

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



SANCOR Seminar
9th July 2015

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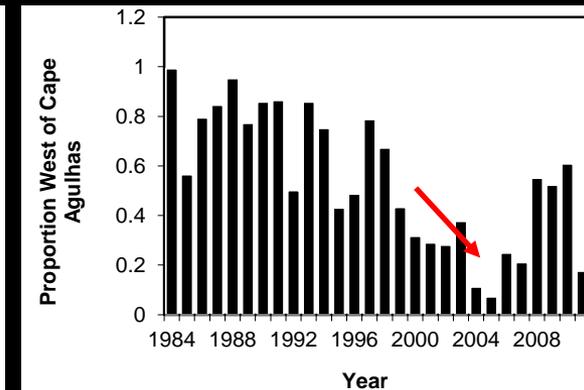
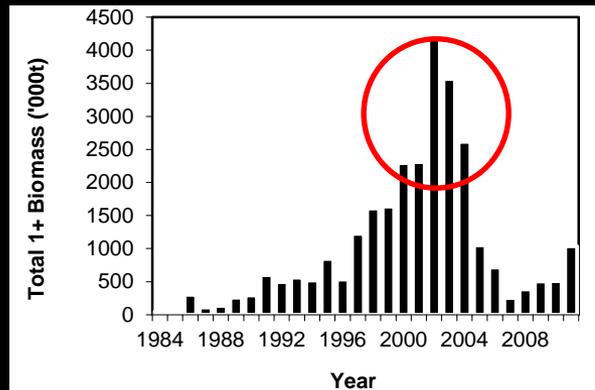
Sardine *Sardinops sagax* distributed off the west and south coasts of South Africa have traditionally been assumed to comprise a single well-mixed stock for assessment and management purposes. New research, however, lends weight to the possibility of two stocks in this region. A precautionary management 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



Background: Alternative Stock Structures



GLOBEC INTERNATIONAL
NEWSLETTER
A CORE PROJECT OF THE
INTERNATIONAL GEOSPHERE-BIOSPHERE PROGRAMME
<http://www.globec.org>

Vol.11, No.2 GLOBAL OCEAN ECOSYSTEM DYNAMICS OCTOBER 2005

Article published in the GLOBEC International Newsletter 11(2): 17-22.

GLOBEC SCIENCE
A column for scientific notes of relevance to the GLOBEC community

An eastward shift in the distribution of southern Benguela sardine
C.D. van der Lingen¹, J.C. Coetzee¹, H. Demarcq², L. Drapeau³,
T.P. Fairweather¹ and L. Hutchings¹,
¹MCM, Rogge Bay 8012, South Africa (vdlingen@deat.gov.za)
²IRD, Sète Cedex, France ³IRD, Rogge Bay 8012, South Africa

Cautioned against the consequences of the depletion of a “west coast sub-stock”, if such existed

Background:

Alternative Stock Structures

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

Coetzee, J. C., van der Lingen, C. D., Hutchings, L., and Fairweather, T. P. 2008. Has the fishery contributed to a major shift in the distribution of South African sardine? – *ICES Journal of Marine Science*, 65: 1676–1688.

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

Background:

Alternative Stock Structures

MCM/2009/SWG-PEL/39

Spatial variability in biological characteristics of southern Benguela sardine and
the possible existence of two stocks

C.D. van der Lingen, M.D. Durholtz, T.P. Fairweather and Y. Melo

MCM

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

Background:

Alternative Stock Structures

MARAM IWS/DEC11/P/OMP/P7

The biological basis for hypothesizing multiple stocks in South African sardine *Sardinops sagax*

C.D. van der Lingen, Offshore Resources Research, DAFF

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

Background:

Alternative Stock Structures

TEMPORAL AND SPATIAL VARIABILITY IN "TETRACOTYLE" TYPE
METACERCARIAE INFECTION IN THE SOUTH AFRICAN SARDINE,
SARDINOPS SAGAX

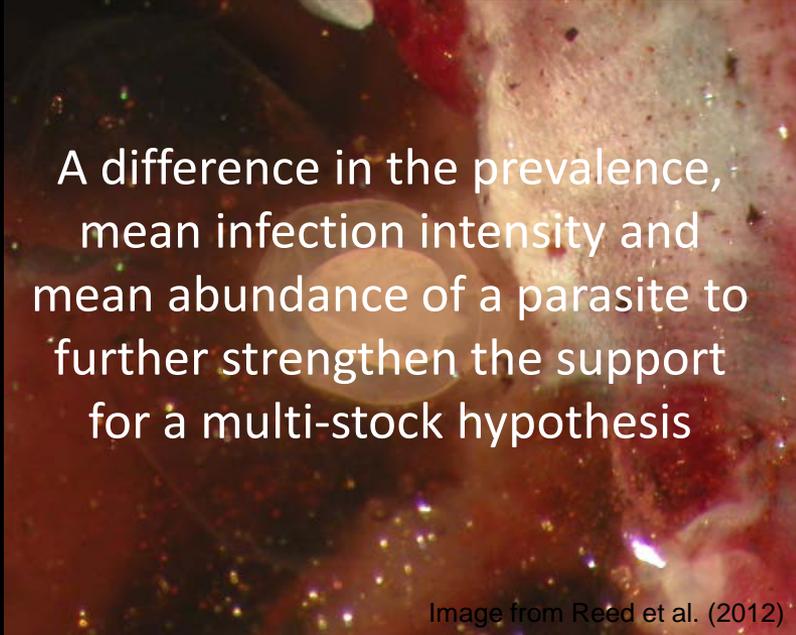
Laura Weston

Dissertation presented in partial fulfilment of the requirements for the degree of MSc in
Applied Marine Science

Department of Biological Sciences

University of Cape Town

April 2013



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

Image from Reed et al. (2012)

Incorporating parasite data in population structure studies
of South African sardine *Sardinops sagax*

CARL DAVID VAN DER LINGEN^{1,2*}, LAURA FRANCES WESTON^{3†},
NURUDEAN NORMAN SSEMPA³ and CECILE CATHARINE REED³

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

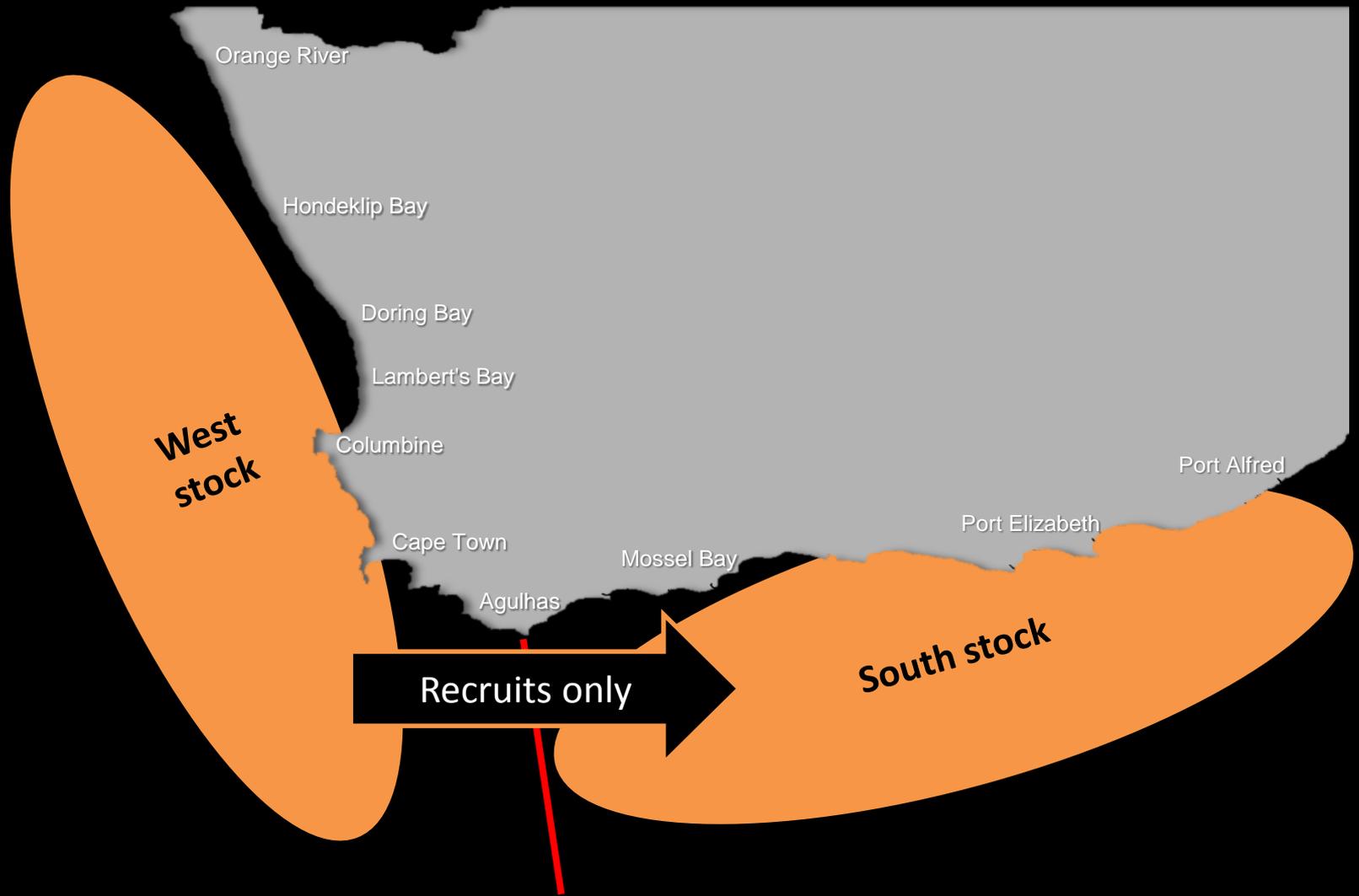
An alternative assessment of SA sardine treating it as two interacting biological populations (“stocks”) rather than only one

Key Question:

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

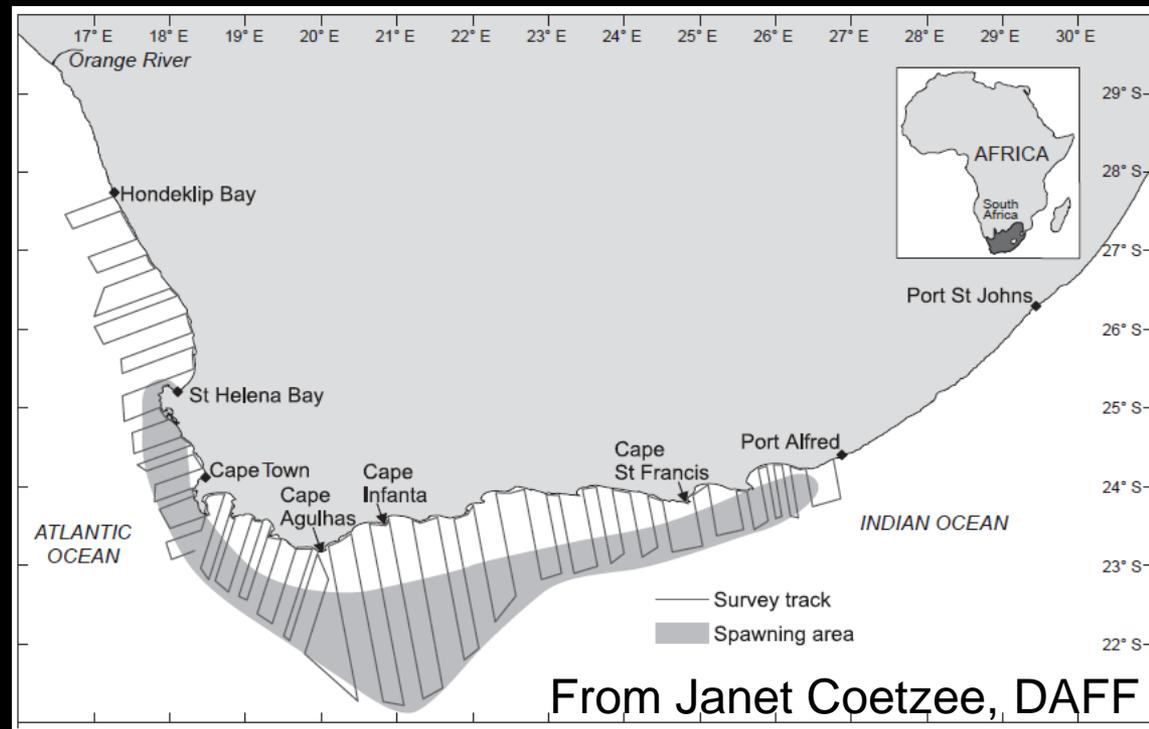
First attempt to assess the sardine resource under the assumption that it comprises two mixing stocks

Two-Mixing Stock Hypothesis



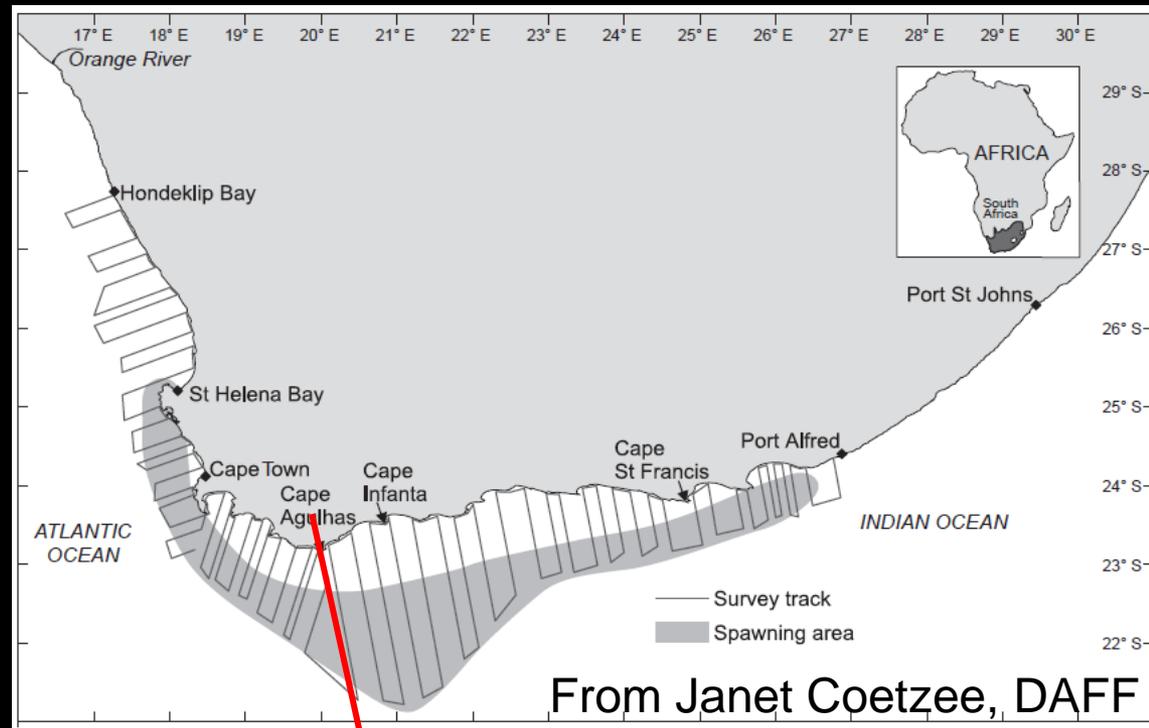
Available Data

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



Available Data - Assumptions

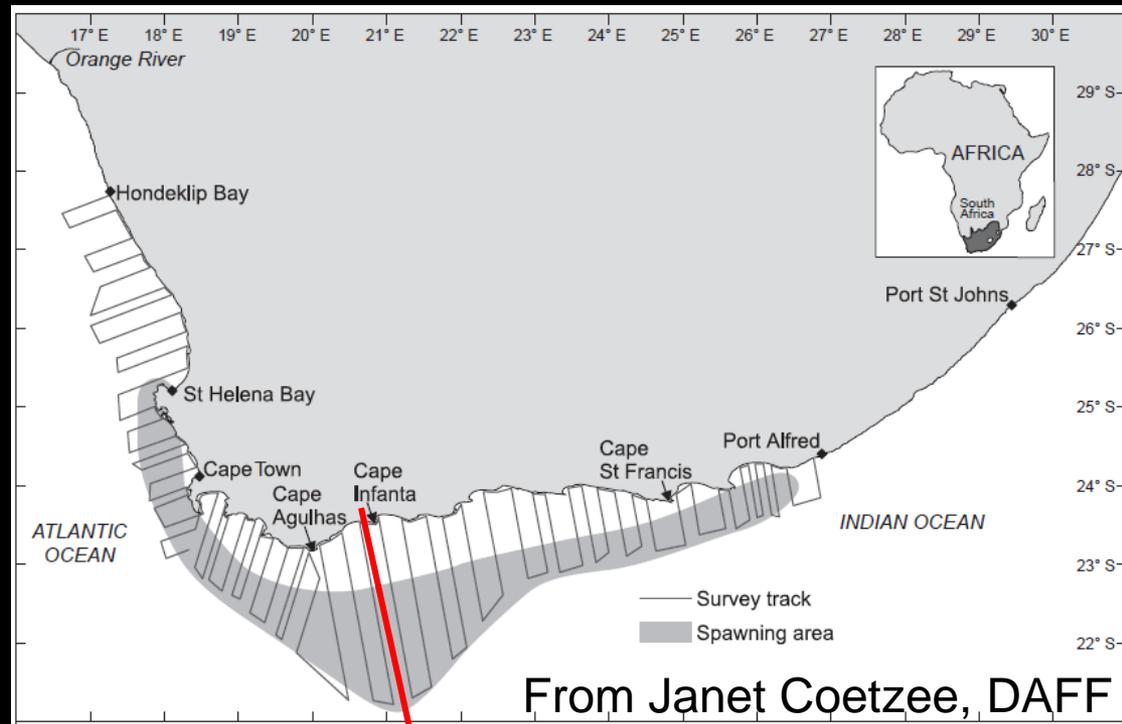
- November survey:
 - Same data for both hypotheses, split at Cape Agulhas for two stock hypothesis
 - Assumed to cover the whole sardine distribution



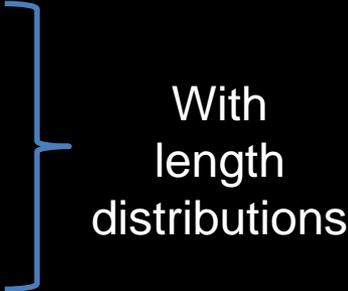
Available Data - Assumptions

- **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 \leq the proportion of west stock recruitment surveyed



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**
- 
- With length distributions

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

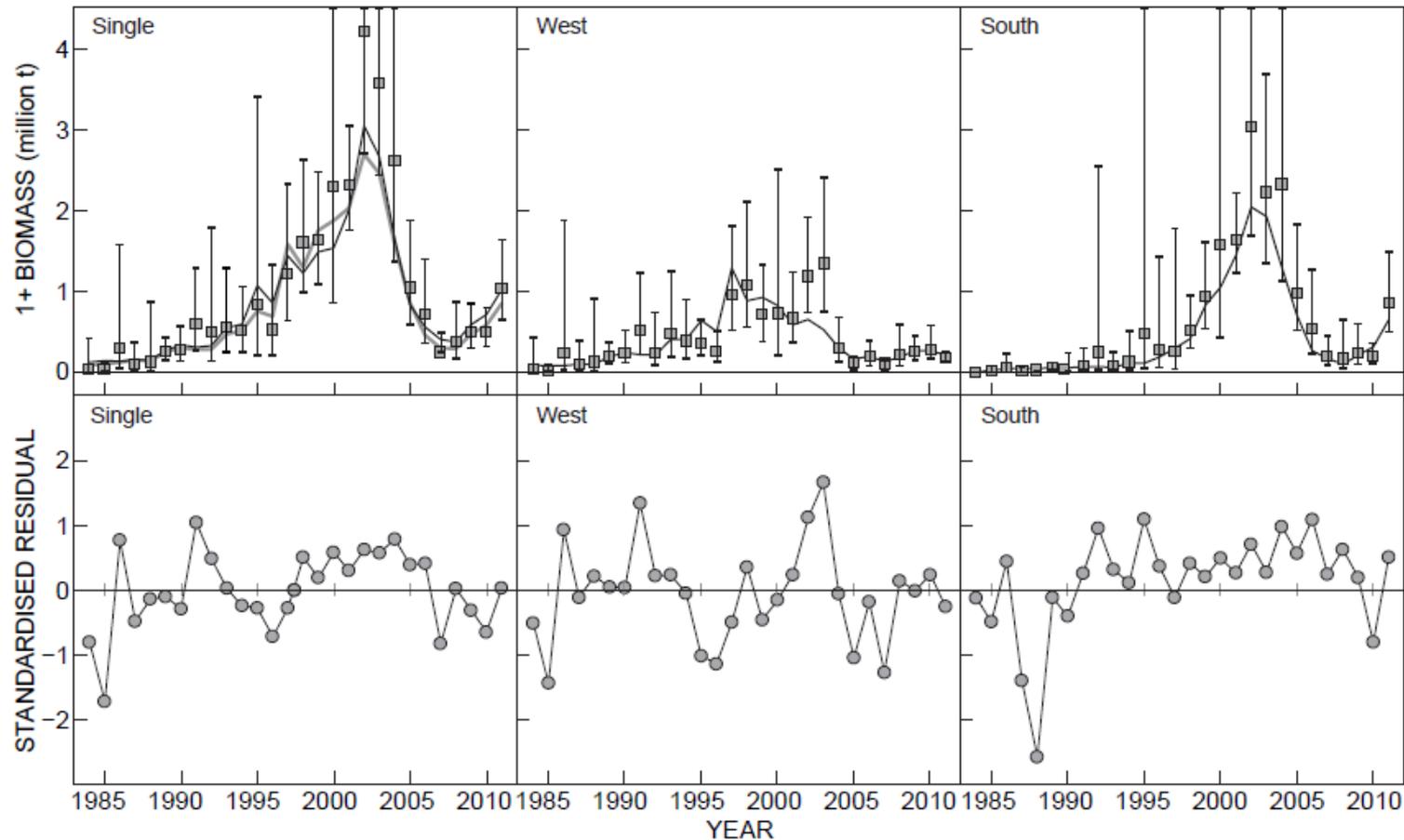


Figure 2: Acoustic survey estimated and associated model-predicted sardine 1+ biomass at the joint posterior mode from November 1984 to 2011 under both the single- and two-stock hypotheses. The observations are shown together with their 95% confidence intervals. The standardised residuals are given in 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

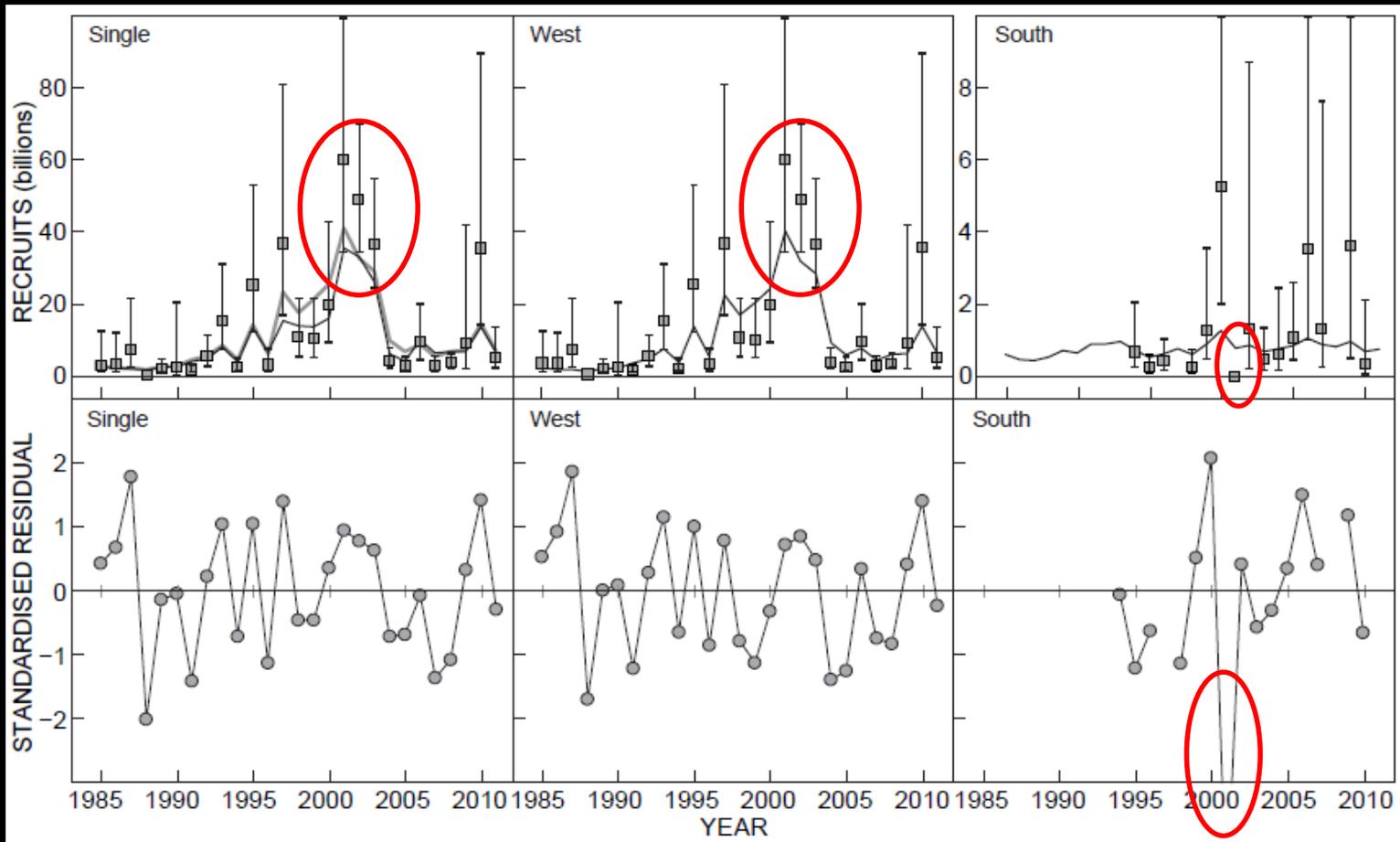


Figure 3: Acoustic survey estimated and associated model-predicted sardine recruitment at the joint posterior mode from May 1985 to 2011 under both the single- and two-stock hypotheses. The observations are shown together with their 95% confidence intervals. Note the scale of the vertical axis for the 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

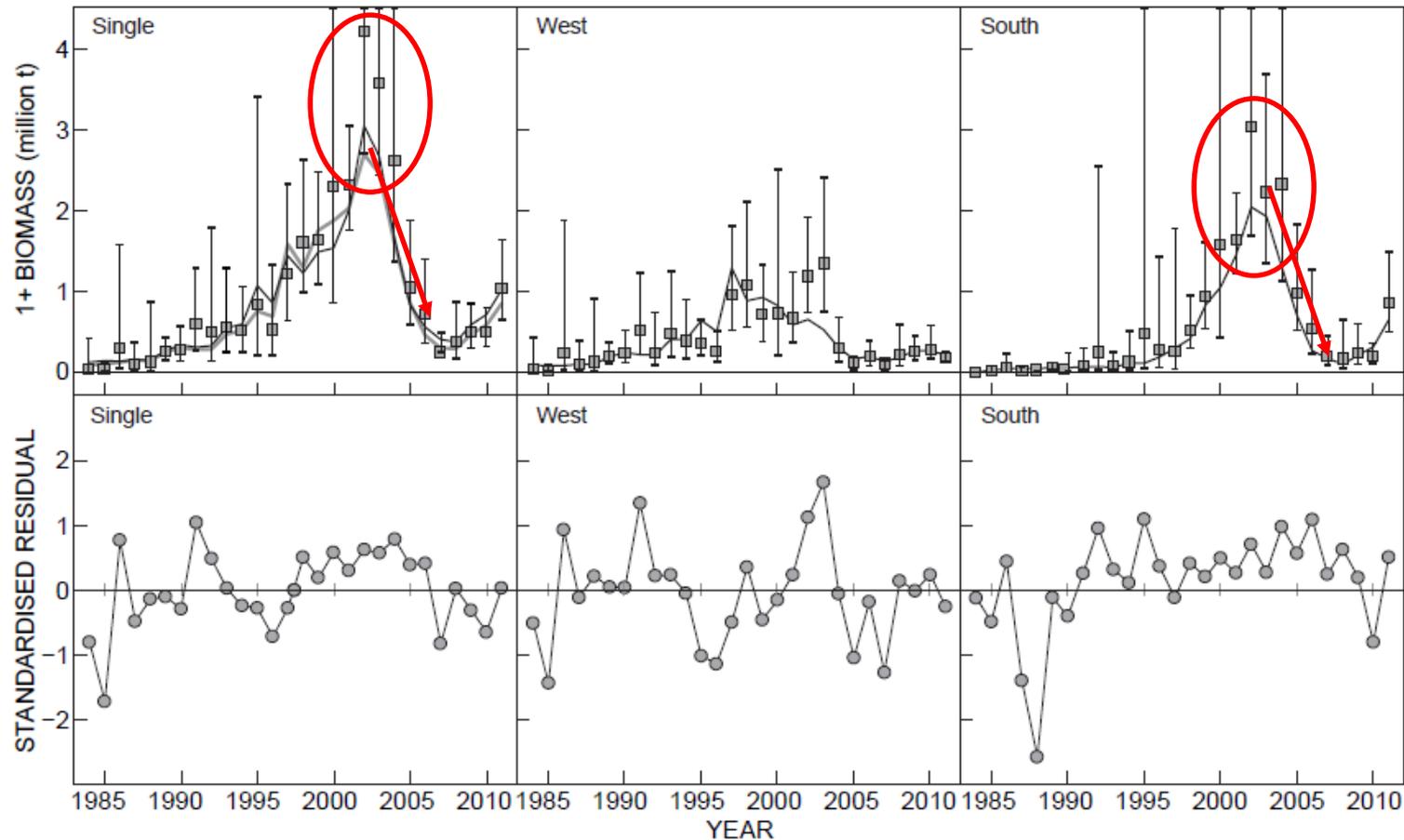


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Results:

Fit to Survey Abundance Indices

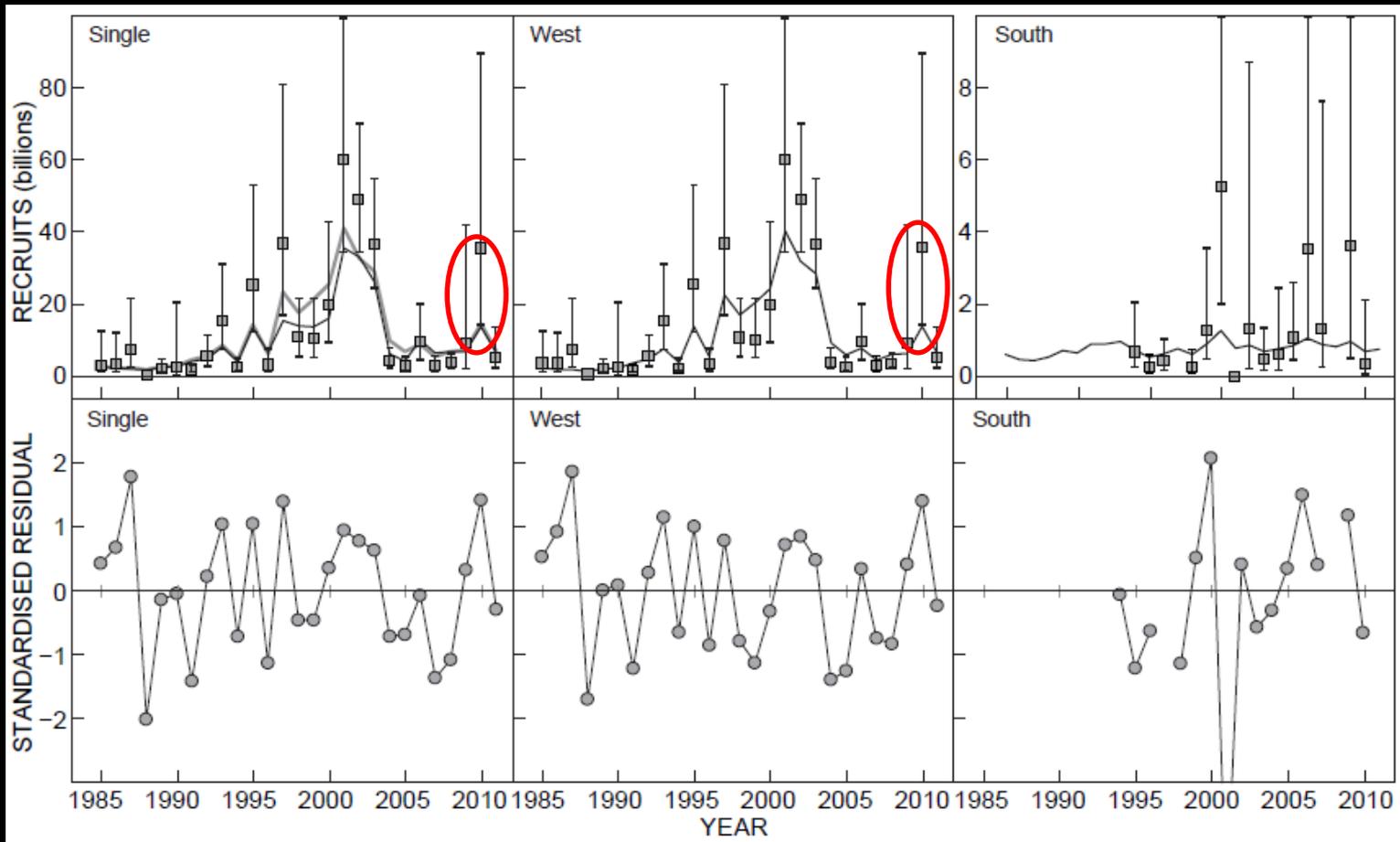


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Results:

Fit to Survey Abundance Indices

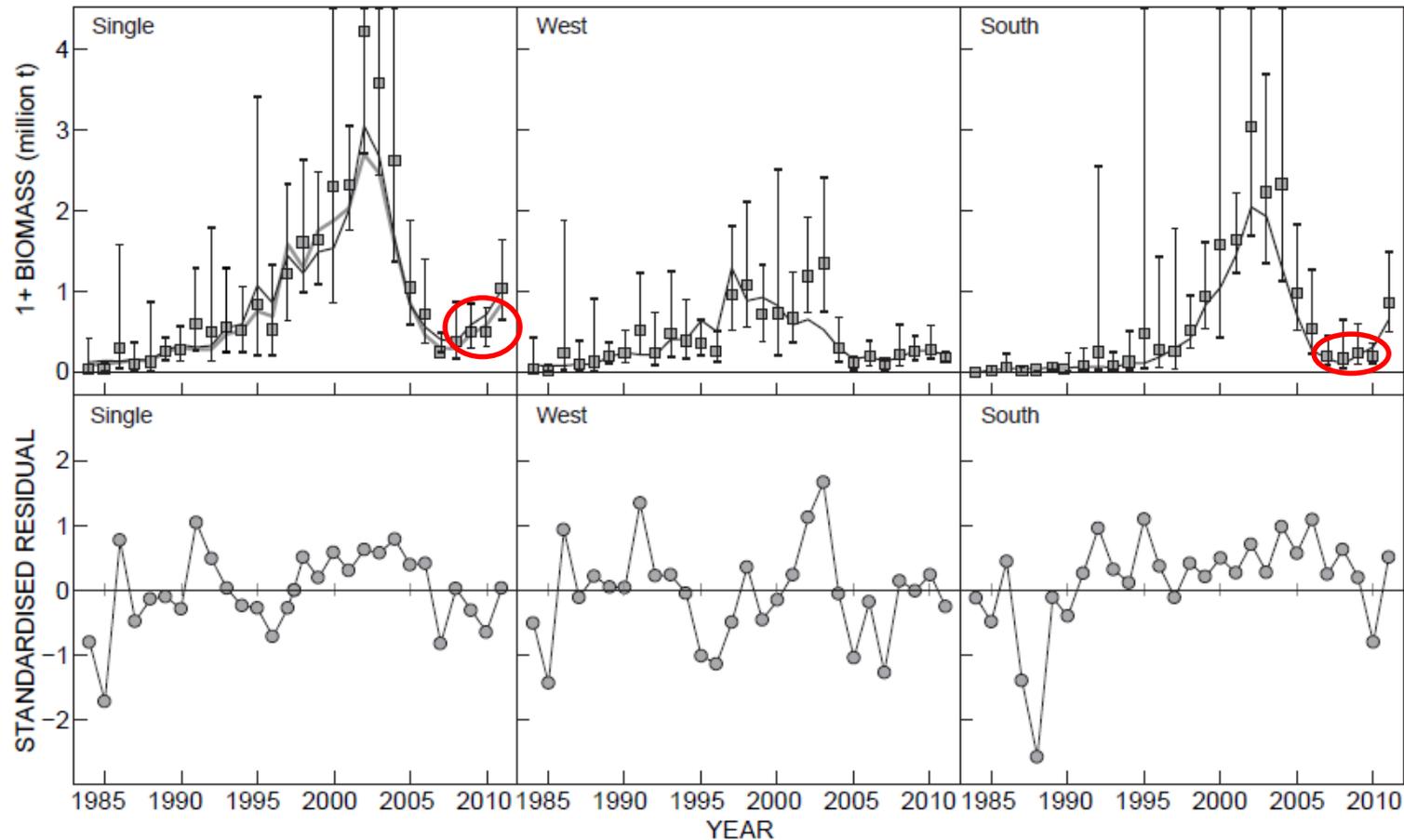


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Results:

Stock-Recruitment Relationships

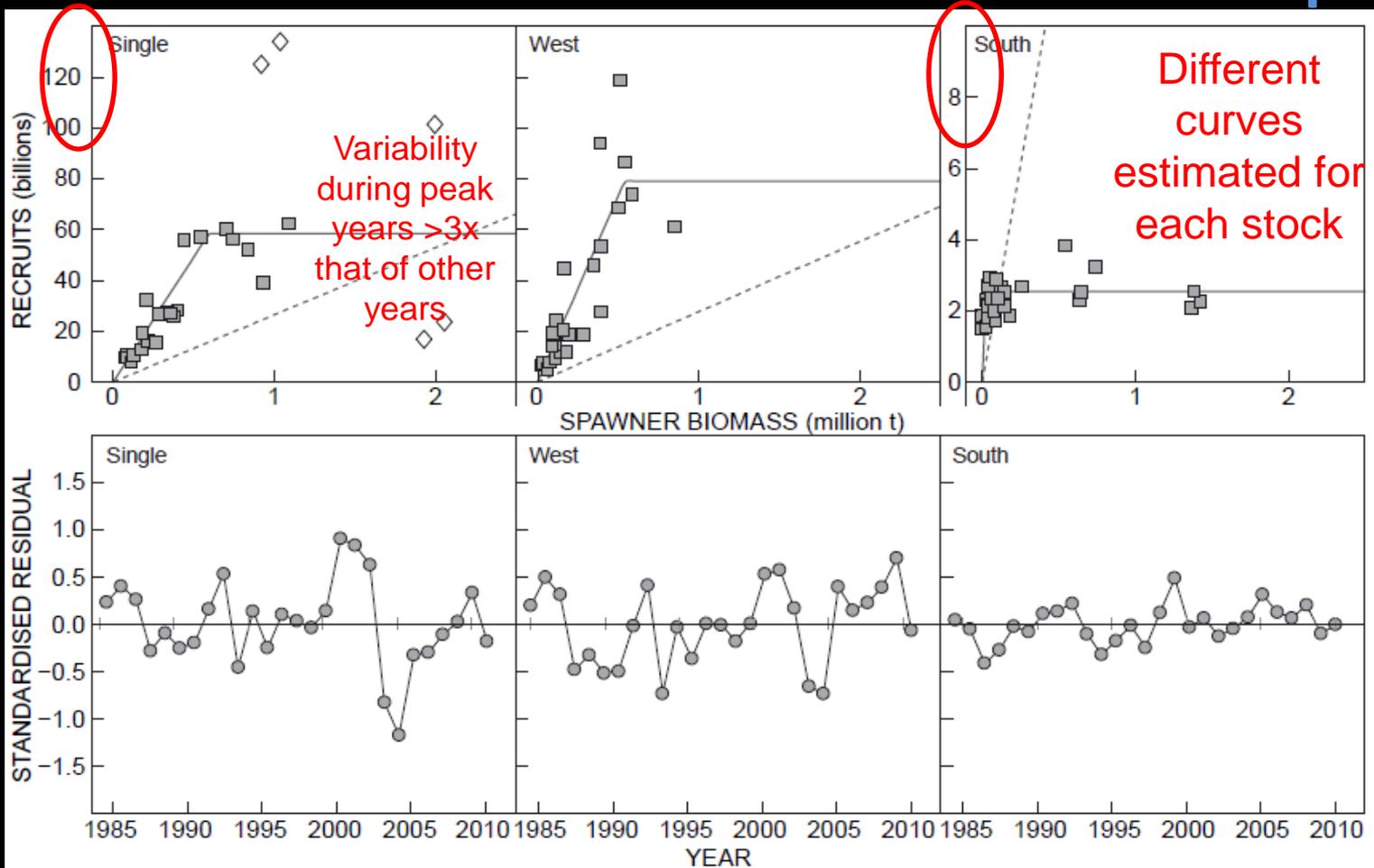
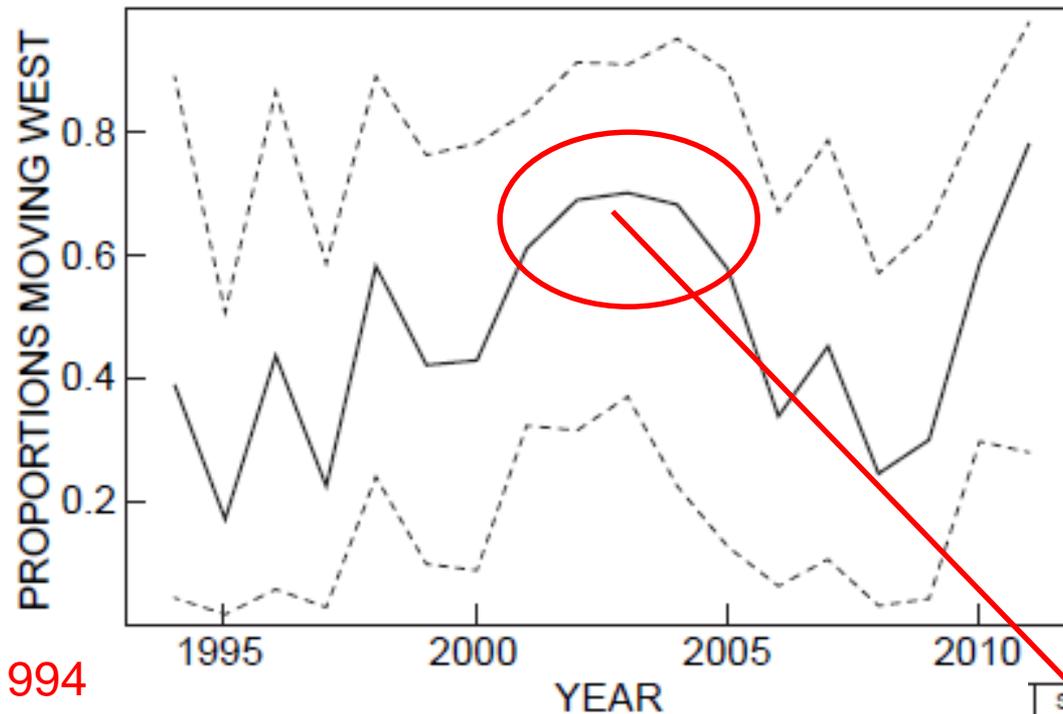


Figure 4: Model-predicted November sardine recruitment under both stock-structure hypotheses plotted against spawner biomass from 1984 to 2011 with the estimated hockey stick stock-recruitment relationships at the joint posterior mode. The open diamonds denote the peak years' (2000–2004) recruitments. 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

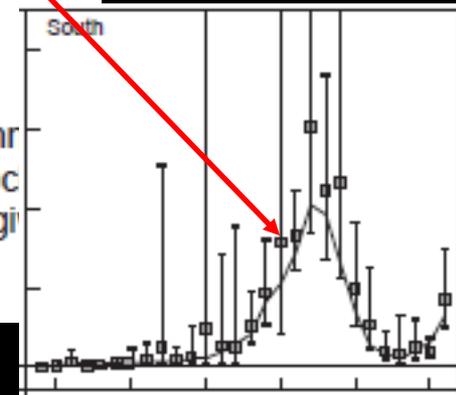
Uninformative
Prior
Distributions

Set to 0 pre-1994



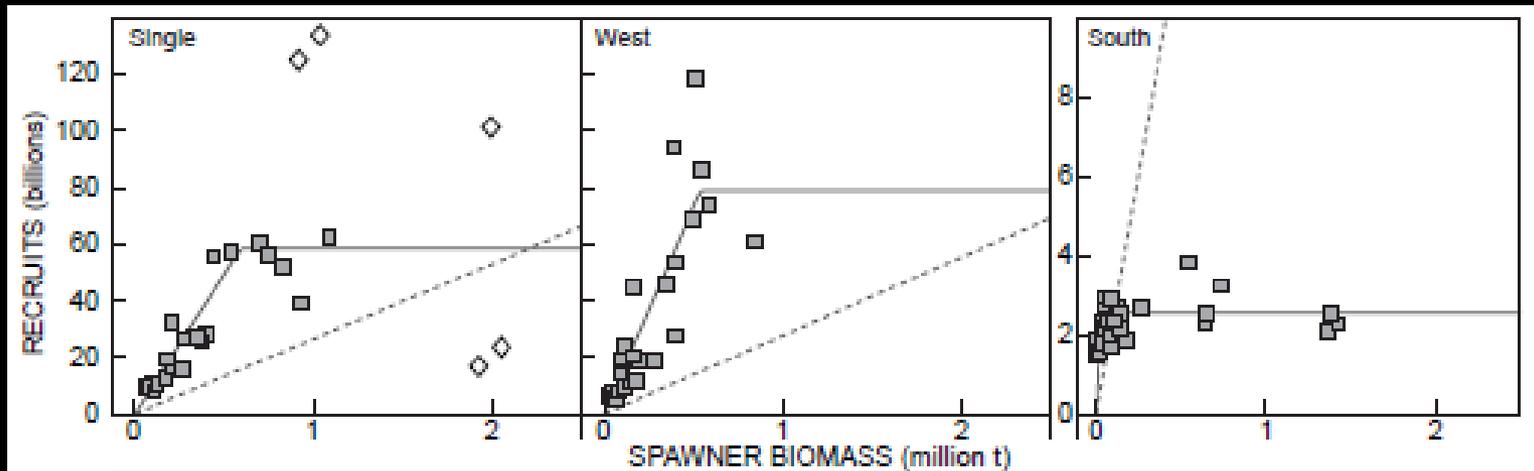
$p(\text{move}) > 50\%$
in 8/18 years

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



Results:

Stock-Recruitment Relationships

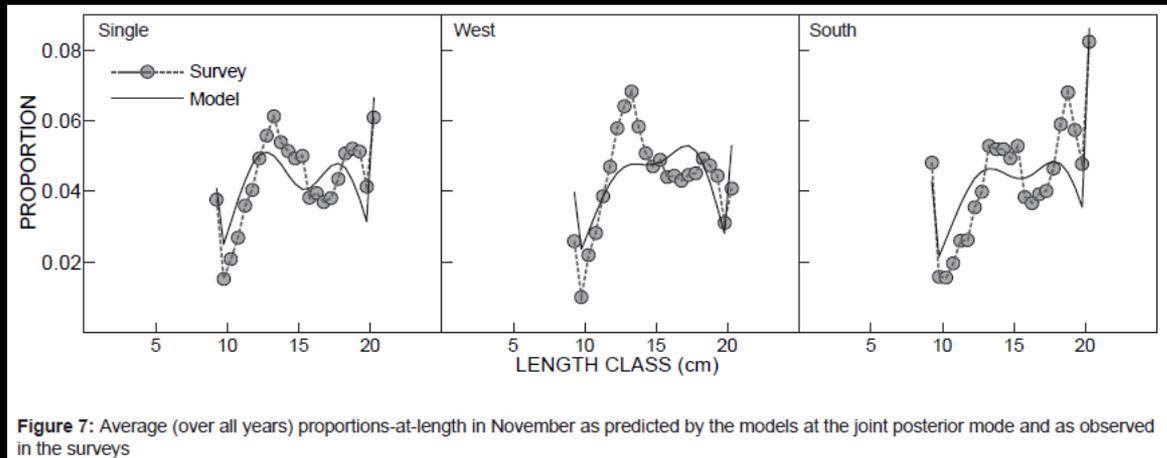
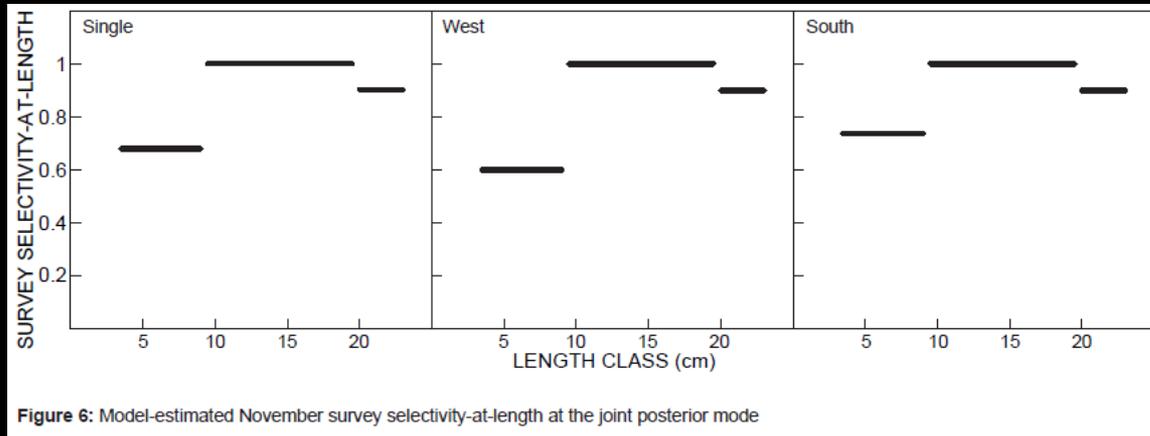


West stock is substantially more productive than the south stock

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

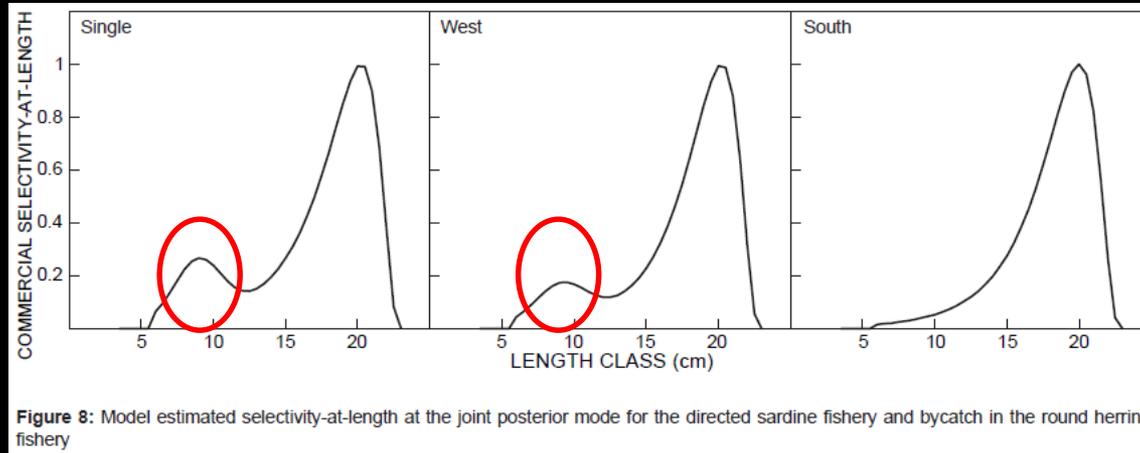
Results:

November Survey Prop-at-Length

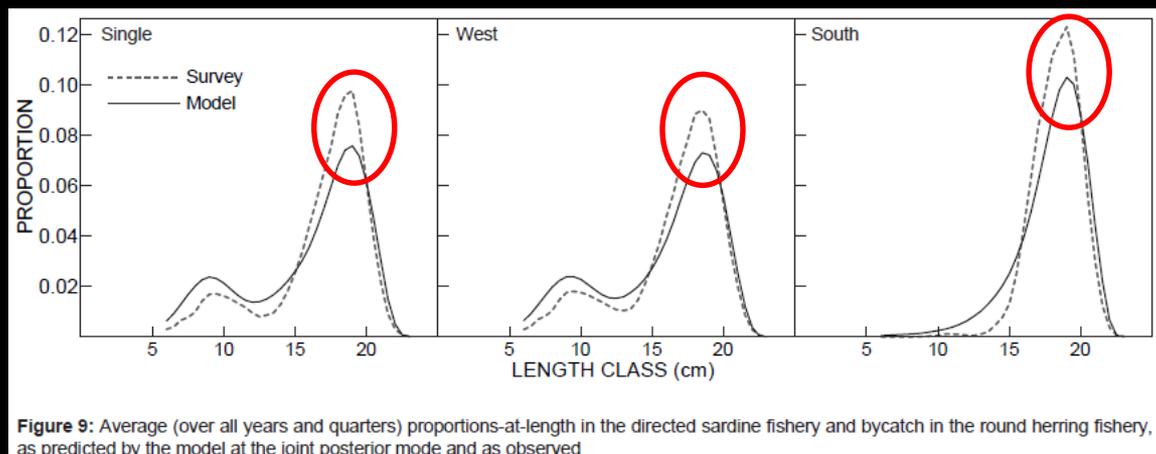


Results:

Commercial Proportions-at-Length



Small sardine
bycaught with
targeted large
sardine
Domed at large
lengths



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:

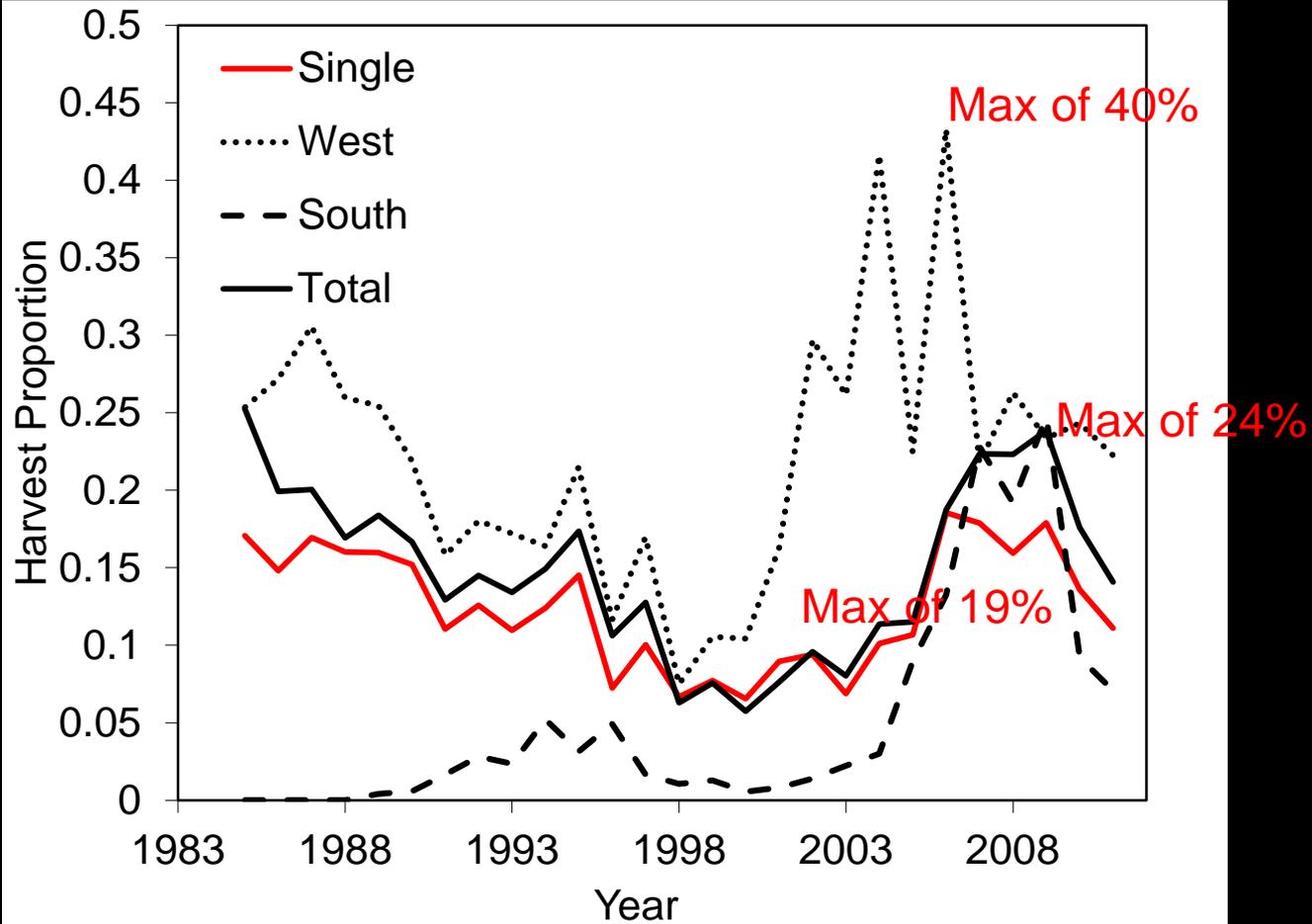
Is a two-mixing stock hypothesis consistent with the data available?

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



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?

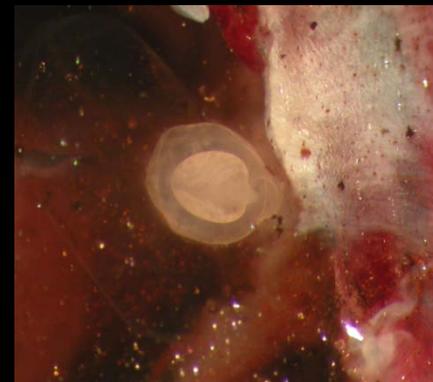


The Story Continues....

- 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



The Story Continues....

Stay tuned for the sequel

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Thank you for your attention