Assessing the South African sardine resource: two stocks rather than one?

SANCOR Seminar
9th July 2015

Carryn de Moor

Marine Resource Assessment and Management Group (MARAM)
Department of Mathematics and Applied Mathematics
University of Cape Town
Assessing the South African sardine resource: two stocks rather than one?

CL de Moor* and DS Butterworth

Marine Resource Assessment and Management Group (MARAM), Department of Mathematics and Applied Mathematics, University of Cape Town, Rondebosch, South Africa
* Corresponding author, e-mail: carryn.demoor@uct.ac.za

Sardine Sardinops sagax distributed off the west and south coasts of South Africa have traditionally been assumed to comprise a single well-mixed stock for assessment and management purposes. New research, however, lends weight to the possibility of two stocks in this region. A precautionary management approach thus needs to consider the impact of management decisions on the hypothesised two individual stocks as well as on the resource as a whole. As a first step in this process, Bayesian assessments of South African sardine are presented, which compare results for the traditional single-stock hypothesis with those that follow from a new two-mixing-stock hypothesis. Recruits from the west stock are assumed to move to and remain part of the south stock in annual pulses of varying size. This movement is estimated to be appreciable, and to take place from a substantially more productive west stock to the south stock. This immigration makes a greater contribution to the south-stock biomass than do years of above-average south-stock recruitment. Importantly, this two-mixing-stock hypothesis is shown to be consistent with the data available. Further alternative sardine stock-structure hypotheses suggested by the most recent data are discussed.

Keywords: assessment, multiple stocks, Sardinops sagax, stock structure, two-mixing-stock hypothesis

Online supplementary material: Supplementary material containing further results and discussion can be found online at http://dx.doi.org/10.2989/1814232X.2015.1009166
Background

• Historically, SA sardine assessed and managed as a single homogeneous fishery management unit under the perception that the resource consists of a single biological population

• A boom in abundance and an almost simultaneous eastward shift at the turn of the century prompted renewed research into the stock structure
Cautioned against the consequences of the depletion of a “west coast sub-stock”, if such existed
Background: Alternative Stock Structures

Observed that the sardine distribution was concentrated in two widely separated areas at low and medium (but not high) biomass levels.

Raised the possibility of the existence of two separate adult spawning aggregations.

Has the fishery contributed to a major shift in the distribution of South African sardine?

Janet C. Coetzee, Carl D. van der Lingen, Laurence Hutchings, and Tracey P. Fairweather

Background: Alternative Stock Structures

Drew attention to the presence of distinct and separated western and southern spawning grounds.
Reported differences in some morphometric and meristic data for sardine caught off the west and south coasts, demonstrating the possible existence of two functionally discrete subpopulations of sardine.

Overlap in other morphometric and meristic data consistent with some limited mixing.
A difference in the prevalence, mean infection intensity and mean abundance of a parasite to further strengthen the support for a multi-stock hypothesis.
Background:

Multi-stock management

If more than one biological population is present, but management proceeds under the assumption of a single fishery management unit, the potential for overexploitation of one or more of the populations if catches are not spread appropriately in space or time is well known (e.g. Kirkwood 1992, 1997, Kell et al. 2009, Kerr et al. 2014)
Key Contribution

- **Step 1**
  An alternative assessment of SA sardine treating it as two interacting biological populations (“stocks”) rather than only one

**Key Question:**
Is a two-mixing stock hypothesis consistent with the data available?
Key Question

If yes...

• **Step 2**

  OMs of the alternative stock structure hypothesis should be considered when developing OMPs for SA sardine

  Best address the impact of future management possibilities
Key Contribution

- **Step 1**

An alternative assessment of SA sardine treating it as two interacting biological populations (“stocks”) rather than only one

**Key Question:**
Is a two-mixing stock hypothesis consistent with the data available?

First attempt to assess the sardine resource under the assumption that it comprises two mixing stocks
Two-Mixing Stock Hypothesis

- Hondeklip Bay
- Doring Bay
- Lambert's Bay
- Columbine
- Cape Town
- Agulhas
- Mossel Bay
- Port Elizabeth
- Port Alfred
- Orange River

Recruits only
Available Data

- Survey estimates of abundance
- Length distributions from trawls during the November survey

From Janet Coetzee, DAFF
Available Data - Assumptions

• November survey:
  - Same data for both hypotheses, split at Cape Agulhas for two stock hypothesis
  - Assumed to cover the whole sardine distribution

From Janet Coetzee, DAFF
Available Data - Assumptions

• Recruit survey:
  - Same data west of Cape Infanta for both hypotheses – single or west stock
  - Data east of Cape Infanta only used for two stock hypothesis – south stock
  - Assumed to correspond to a proportion of the recruit abundance, since not all recruits available by the start of the survey
  - The proportion of south stock recruitment surveyed is assumed ≤ the proportion of west stock recruitment surveyed

From Janet Coetzee, DAFF
Available Data

• **Bycatch with anchovy**
  - dependent on anchovy landings and fraction of juvenile sardine in anchovy shoals, rather than directly on (juvenile) sardine abundance
  - inappropriate to assume time-invariant selectivity
  - separated into ages 0 & 1 with monthly & yearly varying cut-off lengths

• **Directed catch**
  - targets adults for canning, with some juvenile bycatch

• **Bycatch with round herring**

Same data used for both hypotheses, split at Cape Agulhas for two stock hypothesis
Assessment Details

- Age-structured production method framework, incorporating key elements of Statistical catch-at-age and Integrated Analysis methods
- Bayesian analysis, with integration implemented numerically using ADMB
Assessment Details

• Age-structured
• Catch modelled as a pulse every quarter
  bycatch with anchovy modelled separately to directed catch and bycatch
  with round herring
• Natural mortality time-invariant, higher for age 0
• Hockey-stick stock recruitment relationship
  - stock / peak dependent
• Length-at-age normally distributed about von
  Bertalanffy growth curve
• Selectivity
Results:
Fit to Survey Abundance Indices

Figure 2: Acoustic survey estimated and associated model-predicted sardine 1+ biomass at the joint posterior mode from November 1984 to 2011 under both the single- and two-stock hypotheses. The observations are shown together with their 95% confidence intervals. The standardised residuals are given in the lower plots. The combined west- and south-stock biomass is shown by the grey line together with the biomass estimated under the single-stock hypothesis.
Results:
Fit to Survey Abundance Indices

Figure 3: Acoustic survey estimated and associated model-predicted sardine recruitment at the joint posterior mode from May 1985 to 2011 under both the single- and two-stock hypotheses. The observations are shown together with their 95% confidence intervals. Note the scale of the vertical axis for the south stock is different from the others. The standardised residuals are given in the lower plots. The combined west- and south-stock recruitment is shown by the grey line together with the recruitment estimated under the single-stock hypothesis.
Results:
Fit to Survey Abundance Indices

Figure 2: Acoustic survey estimated and associated model-predicted sardine 1+ biomass at the joint posterior mode from November 1984 to 2011 under both the single- and two-stock hypotheses. The observations are shown together with their 95% confidence intervals. The standardised residuals are given in the lower plots. The combined west- and south-stock biomass is shown by the grey line together with the biomass estimated under the single-stock hypothesis.
Results:
Fit to Survey Abundance Indices

Figure 3: Acoustic survey estimated and associated model-predicted sardine recruitment at the joint posterior mode from May 1985 to 2011 under both the single- and two-stock hypotheses. The observations are shown together with their 95% confidence intervals. Note the scale of the vertical axis for the south stock is different from the others. The standardised residuals are given in the lower plots. The combined west- and south-stock recruitment is shown by the grey line together with the recruitment estimated under the single-stock hypothesis.
Results:
Fit to Survey Abundance Indices

Figure 2: Acoustic survey estimated and associated model-predicted sardine 1+ biomass at the joint posterior mode from November 1984 to 2011 under both the single- and two-stock hypotheses. The observations are shown together with their 95% confidence intervals. The standardised residuals are given in the lower plots. The combined west- and south-stock biomass is shown by the grey line together with the biomass estimated under the single-stock hypothesis.
Results: Stock-Recruitment Relationships

Variability during peak years >3x that of other years.

Different curves estimated for each stock.

Figure 4: Model-predicted November sardine recruitment under both stock-structure hypotheses plotted against spawner biomass from 1984 to 2011 with the estimated hockey stick stock-recruitment relationships at the joint posterior mode. The open diamonds denote the peak years’ (2000–2004) recruitments. The dotted line indicates the replacement line. Note the scale of the vertical axis for the south stock is different from the others. The standardised residuals from the fit are given in the lower plots.
Results:
West Stock Recruit Movement

Uninformative Prior Distributions

Set to 0 pre-1994

$p(\text{move}) > 50\%$ in 8/18 years

Figure 5: Posterior median and 95% probability intervals of annual proportions of recruits that move from the west to the south stock in November (prior to 1994, this movement is taken to be zero, given the lack of data to allow its estimation).
Results:

Stock-Recruitment Relationships

West stock is substantially more productive than the south stock.

Movement of west stock recruits to the south stock has a greater impact on the south stock biomass than years of above-average south stock recruitment.
Results:
November Survey Prop-at-Length

Figure 6: Model-estimated November survey selectivity-at-length at the joint posterior mode.

Figure 7: Average (over all years) proportions-at-length in November as predicted by the models at the joint posterior mode and as observed in the surveys.
Results: Commercial Proportions-at-Length

Figure 8: Model-estimated selectivity-at-length at the joint posterior mode for the directed sardine fishery and bycatch in the round herring fishery.

Figure 9: Average (over all years and quarters) proportions-at-length in the directed sardine fishery and bycatch in the round herring fishery, as predicted by the model at the joint posterior mode and as observed.
Implications of Research

• **Step 1**

An alternative assessment of SA sardine treating it as two interacting biological populations ("stocks") rather than only one

**Key Question:**

Is a two-mixing stock hypothesis consistent with the data available?

YES!
Implications of Research

• November 2011 total 1+ biomass 1.2-1.5 million t
  - near long-term average
• November 2011 west 1+ biomass 400 000t
  - 2/3 of long-term average
  - of concern as this two mixing stock hypothesis estimates this stocks spawner biomass and recruitment to be the key ‘feeder’ to the south and west coasts
  - below average recruitment in 7/8 recent years
• November 2011 south 1+ biomass 840 000t
  - above average recruitment in 9/13 recent years
Implications of Research

- **Harvest Proportion**
  - **Single**: Max of 40%
  - **West**: Max of 24%
  - **South**: Max of 19%
  - **Total**: Max of 24%

The Story Continues....

- **Step 1**

  An alternative assessment of SA sardine treating it as two interacting biological populations ("stocks") rather than only one

**Key Question:**

Is a two-mixing stock hypothesis consistent with the data available?

**YES, but...**
A Never-Ending Story?
The Story Continues....

- Its been an iterative process thus far
  - excluded two discrete stocks
- Highlighted key areas of uncertainty regarding stock structure to focus future research
  - exactly how the two stocks mix
  - what is the impact of south coast winter spawning
The Story Continues....

- Alternative stock structure hypotheses
  - two mixing stocks with
    i) older west stock individuals migrate to the south stock
    ii) south stock individuals move to the west coast (but not form part of the west stock) for some part of the year

Image: Reed et al. (2012)
The Story Continues....

Stay tuned for the sequel
Assessing the South African sardine resource: two stocks rather than one?

Thank you for your attention