same set of L/F data (Pauly and David 1981).

[To avoid negative values, recent versions of ELEFAN I use $R_n = 10^{ESP/ASP}/10$, rather than ESP/ASP as goodness-of-fit index (Pauly 1987), a point not further discussed here].

Because the first versions of ELEFAN I were implementations on very slow microcomputers (TRS-80 Model I, Apple II, etc.), complete response surfaces (i.e., tables of ESP/ASP for ranges of L_∞, K values) were not output and used for identification of the best pair of L_∞, K values. Rather a direct search routine was used which, however, often failed to converge to a single set of estimates (see below for reasons). Hence, the suggestion was made by various colleagues who examined the ELEFAN I program to add the output of response surfaces to the ELEFAN I program (see Shepherd et al. 1987).

This advice was followed and response surfaces are now routinely analyzed by users of ELEFAN I (see, e.g., Peñaflor 1988; Murray and Nichols 1990). To support such analyses, we present here a number of three-dimensional ("3D") representations of typical response surface, in the hope that their general features will help users of ELEFAN I better understand the logic of this approach. We also hope that this will help users avoid some of the pitfalls we noted while teaching at a training course in Corvallis, Oregon, USA (August 1986) and at the end of which we decided to perform the work presented herein.

Materials and Methods

The sources of length-frequency data analyzed here are given in Table 1. The analyses were conducted with a CRAY XMP/48 supercomputer operated by the San Diego Supercomputer Center. We adapted for Cray FORTRAN a version of ELEFAN written in FORTRAN by Per Sparre (in Sims 1985) and revised by Thiam (1986).

No attempt was made to optimize the code for the CRAY to make full usage of its parallel proces-

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sing capabilities. Such optimization can typically increase the running speed of a FORTRAN program by a factor of 50 to 100, but the speed of the unoptimized code was already fast enough to conduct several runs in one sitting. The real-world time (as opposed to the computer processor time) for one analysis with a 50 by 50 table of values of ESP/ASP varied from 1 minute to as much as 15 minutes depending on the priority set and on how occupied the computer system was with other users. These tables were then plotted as three-dimensional response surfaces using a graphical utility, DISPLA, available on the CRAY.

Results and Discussion

Shepherd et al. (1987) wrote with respect to the outputs of ELEFAN I and of the SRLCA program of Shepherd (1987) that:

"It has become apparent that a single point estimate of the growth parameters rarely results from the analysis of size composition data but rather a range of K and L_∞ values are produced over a plateau on the goodness-of-fit criteria response surface.

As an example, Table 2 presents the response surface produced when Shepherd's method is applied to monthly 1982 size composition data of Otolithes argenteus *from*

Table 1. Details of the length-frequency files analyzed in this contribution.

Family/Species	Sampling location	Sampling year (n = months covered)	Source
Engraulidae			
Engraulis ringens	Peru, northern/central stock	1969 (9)	Tsukayama and Palomares (1987; p. 101)
Engraulis ringens	Peru, northern/central stock	1976 (11)	Tsukayama and Palomares (1987; p. 105)
Mullidae			
Upeneus moluccensis	Philippines, Ragay Gulf	1980 (7)	Morgan and Pauly (1987; p. 377)
Scombridae			
Sarda chiliensis	USA, California Coast	1973(12)	Campbell and Collins (1975; p. 190)

Table 2. Table of score function resulting from length composition analysis by the SRLCA program of Shepherd (1987) for *Otolithes argenteus* data from Kuwait waters 1982 (adapted from Shepherd et al. 1987); the large shaded areas with values > 25 is that with "best" growth parameters; the smaller areas with values > 20 (shading) and values > 10 (shading) are harmonics.

	Value of K (year^{-1})										
L_∞ (cm)	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60
40	4.1	4.5	3.7	5.7	3.7	3.5	9.6	14.1	12.7	9.5	12.0
45	2.1	2.8	3.5	3.5	*12.8*	*11.3*	*11.1*	11.9	11.3	11.2	15.1
50	3.9	4.9	4.8	*11.3*	*12.3*	10.9	10.2	14.4	13.3	16.6	21.0
55	1.7	1.8	8.5	*12.6*	8.3	11.5	11.1	20.5	23.6	24.6	23.7
60	3.3	5.8	*12.2*	9.8	9.3	15.1	23.0	25.9	19.7	20.7	24.9
65	7.0	5.2	8.7	8.6	13.4	25.1	19.6	*25.6*	*27.5*	*25.1*	*30.8*
70	2.3	11.1	10.4	9.5	21.2	22.2	*28.5*	*28.5*	23.2	16.4	8.0
75	5.5	7.7	9.0	20.0	21.4	*30.0*	*30.0*	22.6	12.2	5.8	13.2
80	3.3	9.6	12.8	18.0	*29.5*	*32.3*	23.0	10.6	9.0	19.3	*29.7*
85	8.7	15.5	16.8	24.0	*34.6*	*26.1*	11.5	10.6	22.2	*33.2*	42.7
90	7.6	3.3	15.8	*32.8*	*31.9*	15.5	9.8	*22.4*	34.3	44.2	52.2

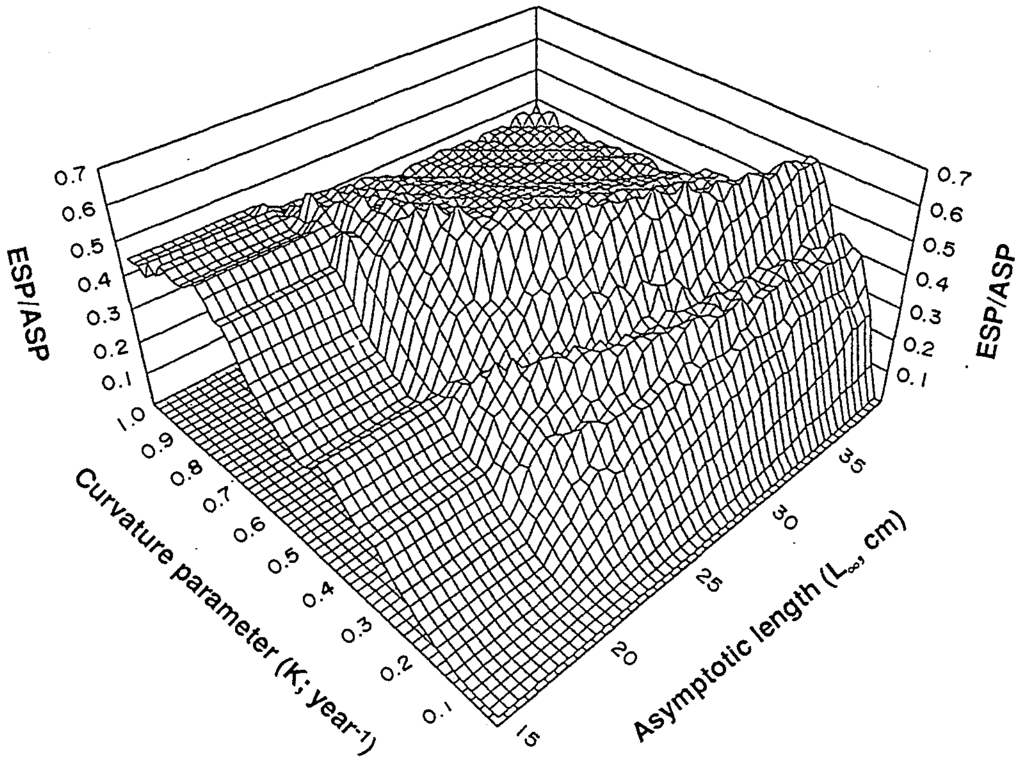

Fig. 1. ELEFAN I response surface, obtained by fitting data on Peruvian anchoveta *E. ringens* (L/F data for 1968, see Table 1); note numerous small peaks on plateau of high ESP/ASP values, and smaller harmonics (ripples of relatively high values of K).

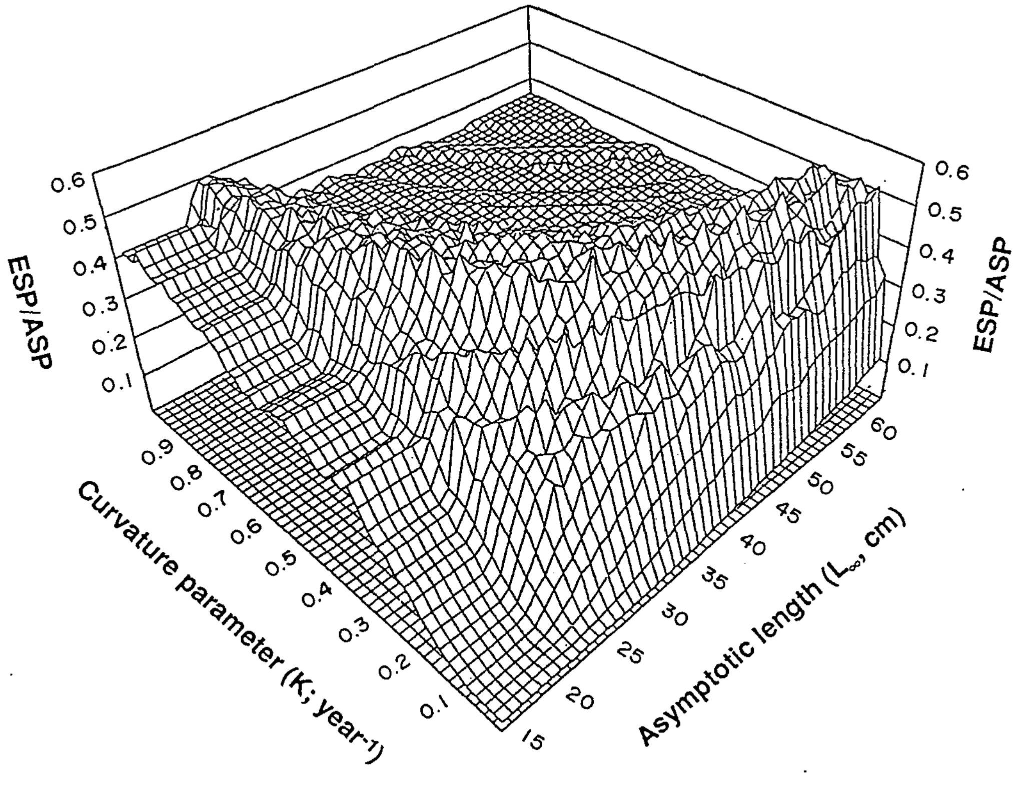

Fig. 2. ELEFAN I response surface, obtained by fitting data on Peruvian anchoveta *E. ringens* (L/F data for 1976, see Table 1); note numerous small peaks on plateau of high ESP/ASP values and smaller harmonics (ripples of relatively high values of K).

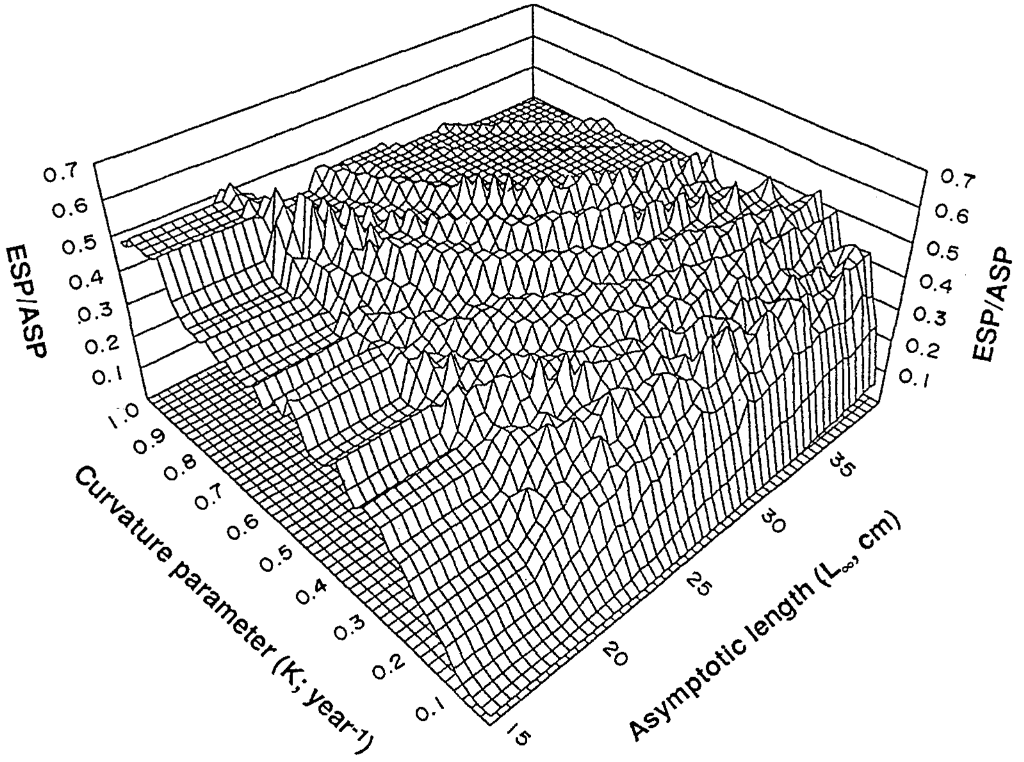

Fig. 3. ELEFAN I response surface, obtained by fitting data on goldband goatfish *Upeneus moluccensis* (see Table 1); note numerous small peaks on plateau of high ESP/ASP values, and smaller harmonics (ripples of relatively high values of K).

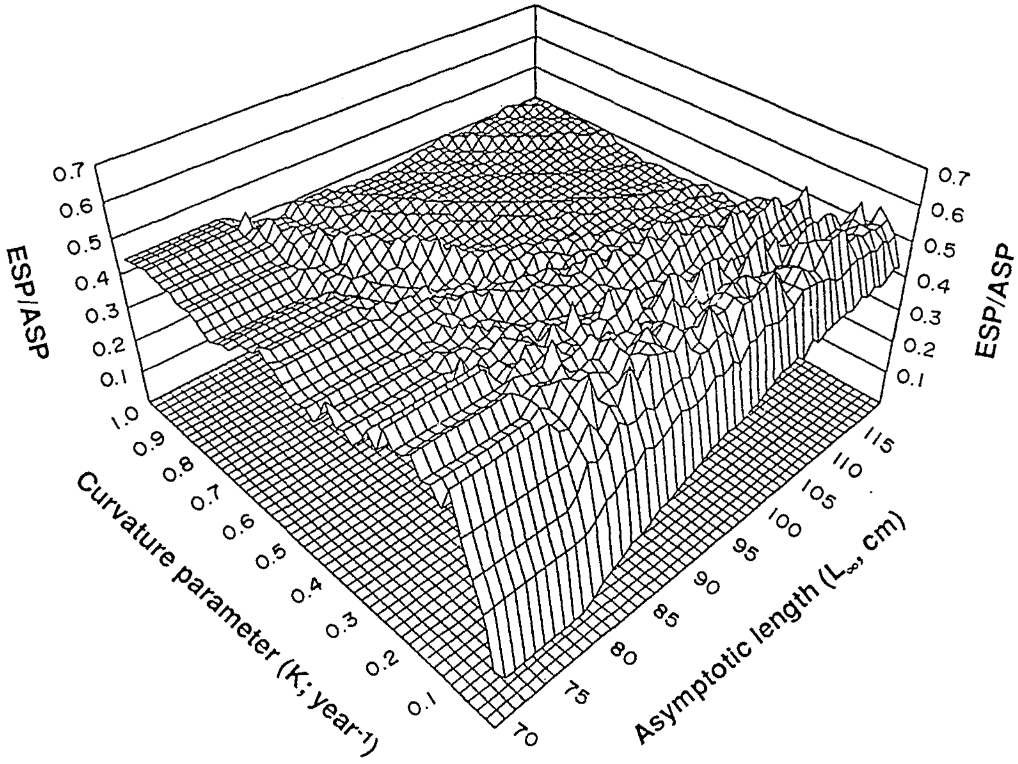

Fig. 4. ELEFAN I response surface, obtained by fitting data on bonito *Sarda chiliensis* (see Table 1); note numerous small peaks on plateau of high ESP/ASP values, and smaller harmonics (ripples of relatively high values of K).

Kuwait. Three plateaus resulted (indicated in Table 2) from which it is not possible to distinguish the correct growth parameter combination on the basis of the length data alone. Additional data are, therefore, required in this example, in order to locate the plateau upon which the correct parameter combination may be found. On the basis of length-at-age data, the correct combination appears to be in the region of $L_\infty = 60$, $K = 0.28$.

It is interesting to note that in Table 2, successive plateaus are produced about multiple values of K. This harmonic property of Shepherd's method appears common and may be a result of mismatching modes. The evaluation of such mismatching may be examined if a knowledge of the number of recruited cohorts per year is available, or if other (e.g., age-at-length, tagging) data exist.

It is, therefore, apparent that an examination of the goodness-of-fit response surface is an essential element in any assessment technique utilizing size composition data (and should also be examined for datasets which utilize age or tagging data) since this surface will contain at least qualitative information on the confidence region of the parameter values and their degree of interdependance."

Figs. 1 to 4 very nicely illustrate the "plateaus" and "harmonics" mentioned by Shepherd et al. (1987) and support their point that it is not L_∞ and/or K which are estimated by ELEFAN I (or SRLCA), but the property, for any set of L_∞ and K values, to generate jointly a given growth curve.

As might be seen on Figs. 1-4, "harmonics" (i.e., "ripples", with relatively high goodness of fit left and/or right of the central plateau of high values) occur with ELEFAN as well as with SRLCA. However, we consider these to be less of a problem than the fact that the plateau itself is not flat, but consists of a vast number of small peaks, none of which is markedly higher than the other.

Thus, there is a distinct need, when using ELEFAN I to "fix" somehow one of the two growth parameters (i.e., to select which part of the "plateau" is going to be used to describe the data at hand).

Given the nature of L_∞ and K, it is the former which is least difficult to estimate independently. "Fixing" L_∞ can be done, e.g., by using the largest fish as reference point (e.g., $L_{max} \approx L_\infty$, or $L_{max}/0.95 \approx L_\infty$ as suggested by Beverton 1963), or better through the (related) methods of Powell (1979) or Wetherall (1986). The properties of the Wetherall method have been well investigated (see Isaac 1990; Somerton and Kobayashi, this issue), and it appears as the method of choice to overcome the above-mentioned problems. Other approaches that might be considered for the analysis of ELEFAN I (and SRLCA) response surfaces involve fitting of trend surfaces, or through various smoothing algorithms, including "kriging" (Davis 1973), such as to allow a consistent identification of the area where the optimum is located. This will be investigated in a future contribution of the second author.

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