Stock assessment in South Africa – building on a consistent yet flexible approach

Éva Plagányi[1)], Anabela Brandão[1)], Doug Butterworth[1)], Carryn de Moor[1)], Jean Glazer[2)], Susan Johnston[1)], Rébecca Rademeyer[1)]

[1]MARAM, Dept. Mathematics and Applied Mathematics, University of Cape Town, 7701, South Africa; e-mail: Eva.Plaganyi-lloyd@uct.ac.za ; [2]Marine and Coastal Management, South Africa

Introduction

Fisheries stock assessments range from fairly simple deterministic models, through statistical catch-at-age models to Bayesian estimation for age-structured models. Statistical approaches are powerful tools for undertaking integrated analyses that are capable of incorporating and outputting the full statistical uncertainty. Here we summarise the stock assessment methodology applied to South Africa's major fisheries. Individual assessments are tailor made such that they are extremely flexible in allowing use of all standard data sources. The accompanying strongpoint is that for most of the major species the assessment models serve as Operating Models within a Management Procedure (MP) framework (Butterworth 2008). Abalone is currently the only of these resources not managed within a MP framework, although the squid MP is still under development.

Which stocks and models?

The most commonly applied approach in the region is that of Age Structured Production Models (ASPMs), which correspond to Statistical Catch-at-Age Analysis (SCAA) (e.g. Fournier and Archibald 1982) when the data fitted by an ASPM include catch-at-age information. The exceptions are the *J. lalandii* assessment which uses a size-structured model because of the large level of variability in the length-age relationship, and the *L. reynaudii* which uses a biomass dynamic model given difficulties in ageing squid. An ASPM approach was specifically chosen in preference to, for example, a Virtual Population Analysis (VPA). VPA requires catch-at-age data be available for all years and essentially reconstructs the history of each cohort, assuming that the observed information is known without error. In contrast the ASPM methodology is more flexible, in that it does not require catch-at-age data for all the years considered, and it can accommodate likely errors in such data by making assumptions about the selectivity-at-age of the catch.

The ASPMs developed range from fairly standard models to more complicated forms such as the recently developed species-disaggregated hake assessment (Table 1). The model incorporating the greatest level of spatial complexity is that for *H. midae* which simultaneously assesses five population components in five adjacent areas, as a means of reducing potential confounding between three sources of mortality.

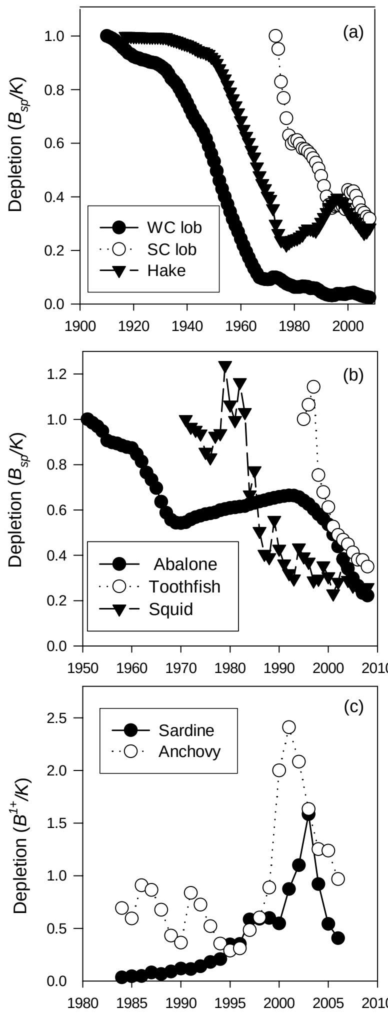

Fig. 1. Comparison of relative depletion (in terms of spawning biomass B_{sp} as a proportion of average carrying capacity K) for a) hake (two-species combined) and West and South Coast rock lobsters; b) abalone, toothfish and squid (as total biomass) and c) sardine and anchovy (in terms of 1+ biomass). Trajectories shown are either "best" assessments, median trajectories or joint posterior modes.

Status of the stocks

Figure 1 compares the relative depletions of each of the key stocks in terms of the spawning biomass (or similar) level relative to the pre-exploitation spawning biomass estimate (recognising that carrying capacity K is not necessarily the best reference level for stocks such as the pelagics). A broad overview suggests a correlation between how recently intensive harvesting of a stock commenced, and the rapidity of depletion of the stock. Although several stocks seem to have shown some signs of recovery during the 1980s, recent trends are mostly downward or stable. Anchovy have shown much greater levels of variability than sardine, with unanticipated record levels of both sardine and anchovy recruitment during the last decade having prompted the need for an earlier than planned refinement of the pelagic management procedure to allow the industry to take advantage of the (expected short-term) record biomass levels. West Coast rock lobster is currently most depleted (Table 1), although the carrying capacity for this latter resource in its formerly highly populated northern areas may have decreased over time. A better measure of the effectiveness of the current assessment and management methods is to consider resource status relative to the level twenty years ago (roughly the start development time of many of the assessments). Viewed this way, hake (the country's economically most valuable resource) is at approximately the same level, whereas the greatest relative depletion is for abalone (which is the most heavily impacted by illegal fishing) (Fig. 1).

Stock assessment challenges

Three major challenges, discussed below, are limited ageing data, the need to quantify illegal, unreported and unregulated (IUU) catches, and difficulties in reconciling conflicting data sources. Person-power shortages over recent years have led to routine ageing of hake and sardine falling well behind schedule, so that models have had to fit to length (with its lesser information content) rather than age composition data for some recent years. Some additional problems pertaining to ageing data are also being examined.

Given massive illegal takes in some fisheries, this aspect can dominate an assessment - a recent model estimate of the illegal catches of abalone was approximately eight times the formal 2007 commercial TAC. Multi-species interactions are impacting this fishery too. In line with an increasing global awareness of the importance of considering the ecosystem effects of fishing, several of the major South African assessment models and MPs are being extended to take greater cognisance of these effects.

An example of conflicting data sources is provided by the South Coast rock lobster fishery for which the CPUE data suggested a more optimistic appraisal than the catch-at-length data. The stock assessment approach has subsequently been developed to be both sex- and area-specific, with the CPUE and catch-at-length data split by sex and area, and the model now fits these disaggregated data series for each of three fishing areas. Time-varying selectivity functions were also developed and partly assisted in explaining the conflict in these data. There is a similar conflict for the Prince Edward Islands toothfish fishery, though there the CPUE data suggest poor status with the catch-at-length data indicating otherwise

Stock Assessment Successes

Successes include the excellent correlations between scientific advice and management action, stakeholder involvement and a good history of sustainable fisheries management. Over the past decade, the TAC recommendations for the major South African fisheries have almost without exception been based exactly on the outputs from assessment models and/or MPs. A major advantage of the MP approach is that it forces a structure that necessitates regular interaction between scientists and stakeholders in order to achieve consensus and buy-in when developing a MP (Butterworth 2008). Unlike the case in many other countries where major fisheries have had to be severely reduced, South Africa has a fairly long and robust history of sustainable fisheries management.

Table 1. Comparison of key features of the stock assessment approaches applied to major South African fisheries as indicated.

	Species	Operating Model for MP?	MLE or Bayesian	Spatial structure?	Current depletion level - spawning biomass /average carrying capacity	2008 TAC (MT)	Reference
I) No age-structure							
Squid	*Loligo vulgaris reynaudii*	Yes	Bayesian	Possibly in future	0.25##	7 442*	Glazer, J. & Butterworth, D.S. MCM/WG/05/08/SQ1 (2005)
II) Size-structured Model							
WC lobster	*Jasus lalandii*	Yes	MLE	Yes	0.02	2 340	Johnston, S.J. & Butterworth, D.S. *New Zeal. J. Mar. Freshwater Res.* 39: 687-702 (2005)
III) Age-Structured Production Model (ASPM)							
Hake	*Merluccius paradoxus* and *M. capensis*	Yes	MLE	Next version	0.28 (species combined)###	130 500	Rademeyer, R., Butterworth, D.S. & Plagányi, E.E. *Afr. J. Mar. Sci*. (in press)
Pelagics	*Sardinops sagax* and *Engraulis encrasicolus*	Yes	Bayesian	Next version	0.41 (sardine); 0.97 (anchovy)#	608 276	Cunningham, C.L., & Butterworth, D.S. MCM/2007/SEPT/SWG-PEL/05 and 06 (2007a,b)
SC lobster	*Palinurus gilchristi*	Yes	MLE	Yes	0.32	363	Johnston, S.J, & Butterworth, D.S. MCM/WG/02/08/SCRL (2008)
Abalone	*Haliotis midae*	No	MLE	Yes	0.22 (Zones A-D)	0	Plagányi, E.E. MCM/WG/AB/07/Jun/01 (2007)
Toothfish	*Dissostichus eleginoides*	Yes	MLE	No	0.34	450	Brandao, A. & Butterworth, D.S. CCAMLR WG-FSA-07/34: 1–25 (2007)

* 2007 Catch as TAE-controlled; # 2006 B^{1+}/K; ## Total biomass ; ### When considering the two hake species separately - *M. paradoxus*: 0.07; *M. capensis:* 0.51

References

Butterworth, D.S. *ICES J. Mar. Sci.* 64: 613–617 (2007).

Butterworth, D.S. In: *Fisheries for Global Welfare and Environment:* 381-397 (2008).

Fournier, D. & Archibald, C.P. *Can. J. Fish. Aquat. Sci.* 39: 1195–1207 (1982).