SCRS/2016/208 Collect. Vol. Sci. Pap. ICCAT, 73(8): 2754-2758 (2017)

SIZE BASED INDICATORS FOR DATA LIMITED STOCKS

Laurence T. Kell[1], Kell L.T., Abid N.[2], Baibat S.[3], and Frédou F.L.[4]

SUMMARY

Small tuna length frequency data are compared to indices based on life history parameters, the asympotopic length L∞, length at which 50% of individual are mature (L50) and Lopt, the size at which a cohort reaches its maximum biomass.

RÉSUMÉ

Les données de fréquence des tailles des thonidés mineurs sont comparées aux indices reposant sur des paramètres du cycle vital, la longueur asymptote (L∞,) la taille à laquelle 50% des poissons sont matures (L50) et la taille à laquelle une cohorte atteint sa biomasse maximale (Lopt)).

RESUMEN

Los datos de frecuencias de tallas de pequeños túnidos se comparan con los índices basados en los parámetros del ciclo vital, la talla asintótica L∞, la talla en la que el 50% de los ejemplares son maduros (L50), y Lopt, la talla en la que una cohorte alcanza su biomasa máxima.

KEYWORDS

Catch-at-size; Indicators; Length frequency; Life history; Small tuna;

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[1] ICCAT Secretariat, C/Corazón de María, 8. 28002 Madrid, Spain.

[2] National institute for fishery reserach (INRH), regional centre of Tangier

[3] INRH, centre régional de Dakhla. Chef du laboratoire

[4] Universidade Federal Rural de Pernambuco (UFRPE), Departamento de Pesca e Aquicultura, Av. Dom Manuel s/n, Recife, Pernambuco, Brazil, 52171-900.

Introduction

Material and Methods

Data

An example dataset, teleost, is provided as part of the package; this includes values for the Von Bertalanffy (1957) growth equation parameters k the rate at which the rate of growth in length declines and the asymptotic length $L \infty$, $L 50$ the length at which 50% of individuals attain gonadal maturity for the first time and b the exponent of the length weight relationship.

The values and the relationship between them are plotted in **Figure 1**. The data are then summarised using principle components analysis (PCA) in **Figure 2**; the ellipses are the 95% normal probability densities, blue points are scrombidae and the black point is albacore. The first principal axis maximizes the variance, as reflected by its eigenvalue. The second component is orthogonal to the first and maximizes the remaining variance. The first two component account for over 70% of the variance and therefore yield a good approximation of the original variables. They therefore correspond to the interesting dynamics and lower ones to noise. The main features of the data as given by the first component are a contrast between large fish ($L \infty$), which mature at larger relative size ($L 50 : L \infty$) and small fish that mature at relatively small sizes. The second component contrasts thin streamlined species with more sedentary types (i.e. b the exponent of the length weight relationship).

Examples

The examples here are provided to illustrate the use of the package. The code full documentation can be found in the package documentation.

Equilibrium Dynamics

The first example simulates the equilibrium, i.e. the expected, dynamics for a population based on albacore and a fishery that selects mature fish. The equilibrium dynamics were derived by combining spawner per recruit and stock recruitment relationship.

The assumed stock recruitment relationship has a big impact of the dynamics, although there is seldom sufficient information in fish stock data sets to determine either the function form or the parameters of the relationship. Five alternative forms, all with steepness of 0.75 and virgin biomass of 1000, are plotted in **Figure 3**.

Maximum sustainable Yield

Reference points such as MSY and B_{MSY} are found at found at the maxima of the production curves i.e. plots of the equilibrium yield against spawning stock biomass (SSB). These are shown in **Figure 4**

Population Growth Rate

The population growth rate at small population size (r) is equivalent to level of exploitation that would drive a population to extinction. Since a population can not replenish itself if the harvest rate is greater than r. In fisheries terminology r corresponds to a limit harvest rate reference point and can be calculated from the Leslis Matrix (Leslie, 1945).

Global MSY

The maximum potential yield of a cohort is taken at a size (or age) where the gains due to growth are equal to the losses due to natural mortality. Although seldom possible to achieve in practice, calculating the length at which this would occurs (L_{opt}) provide a reference point for growth overfishing.

Density Dependence

To evaluate sustainability requires determining the productivity of a population and its response to perturbation. The stability of a population is strongly influenced by its life history characteristics and the form of density dependence.

Production functions, were therefore calculated for density dependence natural mortality and fecundity and contrasted with the usual assumption made in stock assessment that density dependence only acts in recruitment **Figure 6**. Assuming density dependence in M or fecundity results in an increase in MSY, B_{MSY} and F_{MSY}

Next the response of a population to overfishing is evaluated in **Figure 7** and for rebuilding in **Figure 8**, for density dependence in stock recruitment, natural mortality and fecundity. The response to overfishing is similar across processes, however, rebuilding trajectories depend on the form of density dependence. Predicting recovery trajectories based on time series obtained from a period of increasing exploitation is likely to be problematic.

Stochasticity

Stochasticity has important impacts on population dynamics and can be of various forms, e.g. depending on whether it varies due to annual changes in the environment or by cohort where conditions at an earlier age have an effect on later age classes. Examples of stochastic age effects are shown in **Figure 9** and cohort effects in **Figure 10**.

Next populations were simulated for three levels of fishing mortality (0, 1 and 3 times F_{MSY}) and two selection patterns (corresponding to juvenile or mature age classes) for cohort effects in M and fecundity and autocorrelation in recruitment. The time series of SSB are shown in **Figure 11**. The spectral analysis performed for these time series **Figure 12** shows that all time series are dominated by low frequencies (i.e. long-term variations) that result from cohort resonant effects, i.e. the propagation of stochastic recruitment into the age-classes and that led to a smoothing of the SSB (see Bjoernstad *et al*., 2004).

Model misspecification

One of the main uncertainties in stock assessment is the difference between models and reality. Therefore we include a model misspecification example, where in the simulated population natural mortality is a random variable, but is assumed to be constant at age in the virtual population analysis used to estimate numbers-at-age **Figure 13**. The effect is to assume that recruitment is more variable than it actually is.

Management Strategy Evaluation

FLife can be used to conduct Management Stratagy Evaluation where a simulation model, i.e. operating model, is used to test for example a Harvest Control Rule (HCR). An empiriacl HCR has been adopted for southern bluefin tuna (SBT) to set Total Allowable Catches (TACs). The HCR is based on year-to-year changes in indices of relative stock abundance. Before the HCR was implemented the HCR parameters had to be tuned to meet management objectives using management strategy evaluation (MSE). **Figure 14** shows an example MSE using an empirical HCR and an Operating Model generated using Flife.

Empirical Methods

Beverton and Holt (1956) developed a method to estimate life history and population parameters length data. Based on which Powell (1979) developed a method, extended by Wetherall *et al*. (1987), to estimate growth and mortality parameters. This assumes that the right hand tail of a length frequency distribution was determined by the asymptotic length L_∞ and the ratio between Z and the growth rate k. Plotting $\overline{L} - L'$ against L' provides an estimate of L_∞ and Z/k, since $L_\infty = -a/b$ and $Z/k = \frac{-1-b}{b}$.

If k is known then it also provides an estimate of Z (**Figure 15**).

Discussion

FLife has many potential uses e.g. for conducting Ecological Risk Assessments, estimating life history parameters from data, development of priors for use in stock assessment, building simulation model based on population and ecological processes and generating Operating Models for use in Management Strategy Evaluation.

The form of density dependence can affect overfishing and rebuilding trajectories. It is, however, difficult to determine whether density dependence is occurring and on what processes it acts using fisheries dataset (Sinclair *et al*., 2002). The main form of density dependence considered in stock assessment models, is the stock recruitment relationship, primarily as it is required to complete the life cycle. Other forms of density dependence may operate and it is necessary to use caution in selecting the type of density dependence, and specifying its parameters (Ginzburg *et al*., 1990).

Trends and fluctuations in populations are determined by complex interactions between extrinsic and intrinsic dynamics, While the dynamics of many marine fish are characterised by age-structured dynamics forced by stochastic recruitment i.e Cohort resonance. The resulting low-frequency fluctuations can potentially mimic or cloak critical variation in abundance linked to environmental change or overexploitation (Bjoernstad *et al*., 2004).

The tools available in FLife can help to develop robust management control rules by building OMs that can be used to evaluate the robustness to uncertainty about ecological processes.

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