The use of fish scale deposit records to inform on South African sardine and anchovy recruitment patterns

C.L. de Moor[*] and C.D. van der Lingen[≠]

Correspondence email: carryn.demoor@uct.ac.za

Background

The ERA review during 2009 highlighted the following issue as of "high" priority:

> "Improved representation of statistical properties of sardine recruitment variation, particularly over periods with abundance peaks."

A review of work on fossil fish scale deposits, particularly those in Namibia, was requested by the SWG-PEL in November 2009, to determine if information on recruitment variation of sardine (and anchovy) could be extracted, and how frequently peaks in sardine abundance might be expected to occur in South African waters.

Findings

Data which could inform on recruitment variation and/or correlation of South African sardine and anchovy, and in particular the timing and duration of peaks in abundance, was sought. Such data could inform, eg through prior distributions, on model parameters for variance and autocorrelation in the annual recruitment residuals for sardine/anchovy from one year to the next and/or correlation between sardine and anchovy recruitment. The following bullet points review some of the findings of fossil fish scale deposit and related research:

- Decadal-scale variability in anchovy and sardine, based on catch records only, are summarised in Alheit et al. (2009). Little quantitative information that could help with forward projections could be extracted from this work. In addition, catch records may not be reliable indices of recruitment variability, especially for sardine.
- Field et al. (2009) suggest historical observations by explorers and naturalists be examined for indications of substantial changes in the sardine population size. Even if such observations exist for southern Africa, however, they would likely only give us a qualitative large/small biomass which would not be useful for informing quantitatively on the model parameters mentioned above.

[*] MARAM (Marine Resource Assessment and Management Group), Department of Mathematics and Applied Mathematics, University of Cape Town, Rondebosch, 7701, South Africa.
[≠] Marine and Coastal Management, Private Bag X2, Rogge Bay, 8012, South Africa

- Guano harvest data may be useful to provide information on historic pelagic biomass abundance (Field et al. 2009), but it would be a combined species biomass estimate and would not help with modeling future recruitment variation.
- In order to distinguish between changes in population abundance in contrast, for example, to an absence/presence of fish due to population contraction/expansion, samples from multiple sites are ideal, and probably essential (Field et al. 2009).
- Decadal, centennial and millennial variability in abundance of both anchovy and sardine occurs, and appears to be correlated with regional and global climatic changes (Valdes et al. 2008, Finney et al. 2010).
- Valdes et al. (2008) found a positive correlation between sardine and anchovy scale deposition rates over about 250 years from northern Chile, and Field et al. (2009) reported that scale deposition rates of anchovy and sardine from the Santa Barbara Basin (SBB), California, over the past 1500 years were weakly, but significantly, positively correlated. Such observations suggest that the species alternation between sardine and anchovy observed from catch data during the late 20th century may not be typical.
- Although the above suggests that positive inter-annual autocorrelation in sardine and anchovy recruitment should be modeled, this does not inform on quantitative values. The past three full assessments of South African sardine and anchovy have resulted in estimates of positive inter-annual autocorrelation (stronger for anchovy than sardine).
- Shackleton (1988) demonstrated that the relationship between fossil fish scale abundance and fish abundance is not straightforward and is biased by, among other things, variations in the scale shedding of live fish from species to species, eg sardine losing scales 2 to 3 times as fast as anchovy.
- Peaks in anchovy and sardine scale deposit rates in the SBB occur at 50-70 year intervals (Baumgartner et al. 1992), but the SBB dataset does not have a preferred periodicity that differs statistically from the null hypothesis of an oceanic red-noise spectrum (Field et al. 2009).
- Baumgarter et al. (2004) claim that the nature of large-scale variability over not only interdecadal and centennial, but also interannual time scales could be examined from information extracted from marine sediments. However, from the results that are available it seems that the best information we could obtain from scale deposition rates, if the data were available for the southern Benguela, would be inter-decadal, rather than inter-annual, time scales. A finer time scale would probably be needed to usefully inform on the above mentioned model parameters.

Southern Africa

- Shackleton (1987) summarized findings from fossil fish scales from ±500-600 years ago. Unfortunately the samples were from a single area only (Walvis Bay).
- Analysis of sediments from Walvis Bay have shown that sea surface temperature varied considerably over the last 1000 years after a relatively steady phase during the preceding 2000

years, and that the relative abundance of the major fish populations (anchovy, sardine, hake and horse mackerel), determined from fish scale sedimentation records, changed drastically in response (Baumgarter et al. 2004, Finney et al. 2010). Further analyses of core samples from Namibia are presently underway (Juergen Alheit, pers comm.).

- South Africa does not have sufficiently anoxic sediments to preserve fish scales, with very few such sites being found (John Crompton, UCT marine geologist, pers comm.).

Summary

In summary, it seems unlikely that fossil fish scale deposit data could be extracted from South African waters. Even if such data were available, or if data from more than one site in Namibia were available, it seems most likely that these data would provide information on decadal recruitment variations rather than interannual variations, and it is the latter which would be of most importance to inform model parameters used in projecting the sardine and anchovy populations for, say, 20 years into the future.

References

Alheit, J., Roy, C., and Kifani, S. 2009. Decadal-scale variability in populations. Chapter 5 In: Checkley D, Alheit J, Oozeki Y, Roy C (eds) *Climate Change and Small Pelagic Fish*. Cambridge University Press, pp 64-87.

Baumgartner, T.R., Soutar, A. and Ferreira-Bartrina, V. 1992. Reconstruction of the history of Pacific sardine and northern anchovy populations over the last two millennia from sediments of the Santa Barbara Basin, California. CalCOFI Reports 33: 24-40.

Baumgartner, T., Struck, U., and Alheit, J. 2004. GLOBEC Investigation of Interdecadal to Multi-Centennial Variability in Marine Fish Populations. PAGES News 12: 19-21

Field, D.B., Baumgartner, T.R., Ferreira, V., Gutierrez, D., Lozano-Montes, H., Salvatteci, R., and Soutar, A. 2009. Variability from scales in marine sediments and other historical records. Chapter 4 In: Checkley D, Alheit J, Oozeki Y, Roy C (eds) *Climate Change and Small Pelagic Fish*. Cambridge University Press, pp 45-63.

Finney, B.P., Alheit, J., Emeis, K.-C., Field, D.B., Gutiérrez, D., and Struck, U. 2010. Paleoecological studies on variability in marine fish populations: A long-term perspective on the impacts of climatic change on marine ecosystems. Journal of Marine Systems 79:316-326

Shackleton, L.Y. 1987. A comparative study of fossil fish scales from three upwelling regions. South African Journal of Marine Science 5:79-84.

Shackleton, L.Y. 1988. Scale shedding: An important factor in fossil fish scale studies. J. Cons. Int. Explor. Mer. 44:259-263

Valdes, J., Ortlieb, L., Gutierrez, D., Marinovic, L., Bargas, G., and Sifeddine, A. 2008. 250 years of sardine and anchovy scale deposition record in Mejillones Bay, northern Chile. Progress in Oceanography 79:198-207