SOME INSIGHTS INTO SARDINE SUSTAINABLE YIELD RATES

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Summary

A simple approach is used to calculate annual sustainable yield rates (surplus production divided by biomass) for eleven of the world's sardine stocks. The average value across stocks of the median for each over time is 0.34 in relation to spawning biomass. Viewed overall, the corresponding value for the South African sardine is 0.44. The current management procedure used for South African sardine sets the annual directed TAC (at basis) near to 0.09 of the biomass estimate from the November survey each year. Adjusting for biases associated with the hydroacoustic estimates and for the ratio of the November to spawning biomass, this corresponds to a 0.18 fraction of spawning biomass.

Introduction

When Management Procedures were first developed to provide TAC recommendations for the South African sardine resource some 25 years ago, the typical level of exploitation was set on a basis of a somewhat arbitrary risk criterion related to the probability of the resource abundance falling below a particular level over a 20-year projection period. Though assessment methods and results (e.g. the best estimate of adult natural mortality *M*) have changed over time, together with the approach to compute risk, considerable care has been taken to attempt to maintain the same overall "risk" over time, as the original choice had not led to any problems.

For recent assessments, maintaining this same risk has translated into a TAC formula that is, at basis, for an annual directed sardine take of about 9% of the result forthcoming for biomass from the November hydroacoustic survey. That survey covers the full biomass range, but at that time of the year very few 0-year-class fish have recruited so that this is close to the 1+ biomass.

However recent concerns and debates about the sardine exploitation rates on the West coast have led to questions being raised about the "risk" level adopted: is it lower than the norm elsewhere in the world, and leading to TACs that are unnecessarily conservative? The purpose of this document is to initiate addressing this question by examining the productivity of sardine resources worldwide.

Data and Methods

The sardine resources considered are listed in Table 1, together with the sources used to provide the data analysed for each of them.

To calculate the annual surplus production for each resource/stock, which corresponds to the annual sustainable yield *SY(y)* for year *y*, the following simple aggregated population dynamics model is used:

$$B(y+1) = B(y) + SY(y) - C(y) \quad (1)$$

where *B(y)* is the biomass at the start of year *y* and *C(y)* is the catch taken during that year.

Given information on *B(y)* and *C(y)*, the annual sustainable yield *SY(y)* can then be calculated as:

$$SY(y) = B(y+1) - B(y) + C(y) \quad (2)$$

Ideally exploitable biomass or total biomass should be used for *B(y)* in implementing equation (2). However for most of the stocks considered, only spawning stock biomass values were available, so that these have been used to maintain comparability across stocks. However, since this likely underestimates the exploitable biomasses, results are duplicated by multiplying all spawning biomass values by 1.5 to provide some indication of sensitivity.

Results and Discussion

Results from these calculations are plotted in Figure 1 for each stock, showing the annual sustainable yield rate (*SY(y)/B(y)*) by year and in relation to spawning biomass. Medians over the time periods concerned are also shown on the first of these plots. For most stocks the annual points plotted suggest a compensatory relationship with the sustainable yield rate declining with biomass, but interpretative care must be taken as the method of computation used imposes some negative correlation (with the same *B(y)* used in the denominator for the vertical axis and numerator for the horizontal axis).

These results are summarised in Table 1, which lists these medians. Means are also shown, but medians are considered more representative as they are influenced less by the occasional high ”outliers”.

For the South African sardine, the median for the total resource is 0.44, though higher for the west and lower for the south component. This compares with a mean of the medians for all stocks considered of 0.34.

The current management procedure used for South African sardine sets the annual directed TAC (at basis) at near 0.09 of the biomass estimate from the November survey each year. To compare this with the numbers above, however, one needs to adjust for biases associated with the hydroacoustic estimates (these scale observed values upwards by a multiplicative factor of 1.34) and by the ratio of the spawning biomass to the November biomass (which averages at 0.380). The 0.09 fraction used to calculate to directed sardine TAC then corresponds to a 0.18 fraction of spawning biomass. In comparing this to the 0.34 and 0.44 figures above though, one needs to bear in mind that a juvenile sardine bycatch is also taken in the South African pelagic fishery, and allowance for that would need to be factored in to any more detailed comparisons. Such would also desirably calculate an exploitable to spawning biomass ratio for each of the other stocks to render use of equation (1) more defensible.

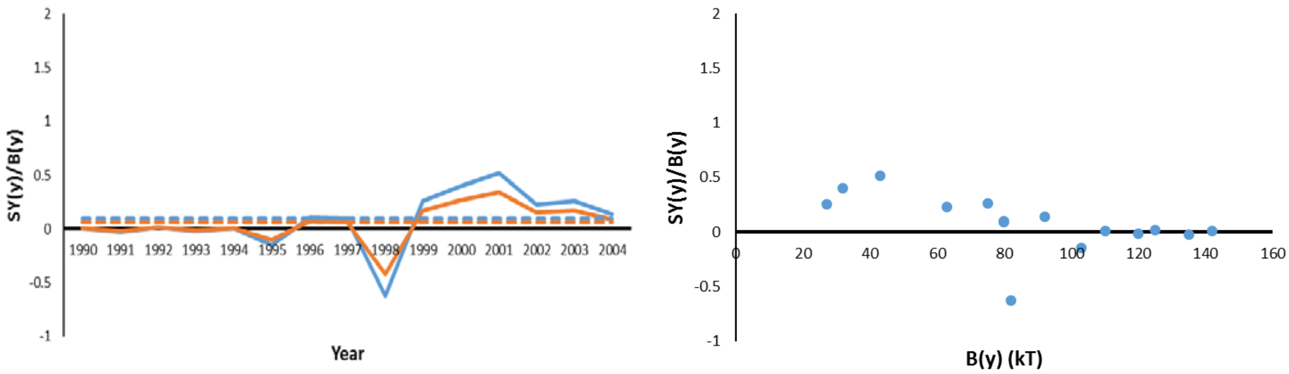
Table 1: Values of median (with mean in parenthesis) sustainable yield rates (SY/B) for the sardine stocks considered. The final column shows the effect of increasing B (for which the data available for use relate to spawning stock biomass) by 50% to be better reflective of the exploitable biomasses to which the catches correspond. The footnotes give the sources of the information used in the calculations.

	Median SY/B	**Median SY/(B*1.5)**
Australia[1]	0.093 (0.081)	0.062 (0.054)
Brazil[1]	0.357 (0.378)	0.238 (0.252)
US West Coast: California[1]	0.208 (0.260)	0.137 (0.169)
Pacific Coast[2]	0.460 (0.480)	0.300 (0.320)
Chile[1]	0.513 (0.719)	0.342 (0.479)
Europe[1]	0.321 (0.361)	0.214 (0.241)
Humbold: N/C Peru[1]	0.393 (0.506)	0.262 (0.337)
Humboldt: S. Peru/ N. Chile[1]	0.671 (0.959)	0.447 (0.640)
Japan[1]	0.157 (0.274)	0.105 (0.182)
Northern Adriatic Sea[2]	0.300 (0.300)	0.300 (0.300)
Northern Benguela[1]	0.168 (0.259)	0.112 (0.173)
South Africa: Total[3]	0.440 (0.585)	0.294 (0.390)
West Coast[4]	0.711 (1.005)[x]	0.474 (0.670)[x]
South Coast[4]	0.210 (0.382)[x]	0.140 (0.255)[x]
Overall average*	**0.340 (0.427)**	**0.235 (0.293)**
standard deviation*	***0.168 (0.236)***	***0.113 (0.156)***

*Omits South Africa: West Coast and South Coast – this is to avoid double counting

[x] These are biased because they do not take the movement from the West to the South Coast into account.

(a) Australia



[1] Barange M, Bernal M, Cercole MC, Cubillos LA, Daskalov GM, de Moor (formerly Cunningham) CL et al. 2009. Current trends in the assessment and management of stocks. In: Checkley D, Alheit J, Oozeki Y, Roy C (eds), Climate change and small pelagic fish. Cambridge: University Press. pp 191–255.

Note that for these stocks the data for catches and spawning biomass was read electronically from the plots.

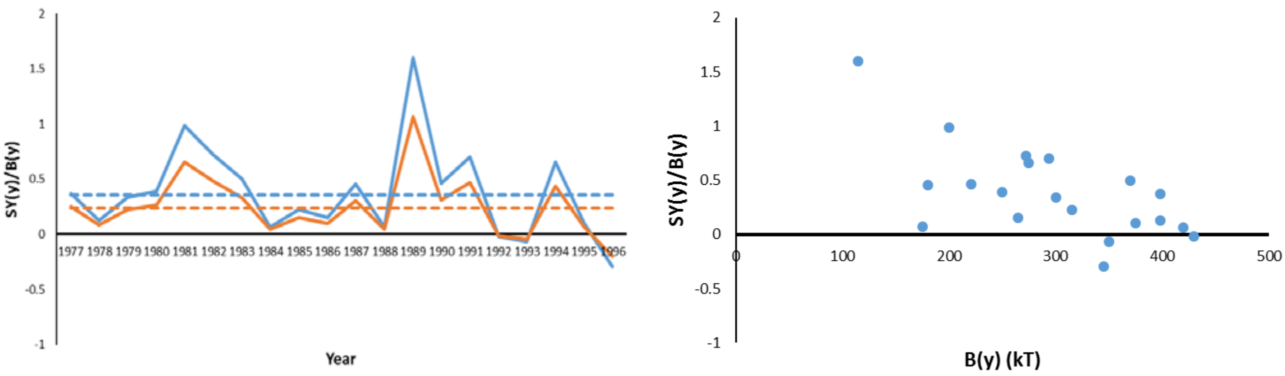
[2] RAM Legacy database: ***ramlegacy****.org*

[3] de Moor, C.L. and Butterworth, D.S. 2016. Assessment of the South African sardine resource using data from 1984-2015: Results at the joint posterior mode for the single stock hypothesis. DAFF Branch Fisheries document: FISHERIES/2016/JUL/SWG-PEL/23REV: 24pp.

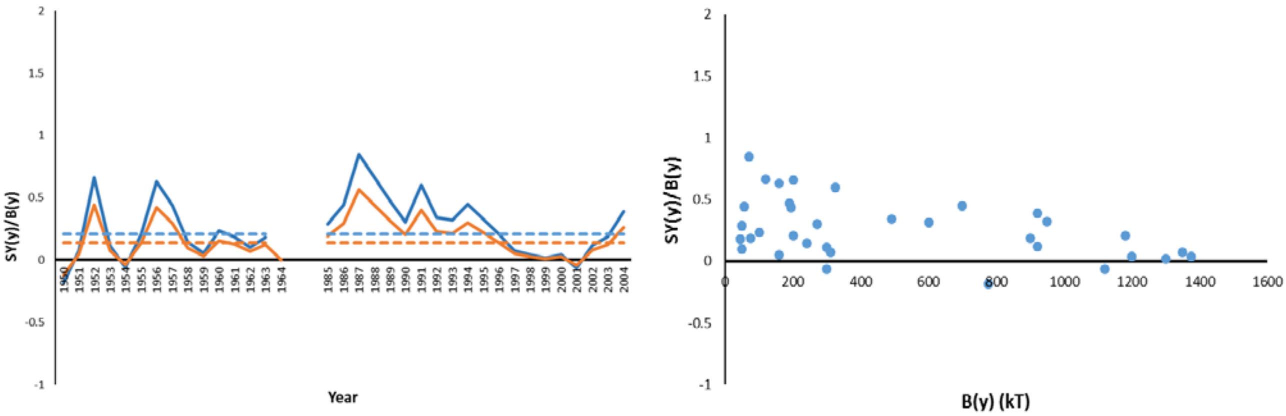
[4] de Moor, C.L. and Butterworth, D.S. 2016. Assessment of the South African sardine resource using data from 1984-2015: Results at the joint posterior mode for the two mixing-stock hypothesis. DAFF Branch Fisheries document: FISHERIES/2016/JUL/SWG-PEL/22REV2: 43pp.

Figure 1. Plots of sustainable yield rate *SY(y)/B(y)* (where *B(y)* is spawning biomass) against *y* and *B(y)* for various stocks given by the blue lines and the dashed blue lines show the medians. The orange lines reflect multiplying the *B(y)* values by 1.5 (see text).

(b) Brazil



(c) US West Coast: California



(d) US West Coast: Pacific Coast

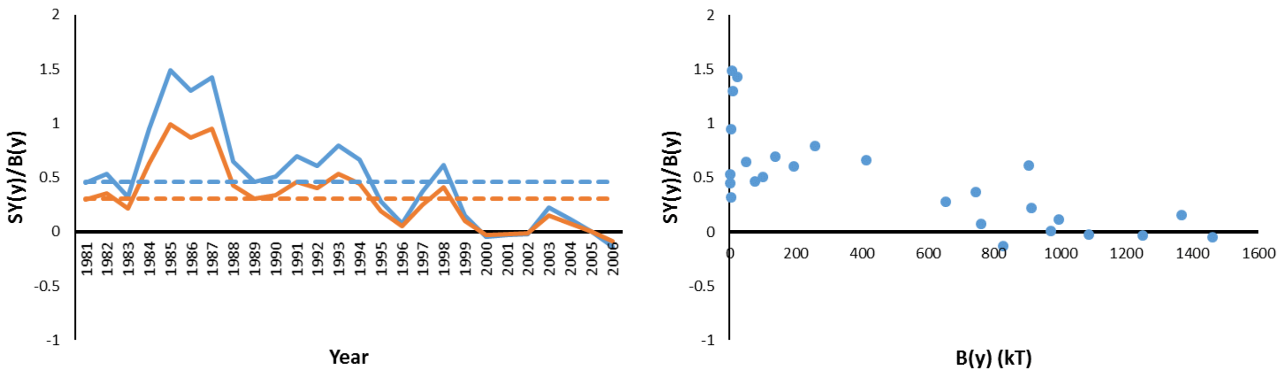
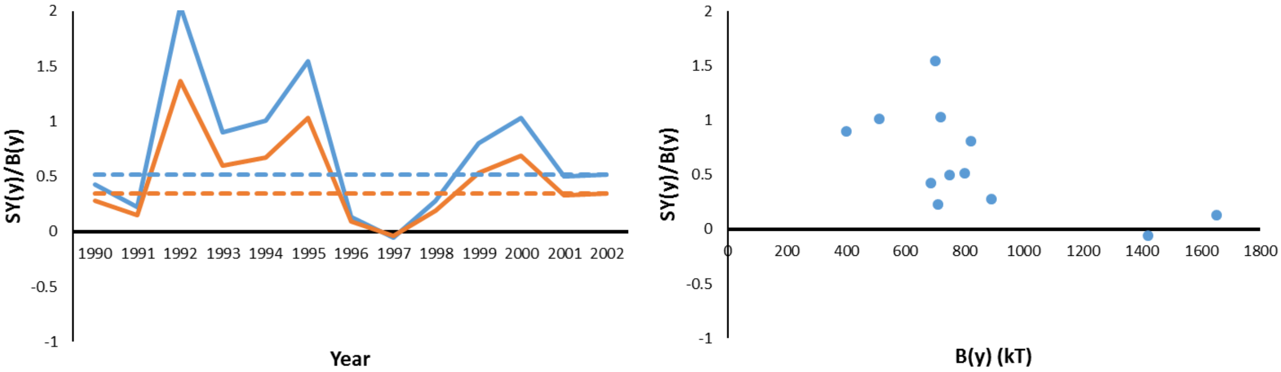
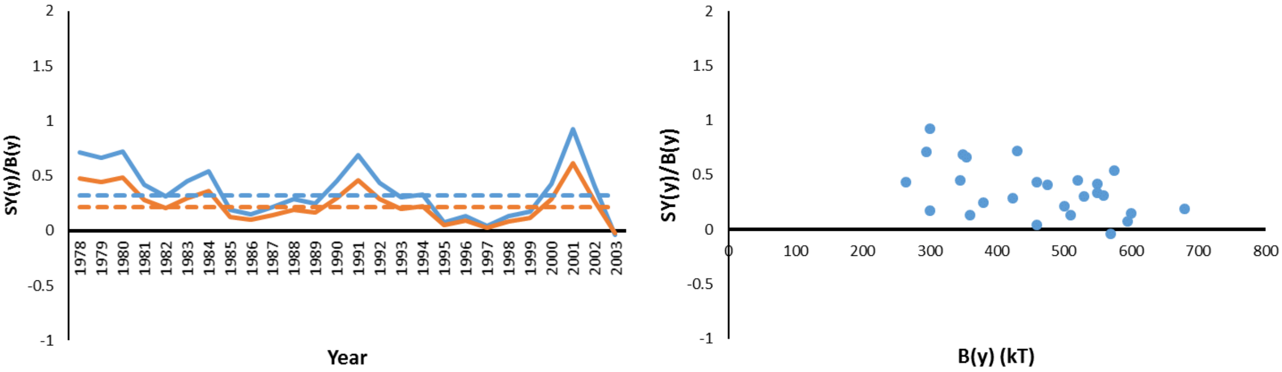


Figure 1 (contd). Plots of sustainable yield rate *SY(y)/B(y)* (where *B(y)* is spawning biomass) against *y* and *B(y)* for various stocks given by the blue lines and the dashed blue lines show the medians. The orange lines reflect multiplying the *B(y)* values by 1.5 (see text).

(e) Chile



(f) Europe



(g) Humboldt - N/C Peru

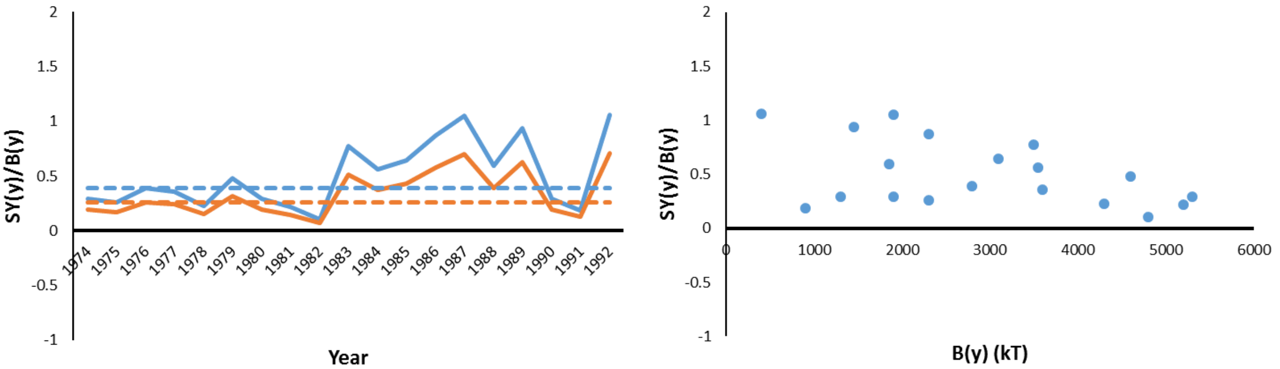
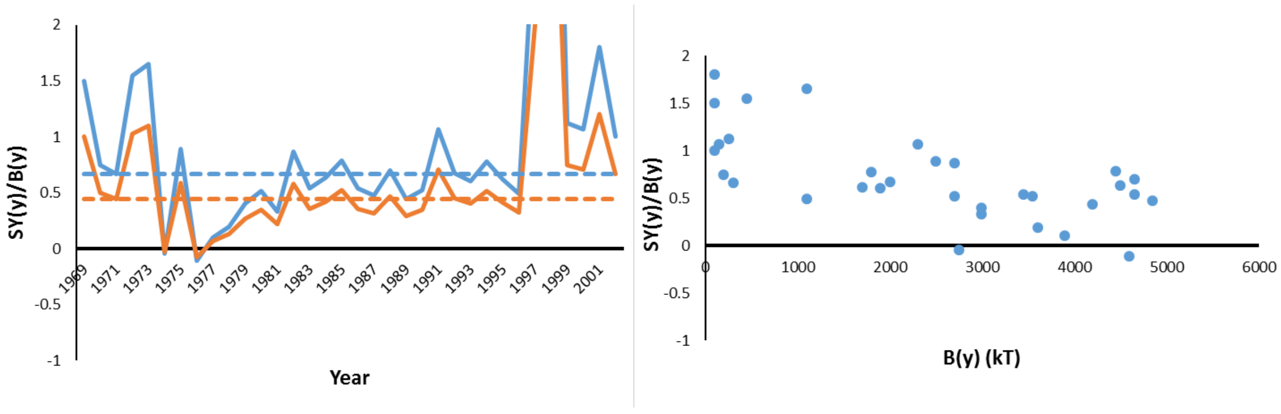
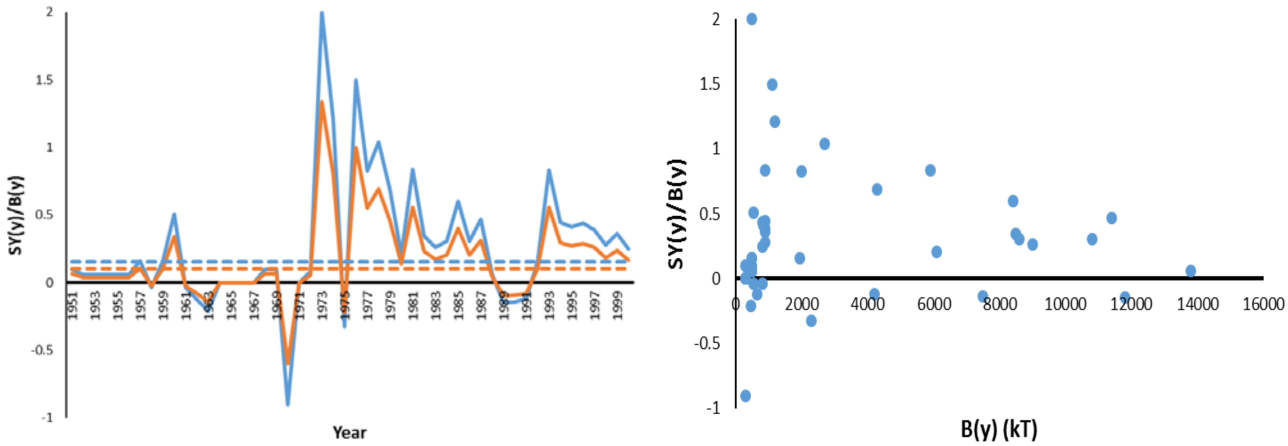


Figure 1 (contd). Plots of sustainable yield rate *SY(y)/B(y)* (where *B(y)* is spawning biomass) against *y* and *B(y)* for various stocks given by the blue lines and the dashed blue lines show the medians. The orange lines reflect multiplying the *B(y)* values by 1.5 (see text).

(h) Humboldt - S. Peru/ N. Chile



(i) Japan



(j) Northern Adriatic Sea

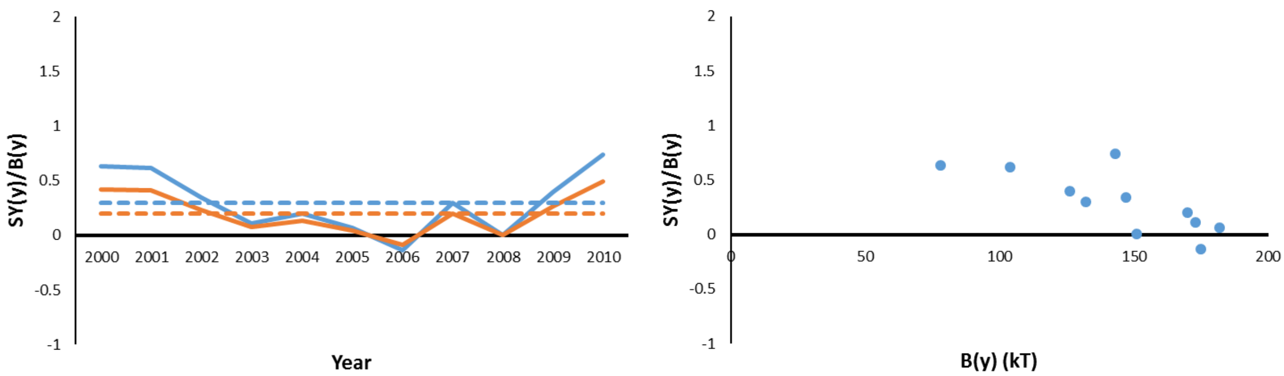
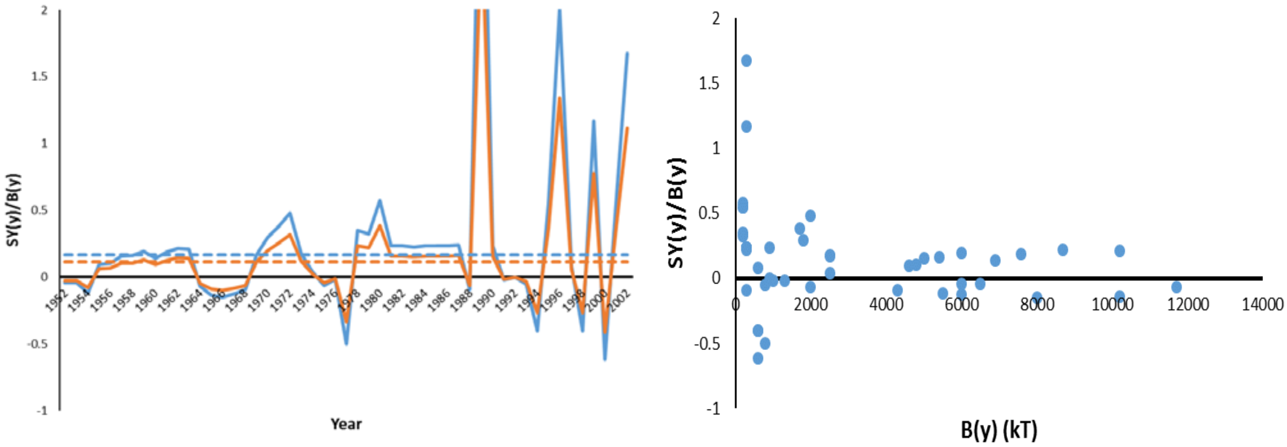
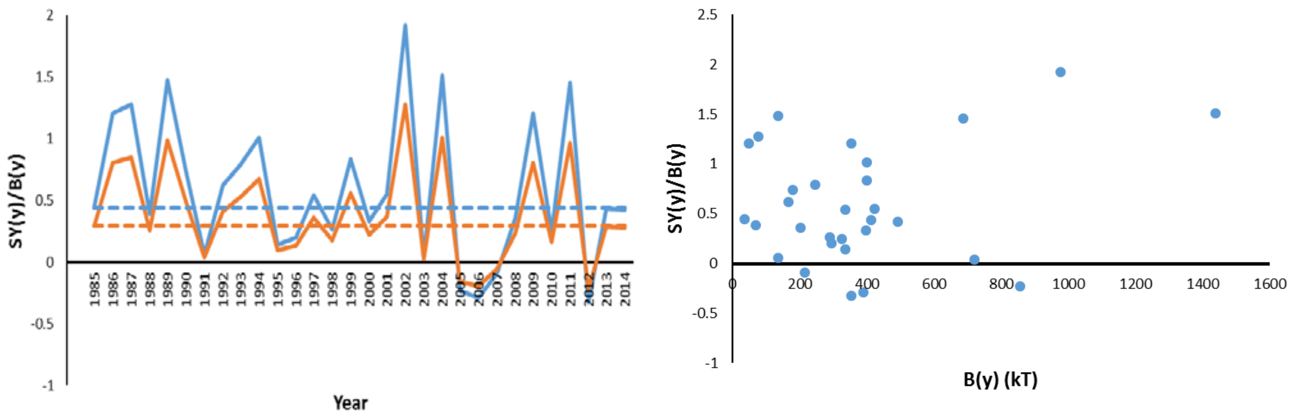


Figure 1 (contd). Plots of sustainable yield rate SY(y)/B(y) (where *B(y)* is spawning biomass) against *y* and *B(y)* for various stocks given by the blue lines and the dashed blue lines show the medians. The orange lines reflect multiplying the *B(y)* values by 1.5 (see text).

(k) Northern Benguela



(l) South Africa - Total



(m) South Africa West Coast

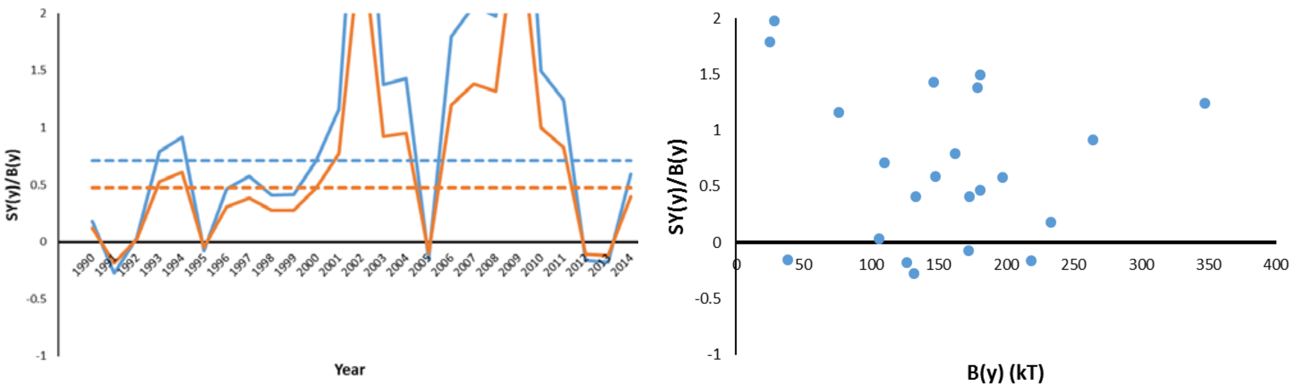


Figure 1 (contd). Plots of sustainable yield rate *SY(y)/B(y)* (where *B(y)* is spawning biomass) against *y* and *B(y)* for various stocks given by the blue lines and the dashed blue lines show the medians. The orange lines reflect multiplying the *B(y)* values by 1.5 (see text).

(n) South Africa South Coast

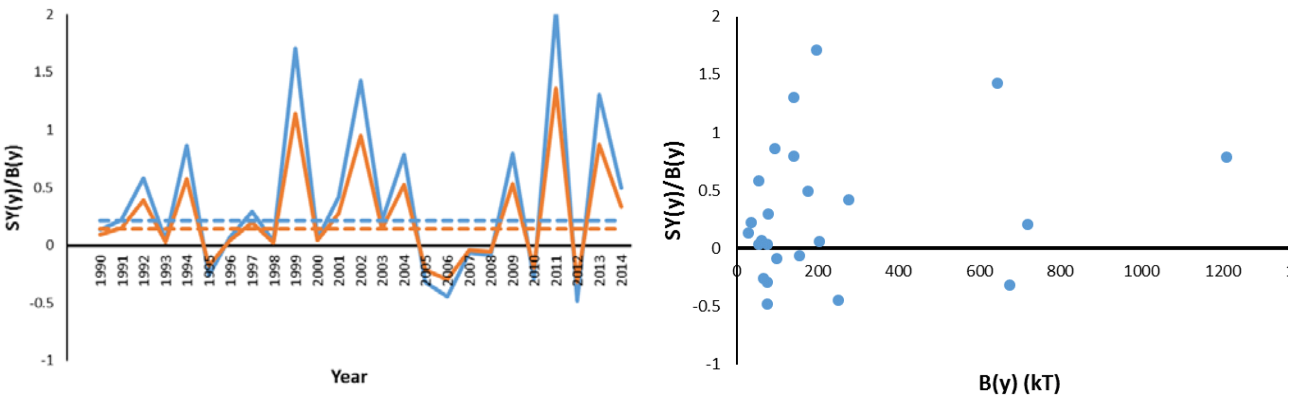


Figure 1 (contd). Plots of sustainable yield rate *SY(y)/B(y)* (where *B(y)* is spawning biomass) against y and *B(y)* for various stocks given by the blue lines and the dashed blue lines show the medians. The orange lines reflect multiplying the *B(y)* values by 1.5 (see text).