Investigating the use of interview data regarding the illegal sector in the stock assessments for Abalone in Zones E and G

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Introduction

Over the last decade, the abalone resource in South Africa has come under severe fishing pressure, largely because of increased and unmitigated levels of illegal fishing. The unquantified illegal exploitation of this resource is a major impediment to our understanding of abalone population dynamics and the dependent management attempts. The implications of uncertainty surrounding the levels of illegal fishing are clear, leading to management based on models that incorporate poorly substantiated assumptions. Here we introduce an approach to stock assessment that can incorporate additional knowledge on the illegal sector, obtained through stakeholder interviews. It is hoped that the use of interview data in the stock assessment will not only increase the involvement of fishermen but improve the reliability of resource predictions.

Background to methods

Here we describe a Bayesian approach to the stock assessments in Zones E and G, which are currently based on a discrete Schaefer model of population dynamics:

$$y_{n+1} = y_n + ry_n\left(1 - \frac{y_n}{K}\right) - C_n^{COMM} - C_n^{REC} - pC_n^{POACH}$$

$$CPUE_n = q\left(\frac{y_n + y_{n+1}}{2}\right)e^{\varepsilon_n}$$

where y is the population biomass, r the intrinsic growth rate, K the carrying capacity, C is the catch and q the catchability coefficient. Observation error is assumed to have a log-normal distribution with $\varepsilon \sim N(0,\sigma^2)$. This model is identical to that used previously, except for the parameter p, which is used to adjust the illegal fishing intensity by scaling up or down its impact on biomass dynamics. Note that $p = 1$ for all years prior to 1999, because we expect recorded levels of illegal fishing to be less accurate after this year.

The fit of this model to observed CPUE values is measured using the negative log-likelihood:

$$lk(CPUE,C \mid r,K,p,q,\sigma) = \ln(\sigma) + \tfrac{1}{2}\ln(2\pi) + \frac{\sum_{n=1}^{n-1}\left[\ln(CPUE_n) - \ln\left(q\left(\frac{y_n + y_{n+1}}{2}\right)\right)\right]^2}{2\sigma^2}$$

with q obtained analytically:

$$q = \frac{1}{n}\sum_{n=1}^{n-1}\left[\ln(CPUE_n) - \ln\left(\frac{y_n + y_{n+1}}{2}\right)\right]$$

Given the small amount of available data, we assume (based on observations from other Zones) that $r = 0.2$. To estimate p and K within a Bayesian framework we estimate:

$$\Pr(p,K \mid CPUE,C) = \tfrac{1}{Z}\int lk(CPUE,C \mid p,K)\Pr(p)\Pr(K)dpdK$$

where Z is an unknown normalising constant. The integral is approximated by sampling from the prior distributions Pr(p) and Pr(K), calculating the likelihood for each combination of parameters (σ is estimated through minimisation of the likelihood function), and summing the likelihood contributions over discrete parameter intervals. Notably, the priors Pr(p) and Pr(K) are assumed to be uniformly distributed with p~U(1,10).

We used this approach to estimate p and illustrate the consequences of unknown levels of illegal fishing on biomass predictions.

Preliminary estimates of *p*

The posterior probabilities Pr(p|CPUE,C) for Zones E and G are shown in Figure 1. The means and Highest Posterior Densities (containing 95% of the marginal likelihood for p) for each zone are:

Zone E: p = 7.72 (2.74, 9.93)
Zone G: p = 6.38 (2.41, 9.72)

Model fit to the data is shown in Figure 2. The predicted CPUE values assuming our estimated values of p are shown alongside the fit assuming p =1 (i.e. the illegal catch is as recorded). The fit assuming estimated p values is clearly improved.

The impact of uncertain levels of illegal fishing on biomass predictions for abalone are shown in Figure 3. The predictions assuming p =1 are shown alongside predictions assuming our estimated values of p.

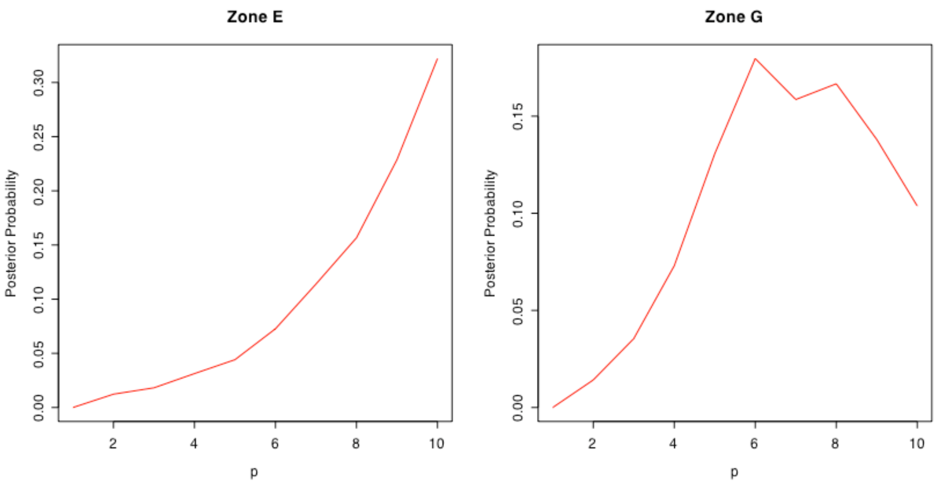

Figure 1. Posterior probability estimates of *p* for Zones E and G

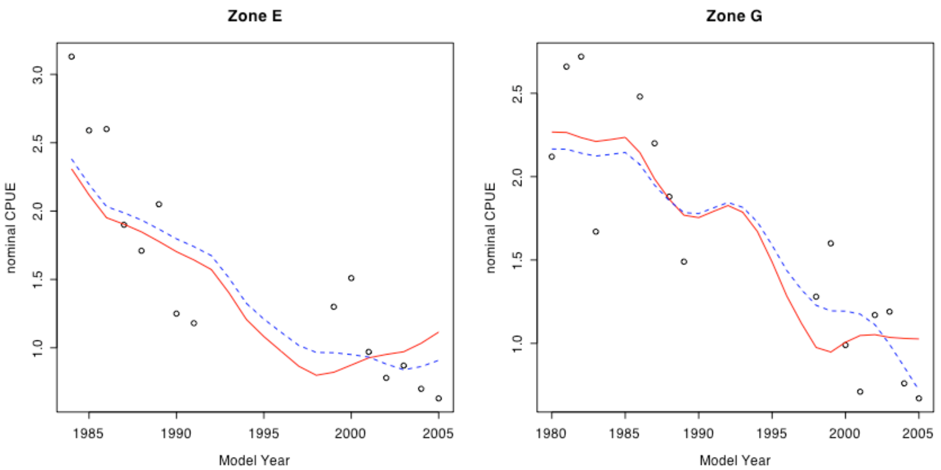

Figure 2. Predicted and observed CPUE values for Zones E and G. Observed CPUE values are shown as points. The lines represent predicted values (solid: *p* =1; dashed: *p* = mean of the posterior probability distribution)

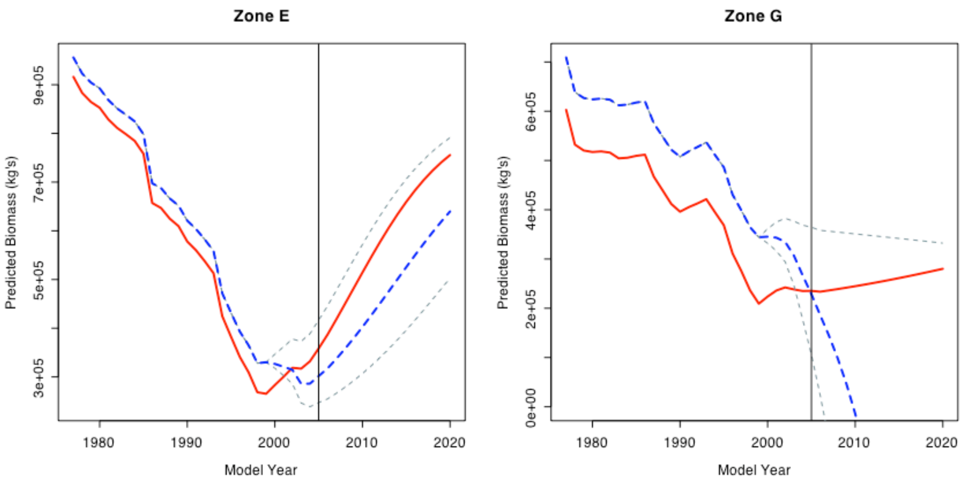

Figure 3. Biomass predictions for Zones E and G. Predictions assuming *p* =1 are shown as a solid line. Predictions assuming *p* equal to the mean of its posterior distribution, with their Highest Posterior Density intervals, are shown as dashed lines.

Conclusions from preliminary Results

Our results suggest that the levels of illegal fishing in Zones E and G have been underestimated ($p > 1$), with implications for predictions of biomass dynamics and the dependent management decisions. However, a great deal of uncertainty remains.

We have assumed *a priori* that p is uniformly distributed between 1 and 10. In other words, that there is an equally likely probability that it will take any value between the upper and lower bounds. Modifying this prior distribution would allow additional information (i.e. information other than catch and effort records) to be formally incorporated into the stock assessment procedure.

In this instance, we have concentrated on the parameter p, which scales the level of illegal catch recorded since 1999 for each zone. If information can be gathered on the likely value of this parameter, then it will improve our understanding of biomass dynamics. However, it is worth noting that the modeling framework can be extended to include a variety of information types pertaining to the illegal sector.

Proposal

It is proposed that interviews be carried out with key individuals in the legal and illegal sectors of the abalone fishery. If necessary small focus groups could also be formed, providing the opportunity for a broader selection of stake-holders to participate. The information gathered may assist in refining Bayesian priors and potentially provide information for the stock assessment model. If catch rate information was available then this could also be incorporated.

The information gathering process will explore the following key areas regarding illegally caught abalone:

- Quantity (including temporal changes)
- Catch rate
- Size composition
- Spatial distribution of effort

The proposed study should be regarded as a preliminary investigation into the viability of this approach and whether it is effective. Effectiveness would be measured by improved confidence in biomass predictions for each zone (i.e. a narrowing of the HPD intervals shown in Figure 3). If successful it could therefore provide the basis for future participatory stock assessments.