Age- or length-based methods of growth estimation. What drives the choice?

G.M. Pilling and A.S. Halls

Abstract

Based upon a global comparison of over 400 fisheries, the Principal Components Analysis (PCA) methodology was used to identify factors affecting the choice of growth estimation methods. Of the six factors examined, the growth rate (K) and asymptotic length (L_∞) explained most of the variations. Financial resources, i.e., Gross National product (GNP), and latitude were also important factors.

Introduction

Growth and mortality model parameter estimates required for analytical fisheries management models are commonly made from either age-at-length data ("age-based" methods) or the analysis of length frequency data ("length-based" methods). Mark and recapture methods may also be used. However, this approach tends to be less common in tropical fisheries, possibly due to a lower probability of returns in artisanal reef fisheries when compared to industrial fisheries.

The utility of length- compared to age-based methods is a contentious issue (Hilborn and Walters 1992; Pauly 1994). Whilst age-based methods are generally regarded as being less prone to bias, particularly when applied to long-lived, slow-growing species (Langi 1990; Mees and Rousseau 1997), length-based methods require less expertise, fewer resources and may be more successful when applied to faster growing species which show distinguishable modes in their length-frequency distributions.

Pilling et al. (1999) concluded that more accurate and reliable management of the relatively long-lived, slow-growing tropical lethrinid *Lethrinus mahsena* can be achieved by using age-based rather than length-based parameter estimation techniques. A UK Department for International Development (DFID)-funded study is currently underway to assess whether similar conclusions apply to species with a range of different life history strategies. Based upon a global comparison of fisheries, this paper seeks to identify potentially important factors, including the life history strategy of target fish, which influence the choice of growth parameter estimation methodology.

Materials and methods

Biological, technical and country-specific variables postulated to affect the choice between age- and length-based growth estimation methods (Table 1) were assembled for 441 fisheries located throughout the world (Figure 1).

Ordination of these data by the Principal Components Analysis (PCA) methodology was used to determine which factors influence the choice of age- or length-

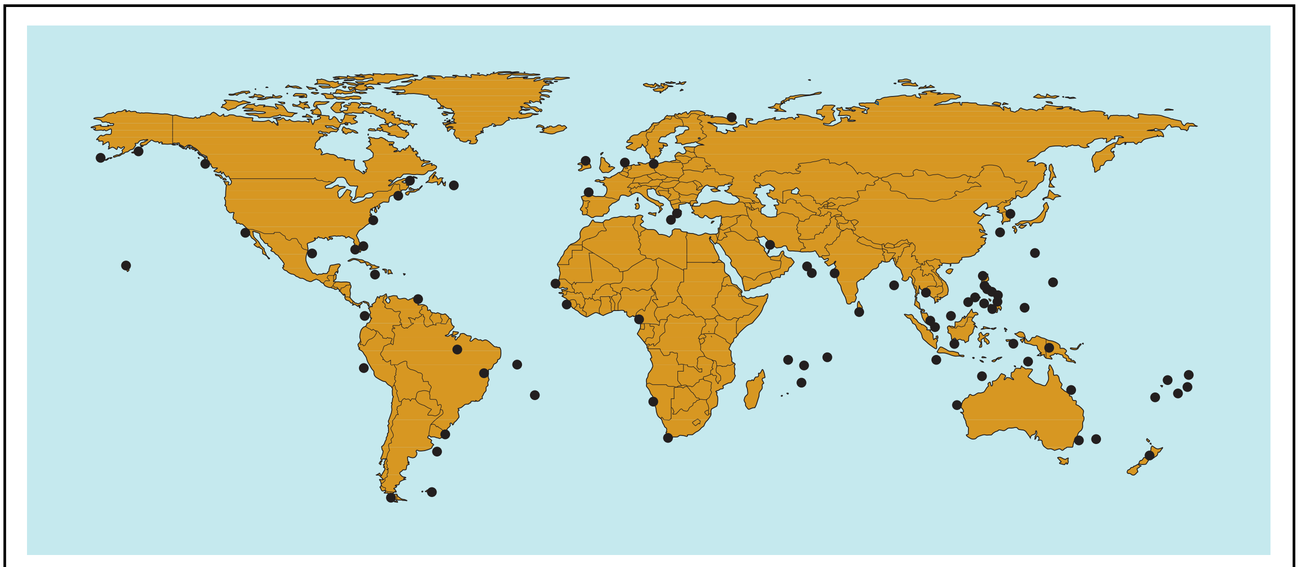

Fig. 1. Distribution of the 441 fisheries for which data were collected for the PCA

based growth assessment methods. Where necessary, data were log transformed (x+1) to ensure normality. To achieve reliable and easily interpretable PCA ordinations, 100 samples were randomly selected from the database (50 corresponding to age-based assessments, and 50 to length-based assessments). The analysis was repeated using a second set of randomly sampled data to determine the effect of this sub-sampling procedure.

Results

The process of random sampling from the 441 stocks identified did not affect the results of the analysis. They are therefore presented for the first random sample only. The first two principal component axes explained 64 per cent of the variance in the set of factors examined. The majority of separation between stocks managed on the basis of age- and length-based growth parameter estimates was along the PC1 axis (Figure 2). Factor loadings on PC1 were highest for K and L_∞ (Table 2), indicating that the choice of assessment method is based largely upon the growth characteristics of the stock.

Length-based methods are generally used for species exhibiting faster growth rates (K) and lower L_∞ values (Figure 3). Conversely, age-based methods appear to be employed for larger species with slower growth rates.

These results may simply reflect bias associated with length-based methods that tend to over-estimate K and underestimate L_∞ particularly for long-lived, slow growing species with relatively high levels of individual variability in growth (Pilling et al. 1999).

The PCA was, therefore, repeated after omitting the growth variables (Figure 4). The first two principal component axes explained 69 per cent of the variance in the remaining data. The majority of separation between fisheries managed on the basis of length- or age-based growth parameter estimates was again along the PC1 axis (Figure 4). The factor loadings indicate that the Gross National Product (GNP) and Latitude are largely responsible for this separation (Table 3). Age-based methods tend to be employed in countries with high GNP or at high

Table. 1. Biological, technical and country-specific variables assembled for each fishery

Variable	Details
Gross National Product (GNP) of country	in $ billions, from the World Bank Development Indicators, 2000. Dependent territories were given the GNP of their "parent" country.
Latitude of stock assessed	absolute value used (i.e., distance from equator, rather than hemisphere in which the stock was located).
Most advanced stock assessment method used to inform management	exploitation rate (F/Z), yield-per-recruit, or VPA/cohort analysis (in order of increasing complexity).
Growth estimation method	length- or age-based
Von Bertalanffy growth parameter L_∞ of target stock	from FishBase* for actual stock or nearby stock.
Von Bertalanffy growth parameter K of target stock	from FishBase for actual stock or nearby stock.
Trophic level of target species	from FishBase for actual stock or nearby stock.

* - *www.fishbase.org*

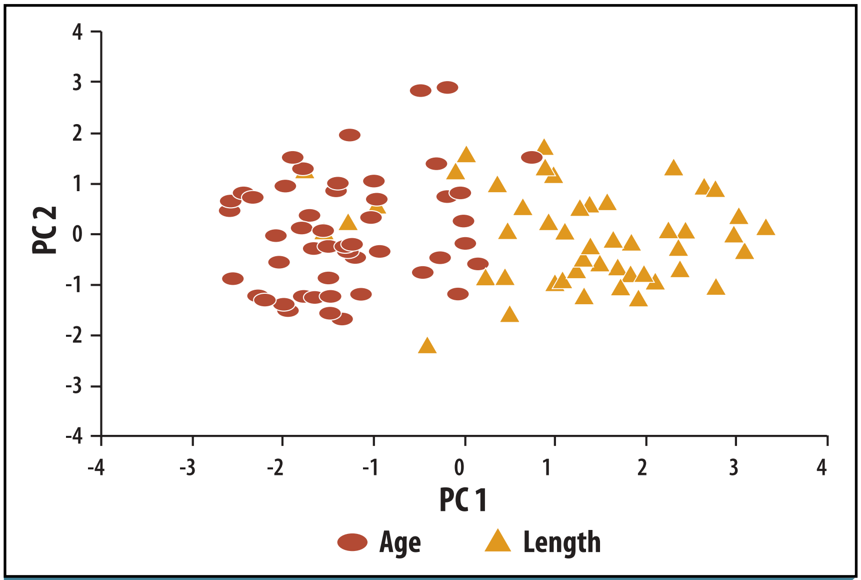

Fig. 2. Two-dimensional PCA ordination of variables postulated to affect the choice between age- and length-based methods

Table. 2. Co-efficients in the linear combinations of variables in the Principal Components. The first two variables with the highest loading on each Principal Component are in bold

Variable	PC1	PC2
GNP	0.372	0.379
Latitude	0.413	0.359
Assessment method	0.383	0.407
L_∞	**0.448**	**0.420**
K	**0.518**	0.206
Trophic level	0.275	**0.586**

Table. 3. Co-efficients in the linear combinations of variables in the Principal Components. The first two variables with the highest loading on each Principal Component are in bold

Variable	PC1	PC2
GNP	**0.570**	0.075
Latitude	**0.567**	0.060
Assessment method	0.427	**0.682**
Trophic level	0.414	**0.725**

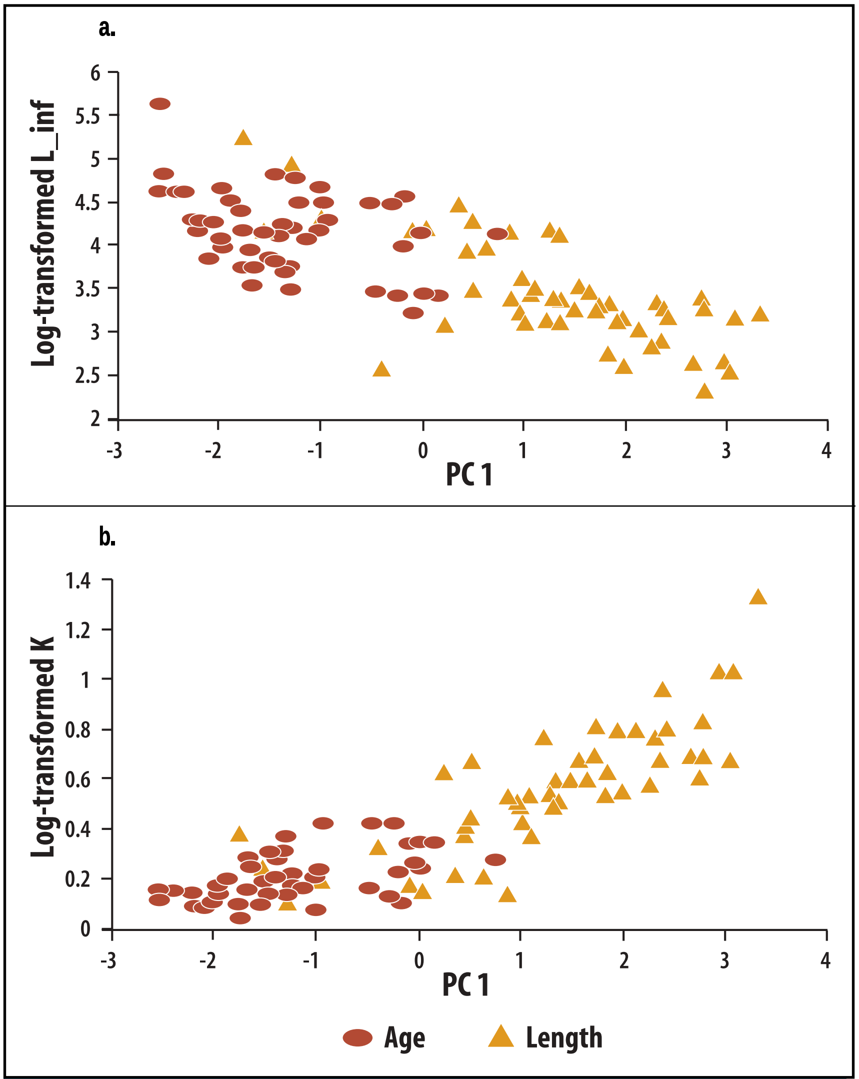

Fig. 3. Relationship between PC1 and log-transformed a) L_∞ and b) K

latitudes. However, GNP and latitude are also positively correlated (R = 0.46).

Discussion

Of the six factors examined, growth rates (K) and asymptotic length (L_∞) explained most of the variation in the growth estimation method employed. The use of length-based methods is generally associated with small, fast growing species whilst age-based methods are more commonly used for larger species with slower growth rates. Assuming that the growth parameter estimates used in this analysis are unbiased, these results suggest that, on the basis of current knowledge, methods are currently appropriately selected according to the life history characteristics of the stocks (Isaac 1990; Gulland & Rosenberg 1992) as well as largely influenced by the overall wealth of the nation. However, this also implies that where financial resources might be limited, especially at low latitudes, the management of large, slow growing fish species important to the livelihoods of tropical artisanal fishers may be sub-optimal if length-based methods have been applied (Pilling et al. 1999; 2000).

The results generated by the on-going DFID-funded study will determine whether the use of age-based assessment methods result in improved management for all species, or merely those with particular life history strategies.

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G.M. Pilling is from CEFAS, Fisheries Laboratory, Pakefield Road, Lowestoft, NR33 0HT, United Kingdom (email: g.m.pilling@cefas.co.uk) and **A.S. Halls** is from MRAG Ltd., 47 Prince's Gate, London, SW7 2QA, United Kingdom.

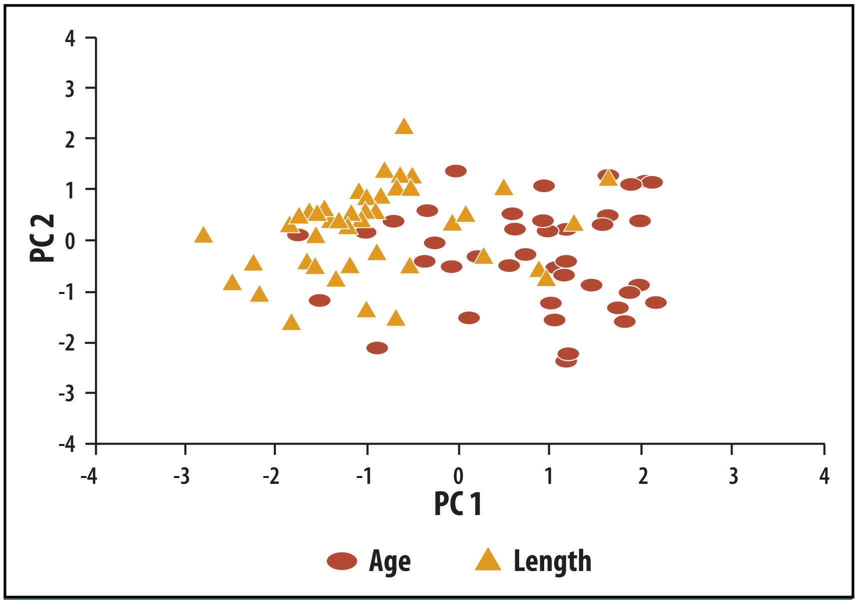

Fig. 4. Two-dimensional PCA ordination of stock characteristics where growth was assessed using length- or age-based methods