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Red grouper: Regression and Chapman−Robson estimators of total mortality from catch curve data

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Introduction

The plot of catch (or abundance or proportion) at age is termed a catch curve. Analysis of catch curves provides a simple means of estimating total mortality rate (Z). Rarely is catch curve analysis alone used for management measures, as its simplifying assumptions are quite strong and rarely if ever met, but instead it serves as a method to understand results from more detailed models. Because catch curves rely on age data, they can reveal issues surrounding the observed age samples. The application of catch curve analysis in this report is primarily for diagnostic purposes.

The two most popular methods for estimating Z from catch curves are regression-based estimators (Quinn and Deriso, 1999) and the Chapman−Robson estimator (Chapman and Robson, 1960; Robson and Chapman, 1961). Perhaps the strongest assumption behind these methods is that the population is in steady state, i.e., that the age structure is stable through time as a consequence of constant recruitment and constant mortality. Both methods also assume that ageing error is negligible and that fish older than some known age are equally vulnerable to sampling. Performance of the two methods will vary across data sets, but in several studies, the Chapman−Robson estimator has been found more robust to violations of assumptions (Murphy, 1997; Dunn et al., 2002).

Methods

Regression estimator

Regression estimators use linear regression to fit the log-transformed numbers or proportions-at-age, under the common assumption of exponential population decay. Thus, the estimated slope from this regression gives an estimate of Z. The regression can be performed by either tracking a cohort through time or to a single year of data (i.e., a synthetic cohort). Regression estimators in this report rely on synthetic cohorts, constructed from proportions of catch at age (although results are identical if based on absolute numbers rather than proportions).

One issue that arises with limited sampling data is the presence of zeros. Because the regression analysis involves log-transformed data, zeros must either be removed prior to fitting the linear model or treated with a small, additive constant. Both approaches were examined in this study. In cases where a constant was added to zero data, the constant was assumed equal to the minimum nonzero value from that synthetic cohort.

Chapman−Robson estimator

The Chapman−Robson estimator is based on mean age ($\bar{a}$) above the recruitment age and the sample size (n),

$$Z = \log\left([1 + \bar{a} - 1/n]/\bar{a}\right)$$

This estimator is considered a minimum variance unbiased estimator (Chapman and Robson, 1960), with variance approximated by,

$$var(Z) \approx \frac{\left(1-e^{-Z}\right)^2}{ne^{-Z}}$$

Additional details

Both methods were applied to landings at age data from the headboat and commercial handline sectors. Synthetic cohorts were included if they met a minimum sample size criterion of 30 fish. Analyses were performed using the R statistical software package.

Both methods require specifying the age at which all fish are vulnerable to capture. Although this age is typically unknown *a priori*, examination of the data can indicate an appropriate starting age for the analyses, typically the modal age or the modal age plus one. Based on plots of age composition, we consider age four as being fully vulnerable for the headboat fishery, and age five for the commercial fishery. Thus for each data set, four different analyses were applied: regression estimator with zeros replaced by the minimum nonzero value, Chapman−Robson estimator with zeros replaced by the minimum nonzero value, regression estimator on original data (observed zeros removed to avoid undefined logarithms), and Chapman−Robson estimator on original data.

Results

Point estimates of total mortality rates suggest that Z generally ranges between 0.4 and 0.6, but with wide confidence intervals and with some point estimates well above or below that range. Assuming a constant natural mortality of M=0.14, which corresponds to the point estimate recommended by the Data Workshop's Life History Working Group, fully selected fishing mortality rates could be expected on the range of F = 0.26 to F = 0.46. As this approximation is only a rough guideline, annual values outside that range should not be surprising.

Literature cited

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Murphy, MD. 1997. Bias in Chapman−Robson and least-squares estimators of mortality rates for steady-state populations. Fish. Bull. 95:863−868.

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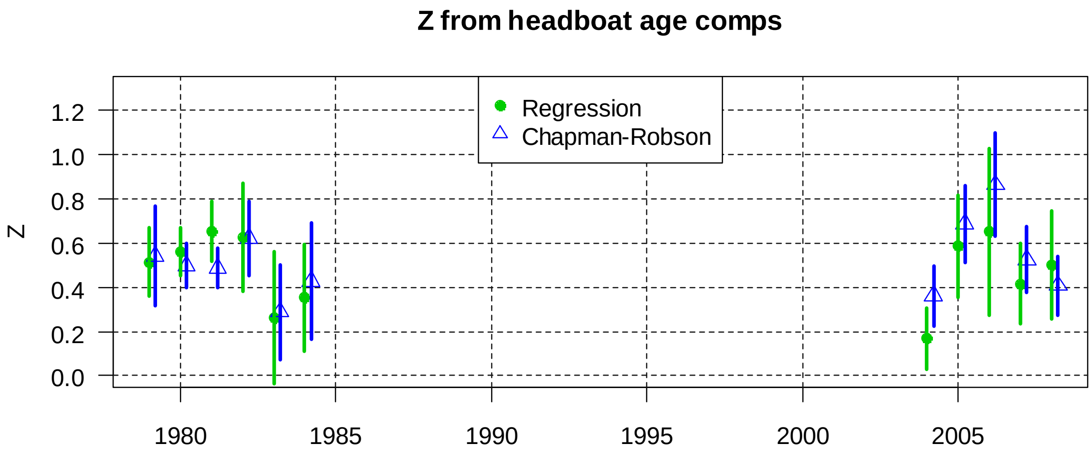
Figure 1. Red grouper: Total mortality estimates (Z) from catch curve data, with observed zeros replaced by the minimum nonzero observation. Analyses were conducted by year (i.e. using synthetic cohorts). Vertical lines represent 95% confidence intervals.



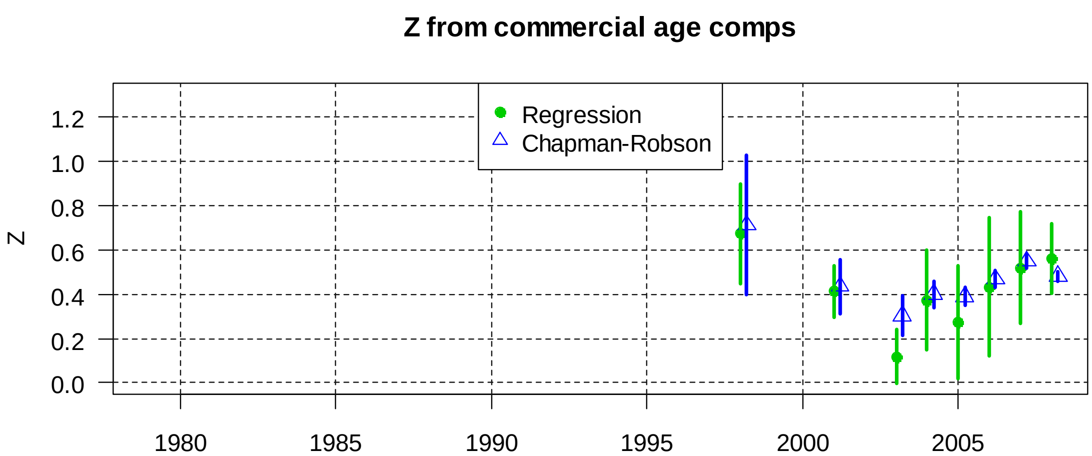


Figure 2. Red grouper: Total mortality estimates (Z) from catch curve data, with observed zeros removed for the regression estimator. Analyses were conducted by year (i.e. using synthetic cohorts). Vertical lines represent 95% confidence intervals.