Using Parasite Data to Quantify Multi-Stock Hypotheses

7th World Fisheries Congress
Busan, South Korea
23-27 May 2016

Carryn de Moor, Doug Butterworth, Carl van der Lingen

Marine Resource Assessment and Management Group (MARAM)
Department of Mathematics and Applied Mathematics
University of Cape Town
Sardine have also been commercially harvested off the south coast since the 1990s.
Background

• Historically, SA sardine assessed and managed as a single homogeneous fishery management unit under the assumption 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 of SA sardine
Alternative Stock Structures

• Cautioned against the consequences of the depletion of a “west coast sub-stock”, if such existed
  
  van der Lingen et al. 2005 GLOBEC International Newsletter Vol. 11

• 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

  Coetzee et al. 2008
  ICES JMS Vol. 65

• Drew attention to the presence of distinct and separated western and southern spawning grounds

  van der Lingen et al. 2009
  DAFF SWG No.39
Simultaneous studies of phenotypic differences between sardine sampled from the west and south coasts began to show differences in some, but not all morphometric characteristics.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Different between sardine from west and south coasts?</th>
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</thead>
<tbody>
<tr>
<td>Spawning habitat/season</td>
<td>Yes</td>
</tr>
<tr>
<td># of vertebrae</td>
<td>No</td>
</tr>
<tr>
<td>Body shape</td>
<td>Yes</td>
</tr>
<tr>
<td>Gill arch length</td>
<td>Yes</td>
</tr>
<tr>
<td># of gill rakers</td>
<td>Yes (for small but not large fish)</td>
</tr>
<tr>
<td>Length-at-maturity</td>
<td>Yes</td>
</tr>
<tr>
<td>Length-at-age</td>
<td>No (but poor age data)</td>
</tr>
<tr>
<td>Otolith shape</td>
<td>No</td>
</tr>
<tr>
<td>Genetics</td>
<td>No</td>
</tr>
</tbody>
</table>

Parasites also considered...
Parasites

• Parasite “bio-tagging” has previously been used to complement stock identification methods

  e.g. Mackenzie and Abaunza (1998)
  Fisheries Research Vol. 38
  Poulin and Kamiya (2015)
  Parasitology Vol. 142
Parasites

• Use of parasite as a “bio-tag”:
  - Host can become infected only within the parasite endemic area
  - Endemic area does not cover the full extent of host range
  - Infected fish found outside the endemic area must have been within the endemic area at some point in the past
Parasites

• For SA sardine (*Sardinops sagax*), the digenean “tetracotyle” type metacercariae found in sardine eyes showed greatest bio-tag potential
  - spatial variability in prevalence
  - endoparasite
  - long lifespan in host
  - site specificity to ensure ease of detection and identification

• “Tetracotyle” considered to be of the genus *Cardiocephaloides*, species not definitively identified - either *physalis* or *longicollis*
  bio-tag used in stock ID of Argentinian anchovy
Parasite Life Cycle

1st intermediate host
Fish (sardine)

2nd intermediate host
Fish (sardine)

Definitive host
Bird (African penguin)

No fish-to-fish transmission
Parasites

- 1\textsuperscript{st} intermediate host unknown:
  - hypothesised to be \textit{Burnapaena papyracea}, abundant subtidal gastropod distributed from Cape Agulhas to Lüderitz
  - endemic to west coast only
  - if sardine infected with parasite found on south coast, must have spent some time on the west coast
Alternative Stock Structures

- A difference in the prevalence, mean infection intensity and mean abundance of the parasite to further strengthen the support for a multi-stock hypothesis.

Weston 2013
MSc, UCT
van der Lingen et al. 2015
Parasitology Vol.142
Weston et al. 2015
Fish. Res. Vol.164
Do We Need Multi-Stock Management?

Harvest rate on “west stock” much higher
Two Sardine Stocks?

• First attempt to assess the sardine resource under the assumption that it comprises two mixing stocks
• Showed a two mixing-stock hypothesis for SA sardine is consistent with the data available
Two Mixing-Stock Hypothesis

West stock

Recruits only

South stock
Assessment Details

• Age-structured production method framework, incorporating key elements of Statistical catch-at-age and Integrated Analysis methods
• Fit to survey estimates of recruitment and total abundance, catch data and length frequencies
• Estimate time-invariant growth curve with variability about length-at-age
• Bayesian analysis, with integration implemented numerically using ADMB
Results:
Fit to Survey Abundance Indices

Single Stock

West Stock

South Stock

November biomass survey

1+ Biomass (million t)

Year


May recruit survey

Recruits (billions)

Year


Single Stock Hypothesis

Two Mixing-Stock Hypothesis
Results: Stock Recruitment Relationships

Single Stock Hypothesis

West Stock

South Stock

Variability during peak (◊) years >3x that of other (♦) years

West stock is substantially more productive than the south stock
Results:
West Stock Recruit Movement

Uninformative Prior Distributions

Movement of west stock recruits to the south stock had a greater impact on the south stock biomass than years of above-average south stock recruitment.

Of concern given poor recruitment to west stock in recent decade if this is a “feeder” to both coasts.

But: Movement proportions not precisely estimated.

What do we assume for future movement?
Parasites

- Samples obtained from annual November hydro-acoustic surveys of pelagic biomass

Sample locations during November hydro-acoustic surveys 2010-2015
(124 trawls from which 3,130 fish were processed for TTM)
Parasites

- Indicates:
  - Fish on south coast are infected
  - Parasite prevalence on west coast higher than on south coast
  - Prevalence increases with length on both west and south coasts

Sardine must move at older ages
Revised Two-Mixing Stock Hypothesis

\[ p(y,2^+) = p^{2+} \times p(y,1) \]
Revised Two-Mixing Stock Hypothesis

• Three more years of data
• Inclusion of parasite prevalence-by-length in likelihood (binominal)
• Estimation of annual proportions of west stock sardine infected with the parasite
• Other key changes to model
  - maturity-at-length
  - alternative parametric form for commercial and survey selectivity-at-length
  - time-varying growth curve
  - time-varying commercial selectivity
  - alternative informative prior distribution for survey bias
Results:
Fit to Survey Abundance Indices

- **West**
  - Total Biomass ('000t)
  - Recruits (in billions)

- **South**
  - Total Biomass ('000t)
  - Recruits (in billions)

*Including parasite data*

*Excluding parasite data*
Results:

Estimated Stock-Recruit Relationships

West stock still estimated to be more productive
South stock estimated to be ~35% more productive when parasite data included
Results:

Estimated Movement

Peak in south stock biomass still estimated to result from movement of sardine from the west stock

\[ p(y,2^+) = p^{2^+} \times p(y,1) \]

- \( p^{2^+} = 0.75, \text{ SE } = 0.17 \)
- \( p^{2^+} = 0.10, \text{ SE } = 0.35 \)
Results:
Fit to Parasite Prevalence

2010
West

2014
South

2015

Sample size
Observed
Predicted
X

Proportion infected

Year

Results:
Estimated Movement

On average, the movement parameters are more precisely estimated once parasite data are included in the model.

Average 2010-15 SEs:
- 0.10 with parasite data
- 0.21 without parasite data
In Summary

• Parasite bio-tagging helped to quantitatively develop stock structure hypotheses for SA sardine

• Relatively large sample sizes enabled the use of parasite prevalence-at-length data in the model

  - estimate annual infection rates
  - estimate movement rates more precisely
  - distinguish between juvenile and adult movement
Ongoing Research

• Further parasite data - commercial samples
  - parasite infection intensity data

• Definitive identification of 1\textsuperscript{st} intermediate host and endemic area

• Alternative stock structure hypotheses?
  - south stock spend some time on the west coast without joining the west stock?

• Consideration of two mixing-stock structure hypotheses when developing OMPs
  - future movement hypotheses
Using Parasite Data to Quantify Multi-Stock Hypotheses

Thank you for your attention

Acknowledgements:
National Research Foundation for financial assistance
Small Pelagic Scientific Working Group for ongoing discussions
Team of DAFF personnel collecting and analyzing sardine parasites
RSA International Stock Assessment Review panel members