

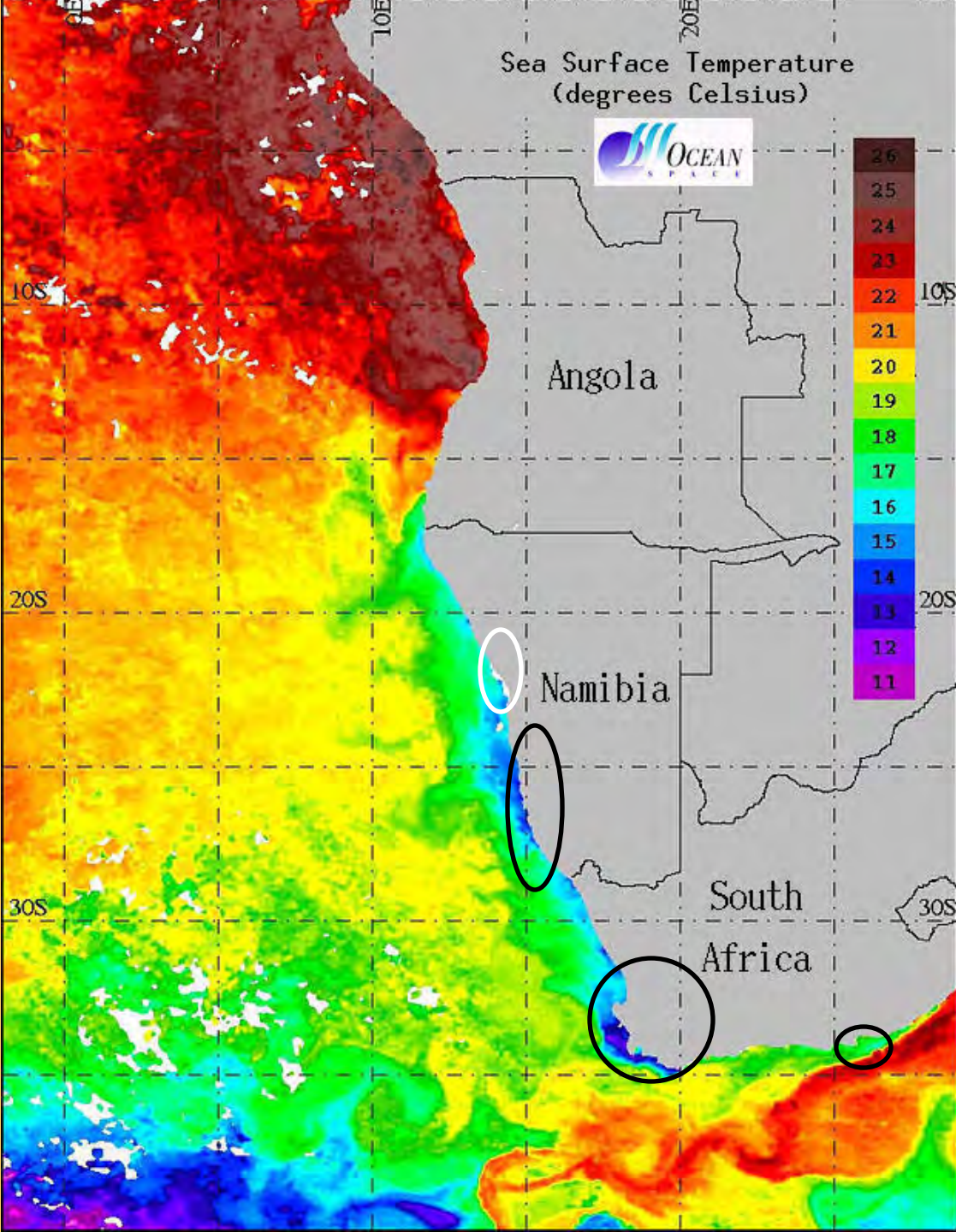
Famine in a time of plenty – a recent paradox in the Benguela upwelling system

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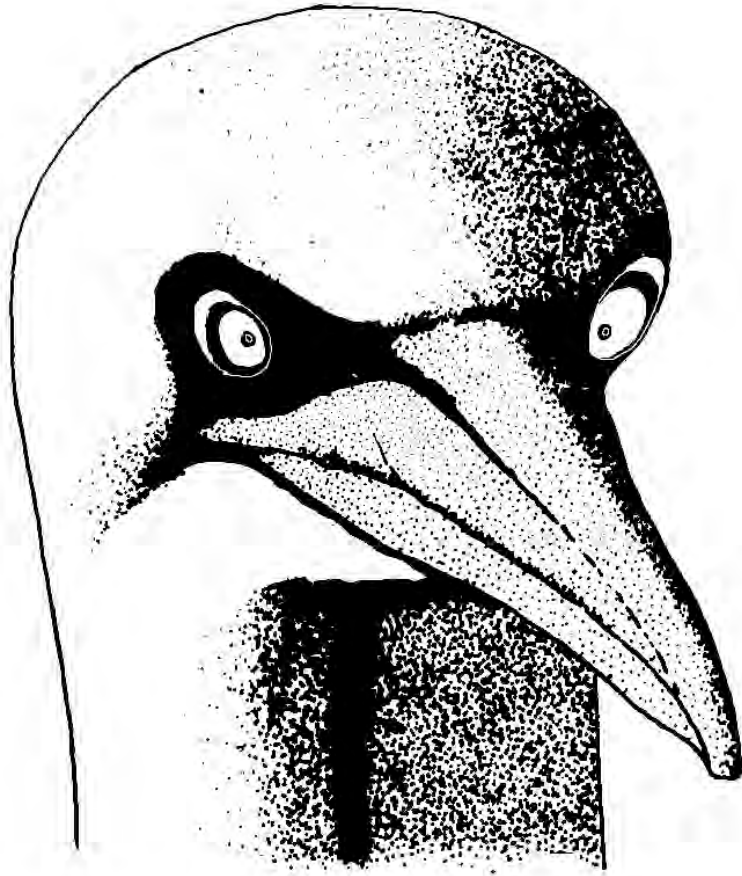
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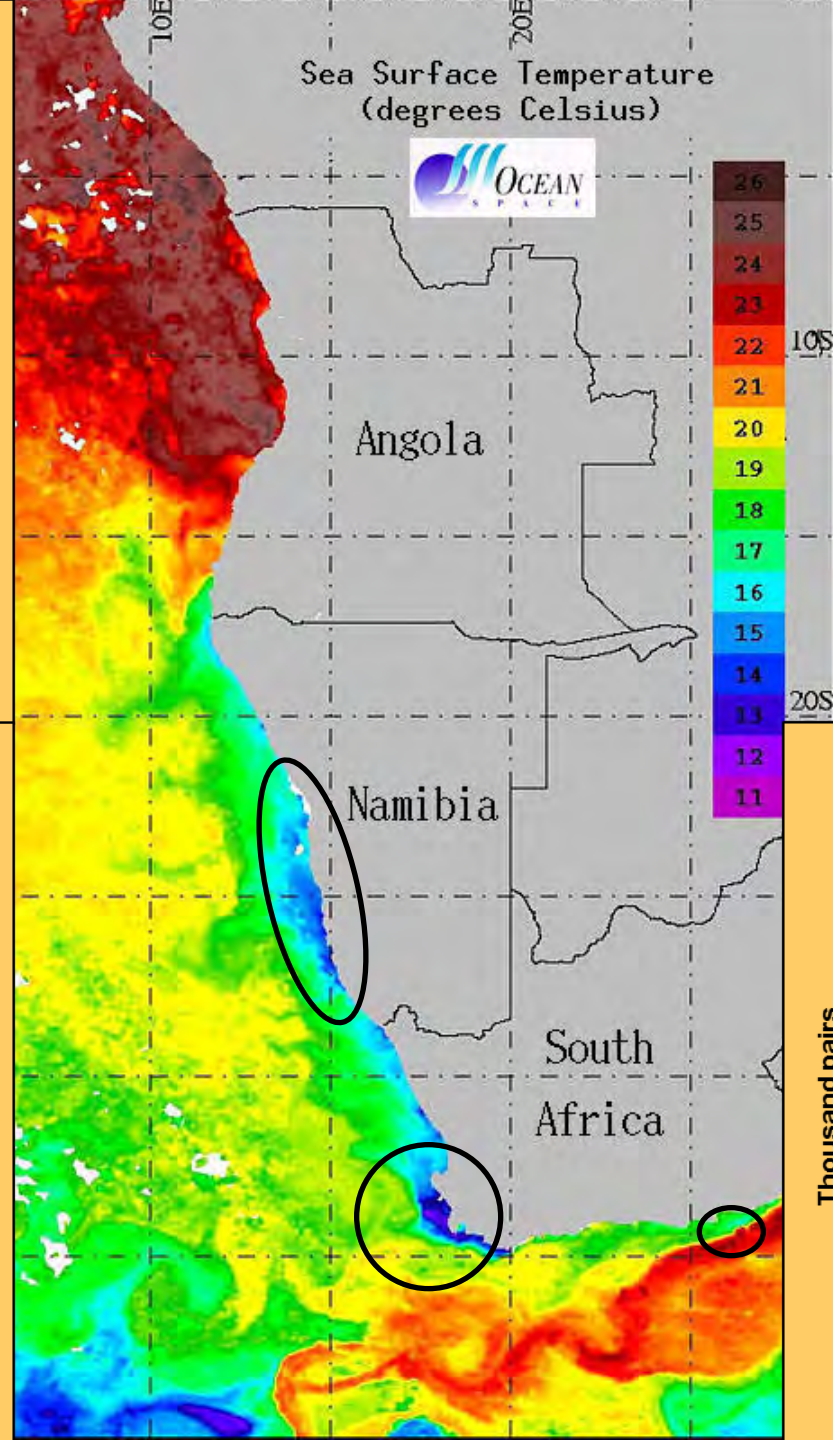
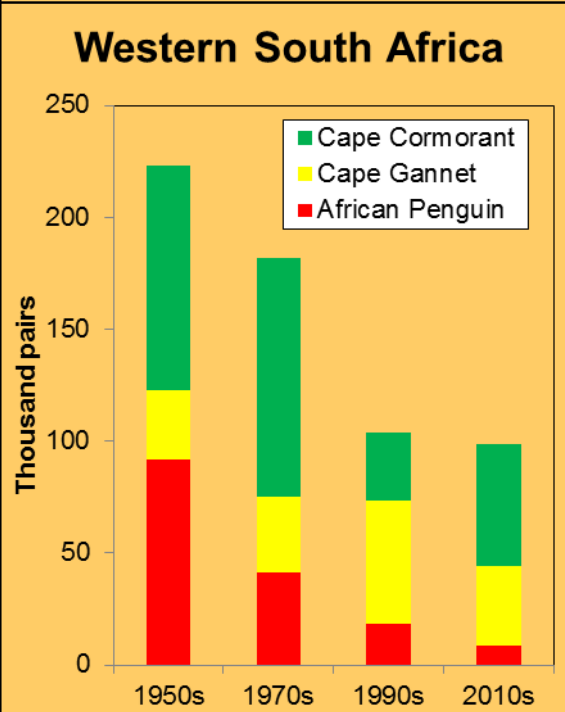
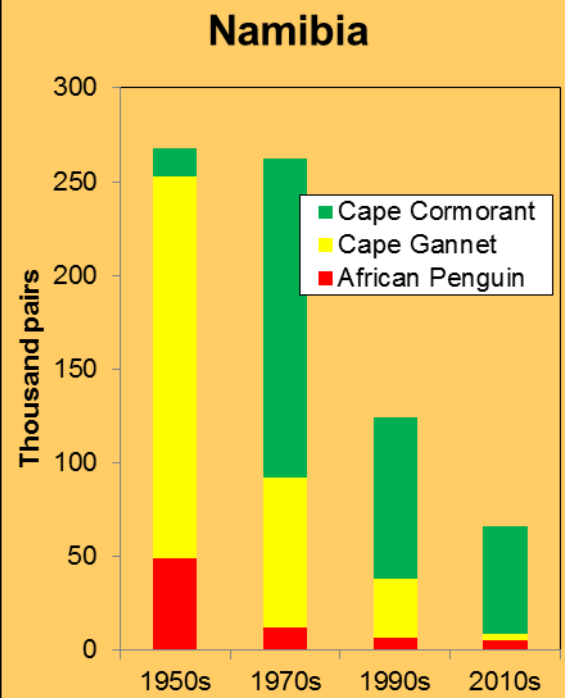
Major breeding localities of seabirds in the Benguela ecosystem





Three endemic seabirds that feed predominately on exploited, nutritious forage (sardine, anchovy) are now Endangered

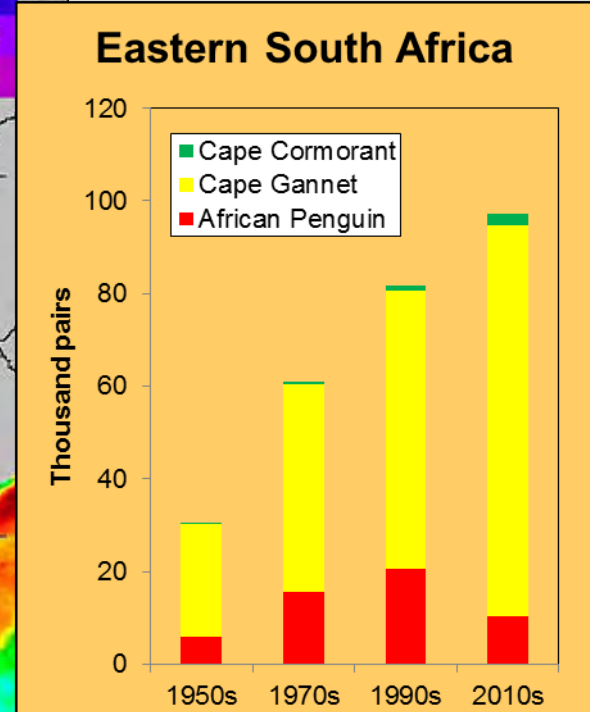




Wrt species on the move:

large decreases in numbers of these seabirds in the west Benguela;

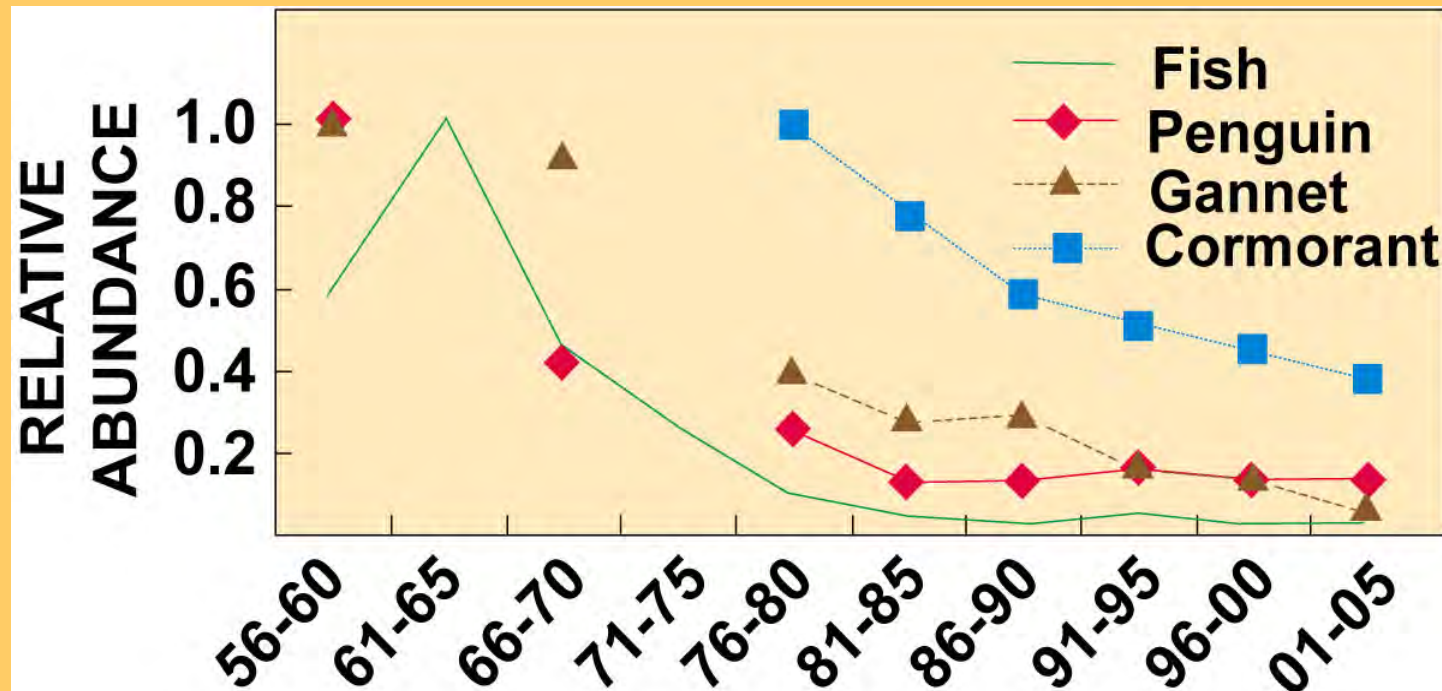
increases in the east, which did not offset the decreases.



Namibia



Decreases followed collapse of sardine (without replacement) after 1960s.
Range of collapsed sardine contracted to the north away from islands.
Penguins with limited swimming range decreased first.
Gannets with foraging range > 100 k followed.
Cormorants (able to breed at northern platforms) decreased less severely.



Western South Africa

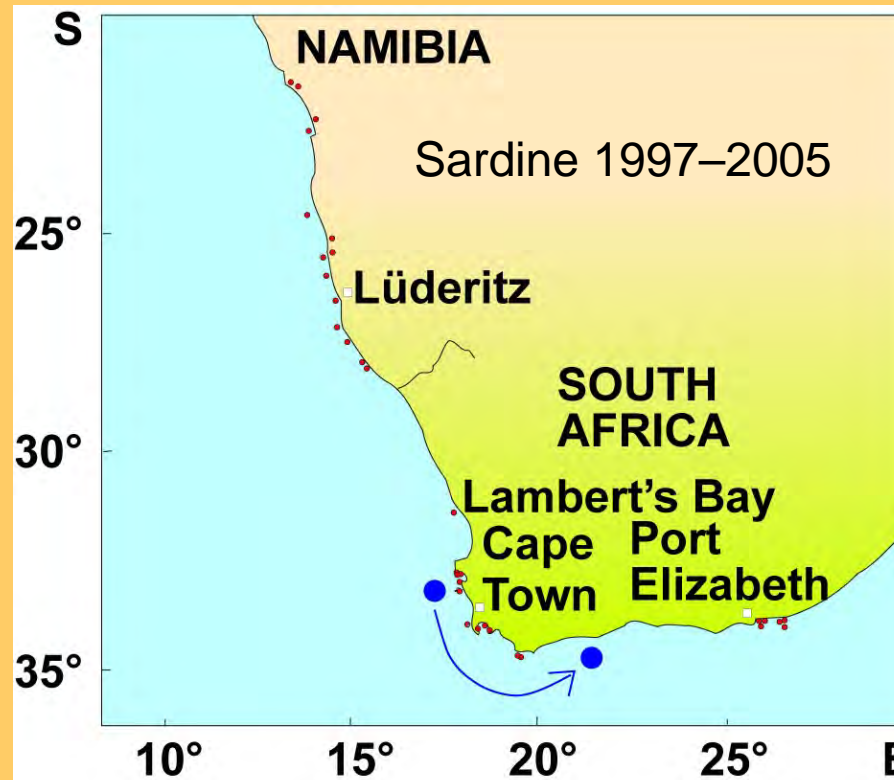
A shift east in the centre of distribution of adult sardine and adult anchovy occurred between the mid-1990s and mid-2000s.

Fairweather et al. 2006. *African Journal of Marine Science* 28, 661–680.

Roy et al. 2007. *African Journal of Marine Science* 29, 309–319.

Coetzee et al. 2008. *ICES Journal of Marine Science* 65, 1676–1688.

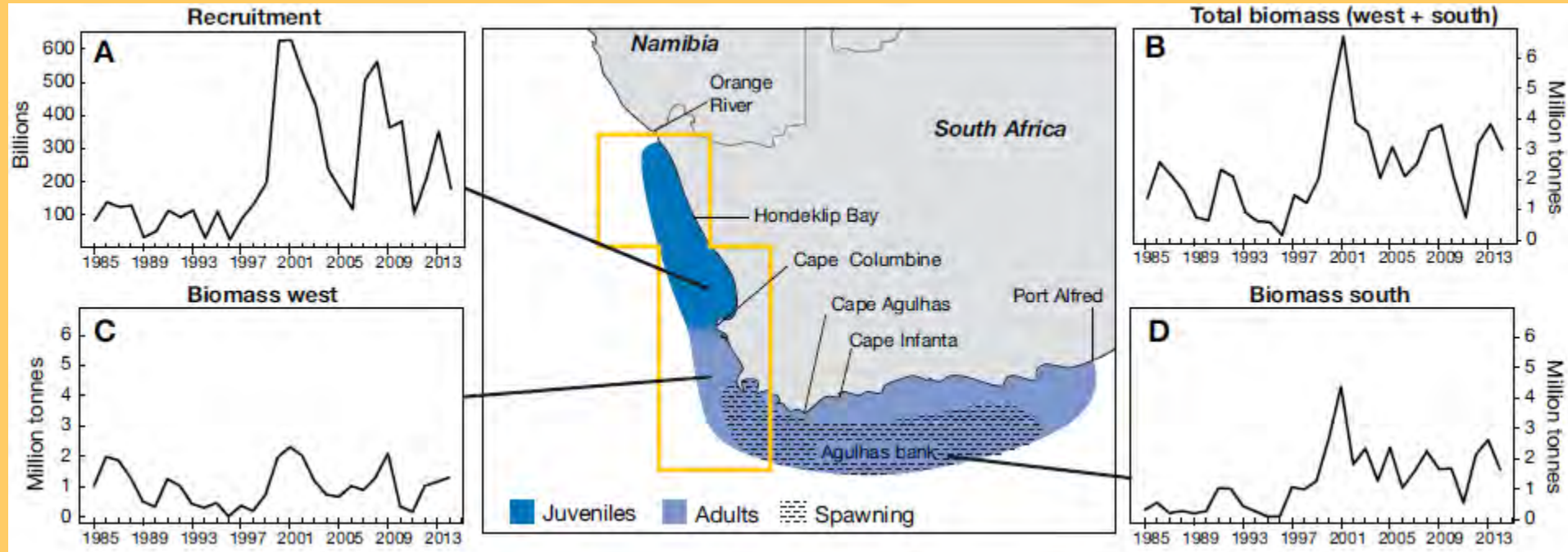
Consequent mismatches in the distributions of breeding localities and prey caused decreases of seabirds that eat these fish.



Although sardine collapsed, anchovy increased and its adult biomass in the west showed no long-term trend.

Young-of-the-year anchovy recruiting along the west coast increased.

Forage for predators should have been plentiful.



Van der Sleen et al. 2018. *Marine Ecology Progress Series*, 596: 155–164.

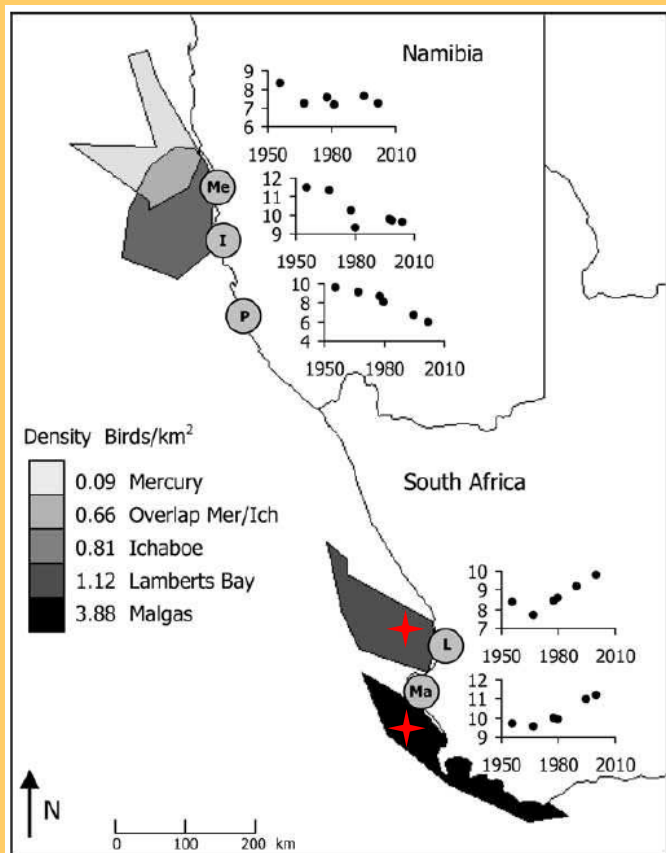
Paradoxically, predator decreases and behaviours indicated extreme scarcity of prey.

Apparently, a decreased portion of prey biomass was available to seabirds.

The diet of Cape gannets (*Morus capensis*) was examined to investigate the availability of forage resources

Forage widely, dive to c. 20 m, able to switch prey. Hence diet is likely to reflect epipelagic prey availability.

Diet sampled monthly in their summer breeding season, at both their localities off South Africa's west coast, over a 38-year period: 1978/79–2015/16.



Lewis et al.. 2006.
Oecologia 147: 606–614

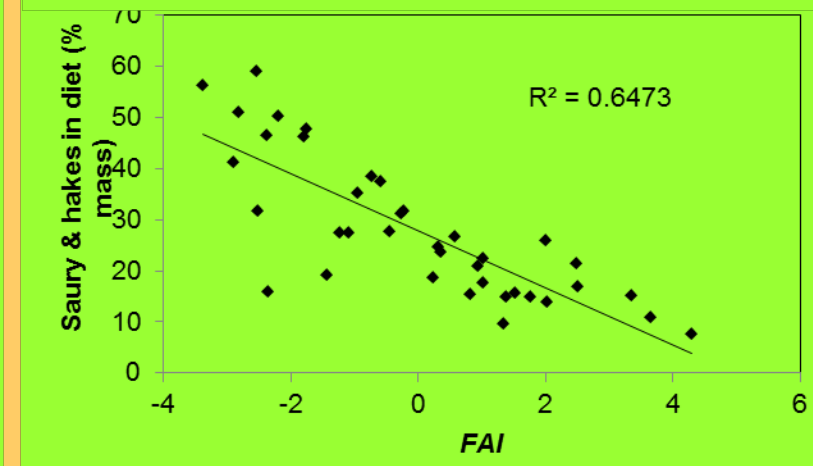
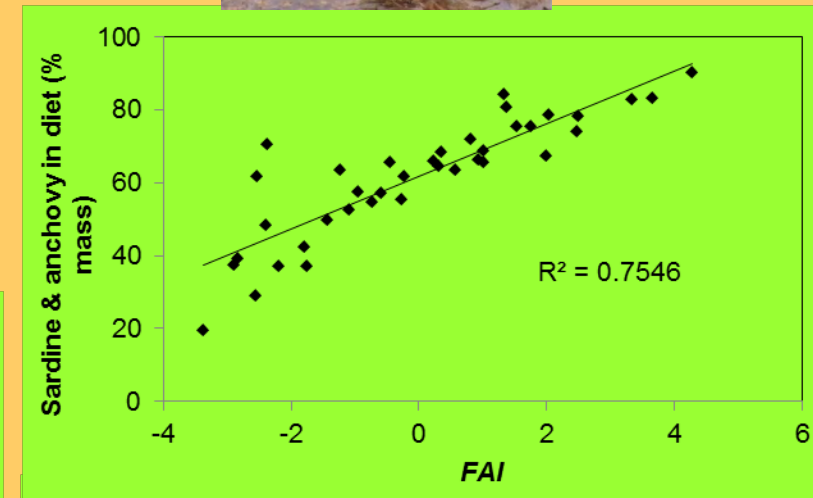
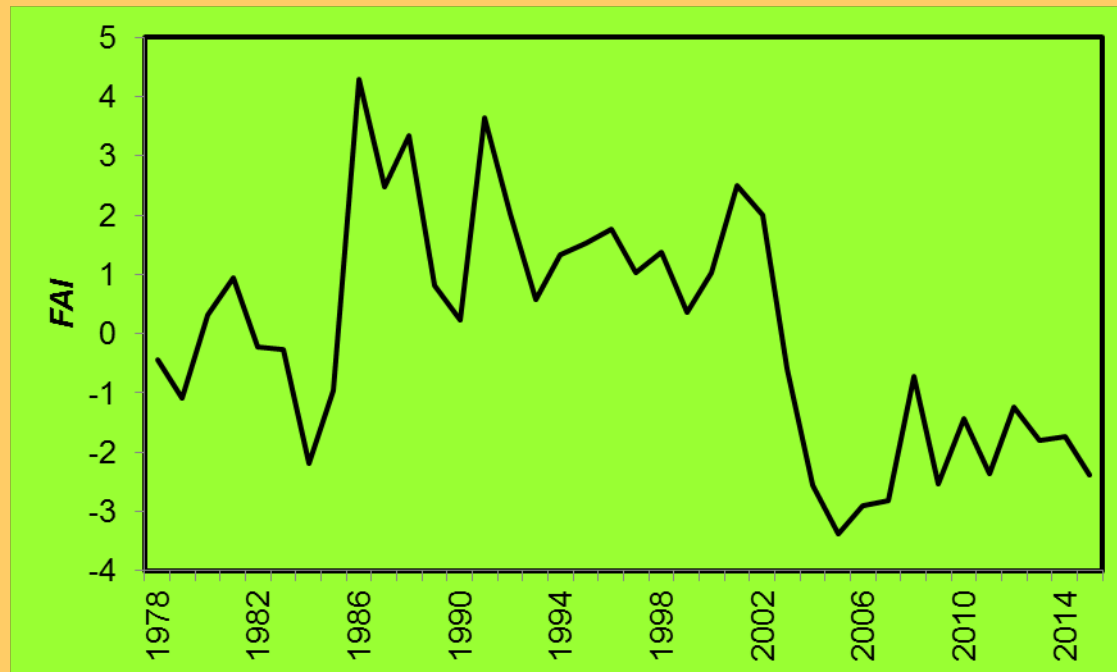
Principal Component Analysis was applied to the diet time series to obtain forage indices.

One significant PC, termed Forage Availability Index (*FAI*), was:

positively related to the combined contribution of sardine and anchovy to the diet;

negatively related to less-nutritious hake offal scavenged from bottom trawlers and to the offshore saury.

Values of *FAI* were lowest after 2002, mostly < -1.



GAMs indicated:

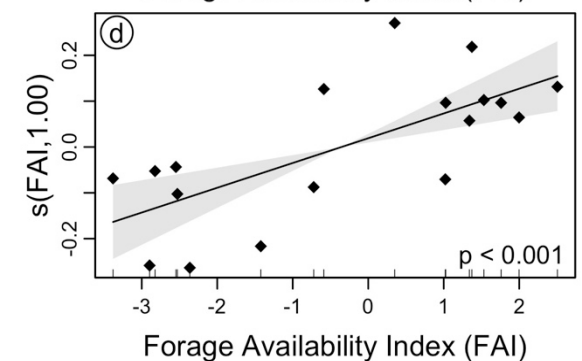
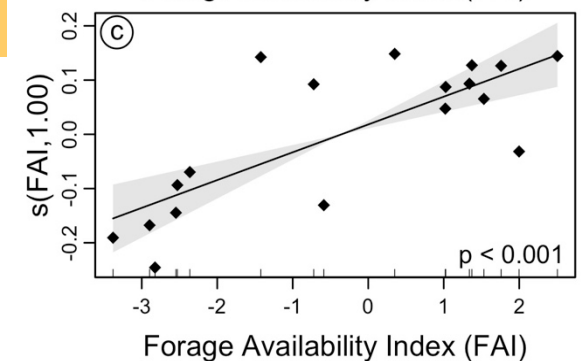
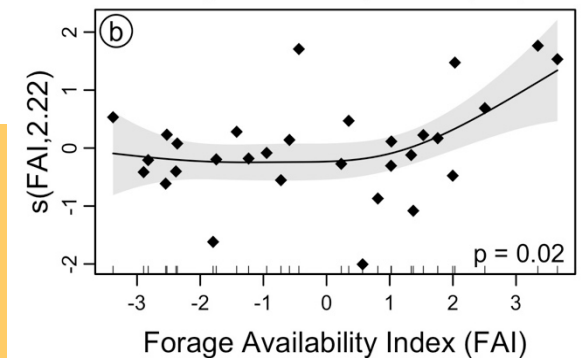
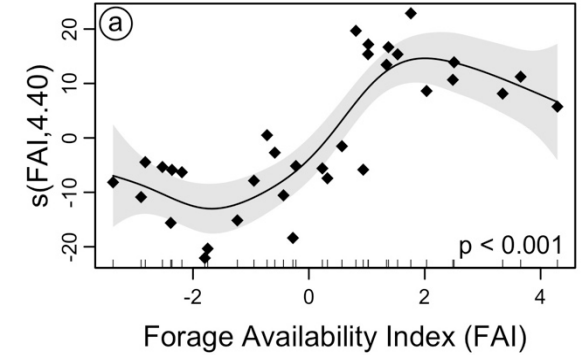
1) *FAI* significantly related to numbers breeding or survival of each of the three Endangered seabirds.

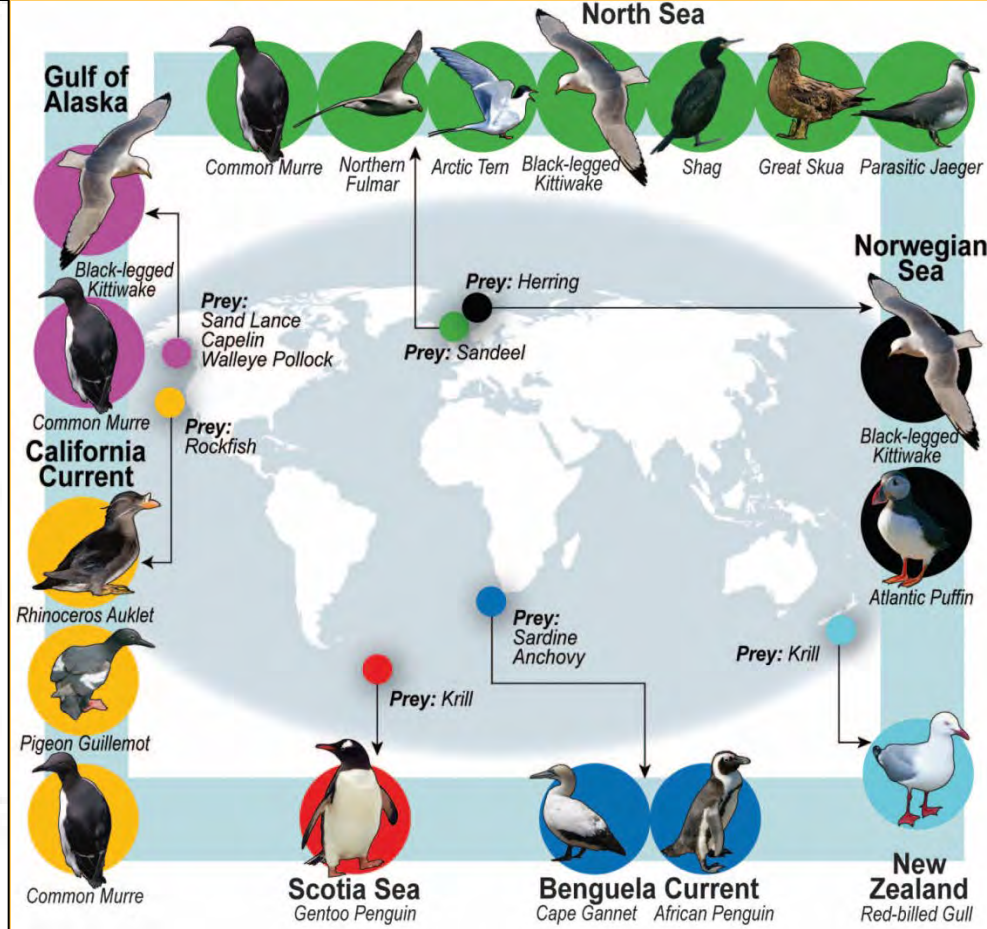
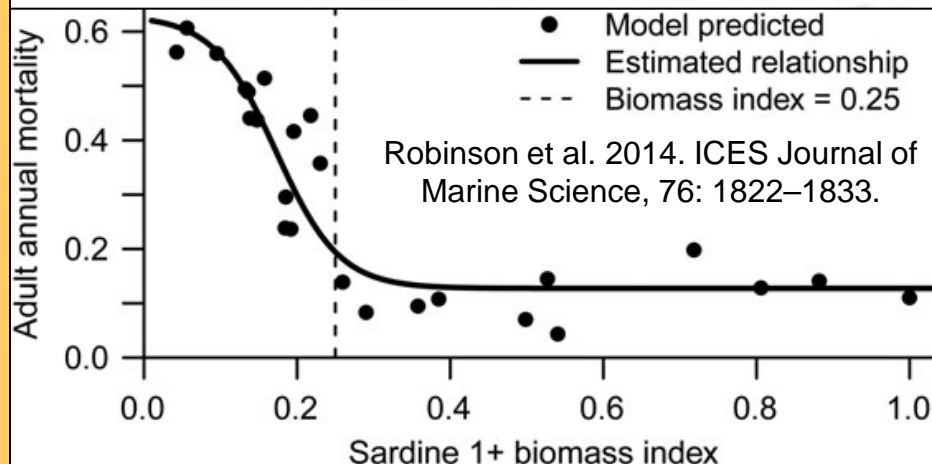
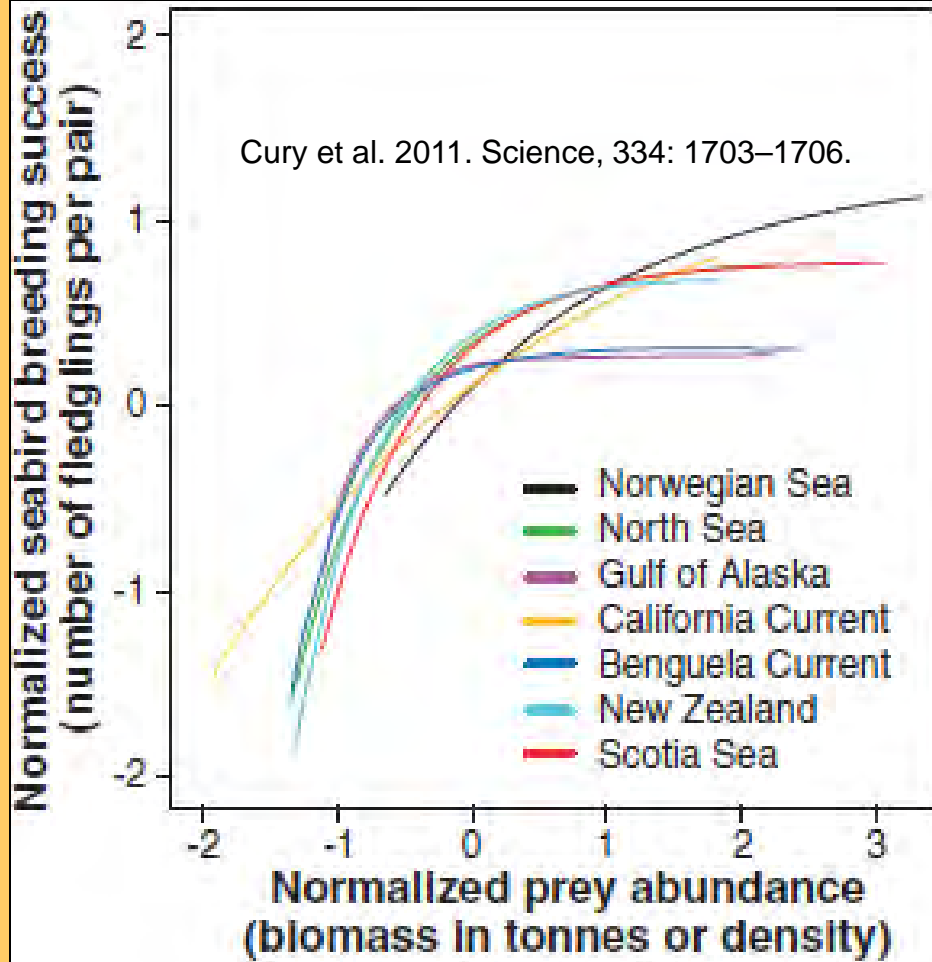
- a) numbers of Cape gannets breeding;
- b) numbers of Cape cormorants breeding;
- c) d) survival of adult African penguins at Dassen and Robben islands.

2) Suggests *FAI* is a valid indicator of availability of nutritious forage.

3) *FAI* showed (different) thresholds, above which numbers breeding would increase, or survival improve.

4) Recent *FAI* values were below all thresholds.





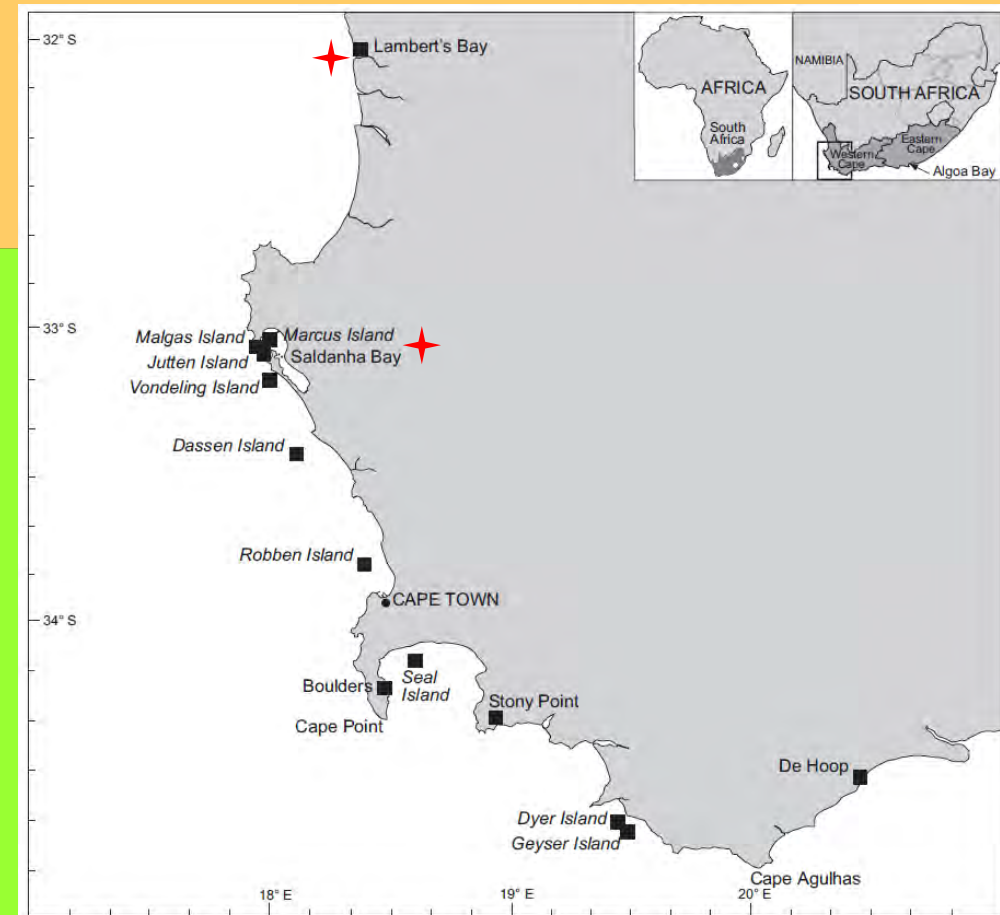
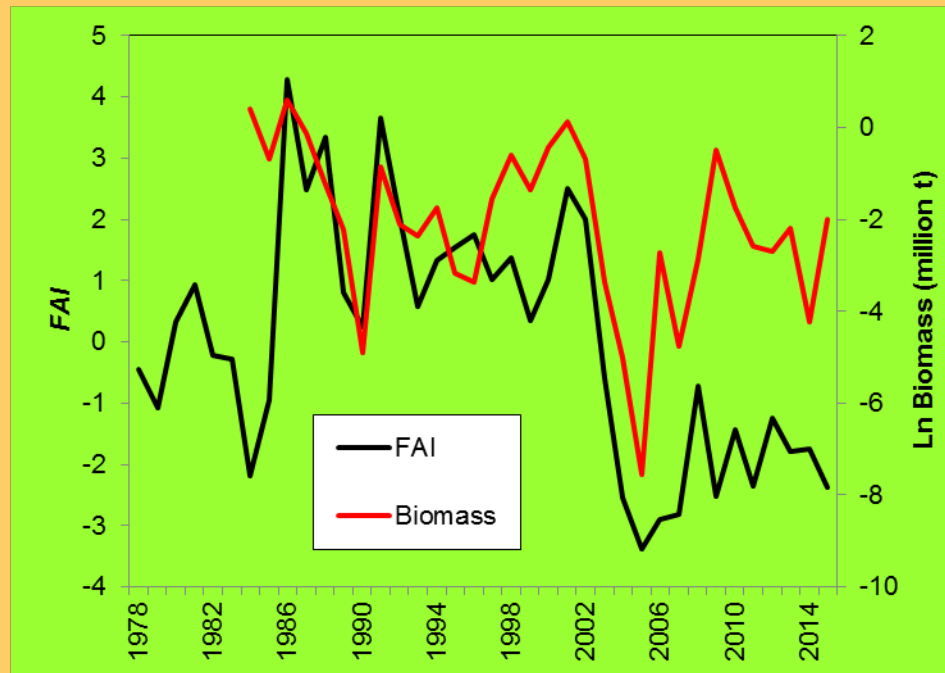
Previous ecosystem thresholds available for the southern Benguela ecosystem using estimates of overall forage biomass, rather epipelagic availability.

FAI positively related to the combined biomass of adult sardine and anchovy found north of Cape Point until 2005.

Relationship then broke down suggesting some factor other than horizontal distribution recently influenced availability.

Fishers also unable to fill anchovy catch allocations; asserted anchovy had moved deeper.

Cf. Humboldt system Boyd et al. 2017. *Journal of Applied Ecology* 54: 1362-1372.



To conclude:

Seabirds can be used as indicators of climate-change impacts on marine ecosystems.

The Forage Availability Index suggested a change in depth (z-axis) distribution of prey, since biomass of anchovy in west (x,y) remained high through the period.

Climate-change impacts on prey availability may be as important as changes in abundance, especially to central-place, shallow-diving predators, such as some seabirds. Seabirds are sensitive, and readily observable, indicators.

Biomass *per se* doesn't always predict important aspect of trophic relationships – more information is needed to understand climate-change impacts on ecosystems.



Thank you!

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The conveners of this session

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