Assessing the impact of fishing on the African penguin population

William Robinson

Marine Resource Assessment and Management Group
Department of Mathematics and Applied Mathematics

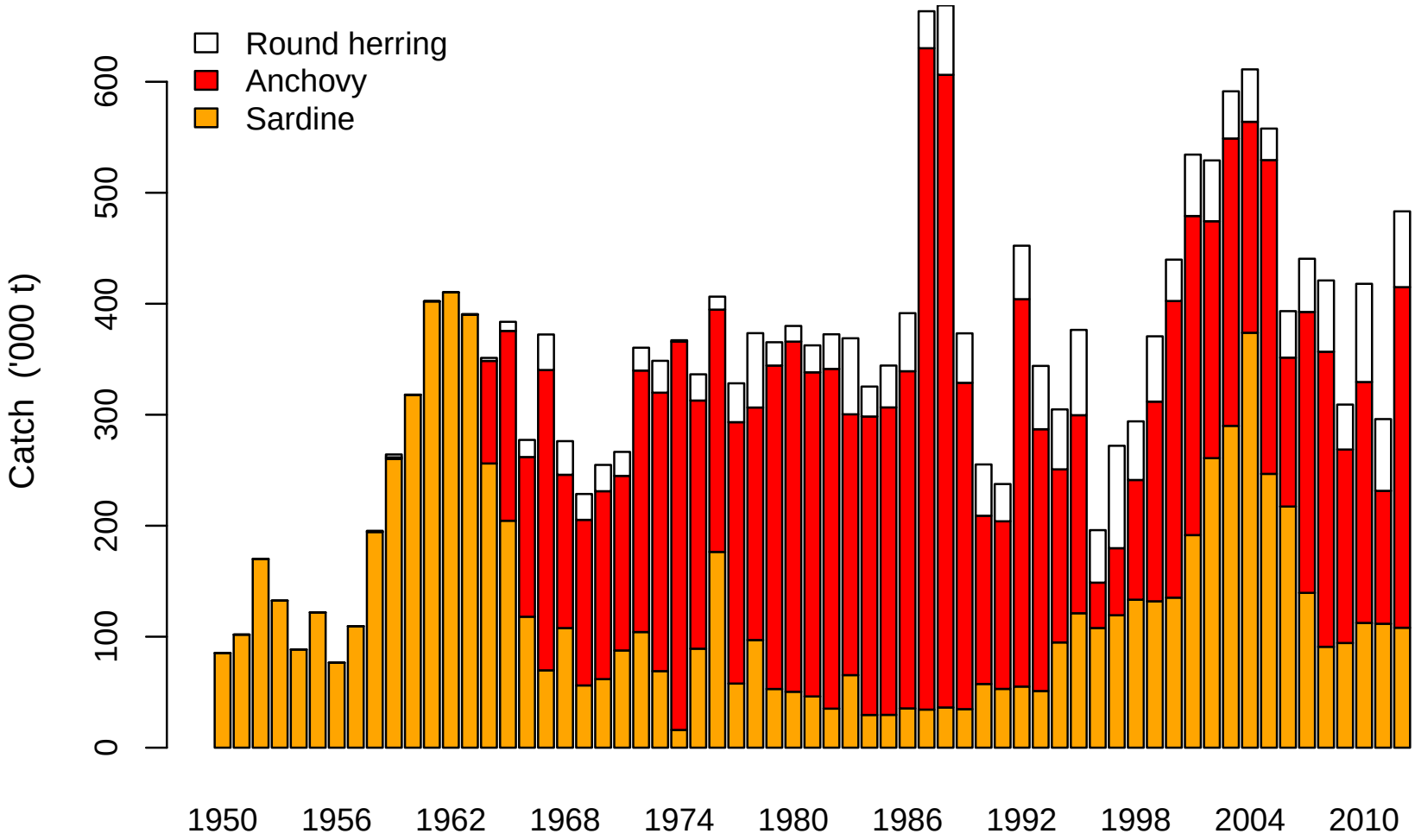
Post Graduate Science Symposium
4 September 2013

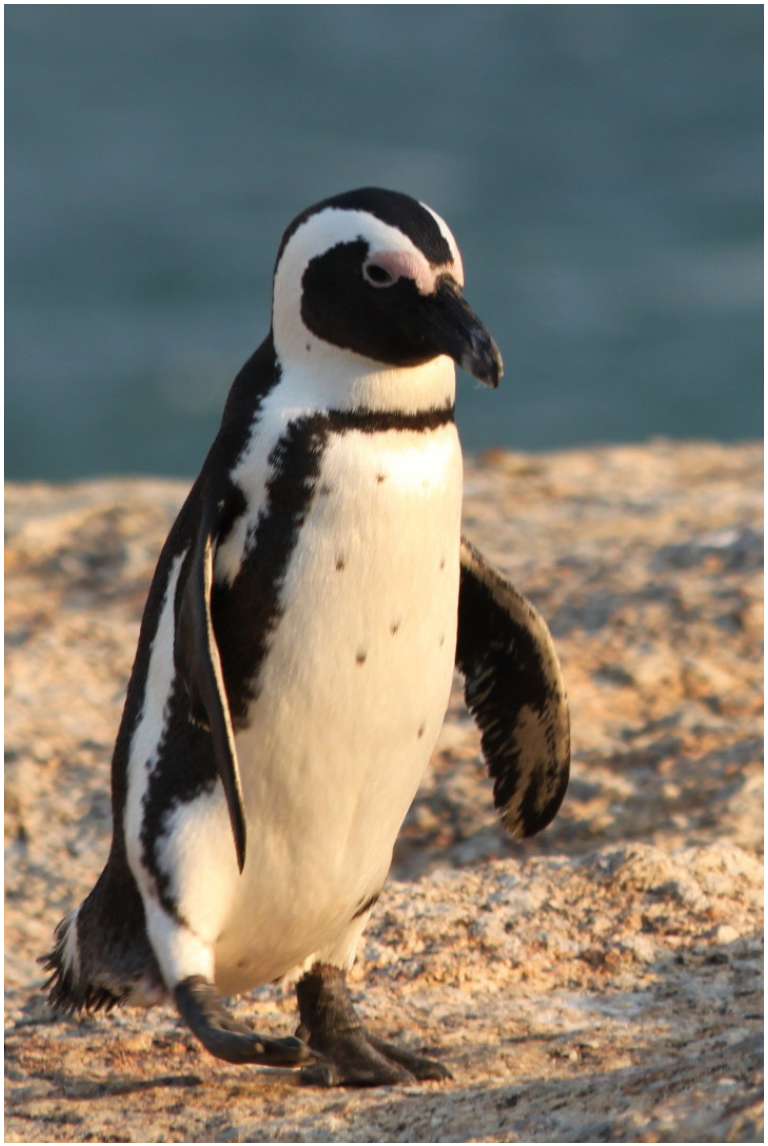
Outline

Management of the small pelagic fishery

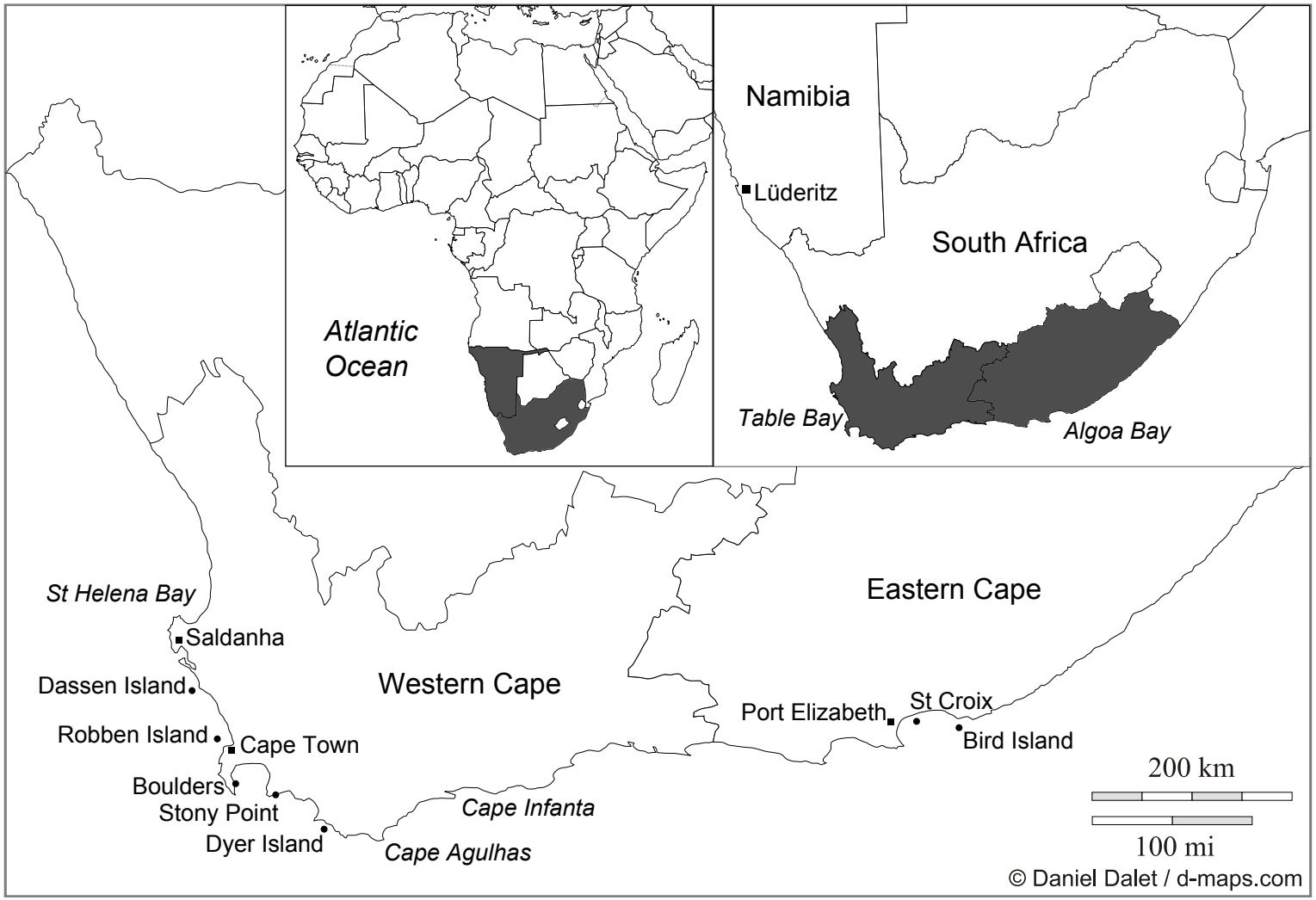
- DAFF Pelagic Scientific Working Group
- Total allowable catch (TAC) set annually
- Operational Management Procedure (OMP)
- Ecosystem approach to fisheries management

South African small pelagic fishery catches
1950–2012



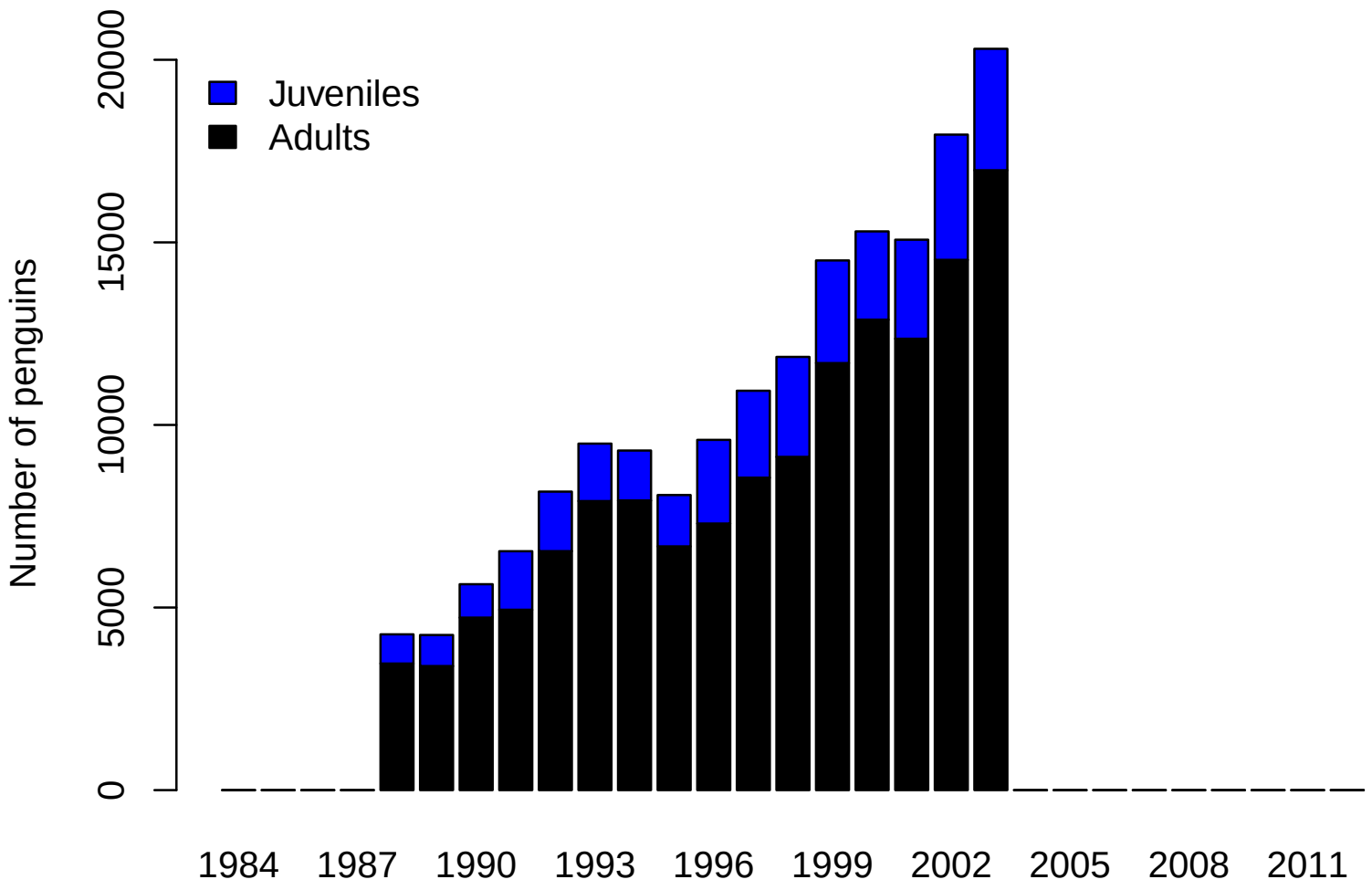


Locations of African penguin breeding colonies



Penguins moulting at Robben Island

1988/1989–2003/2004



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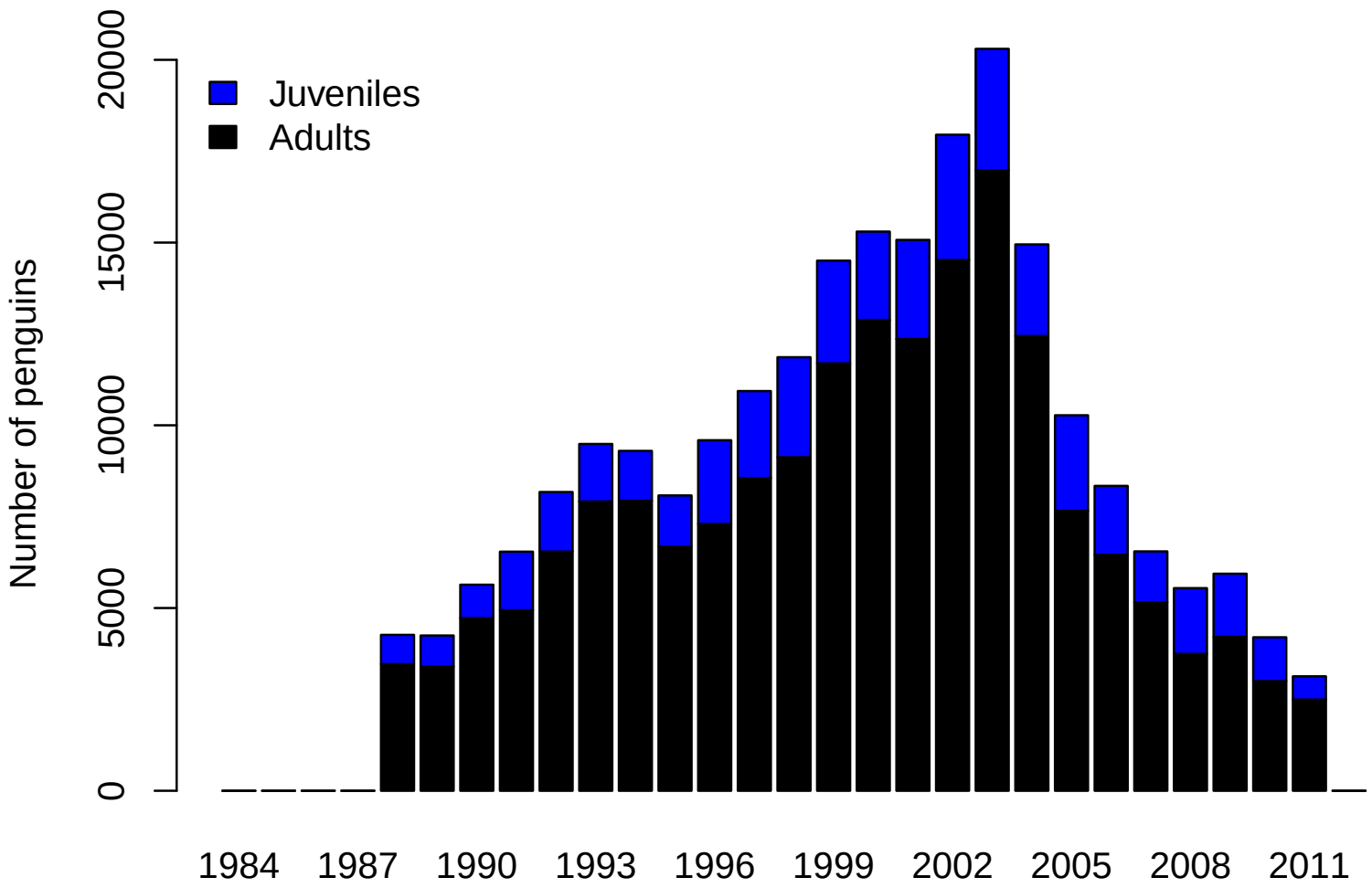
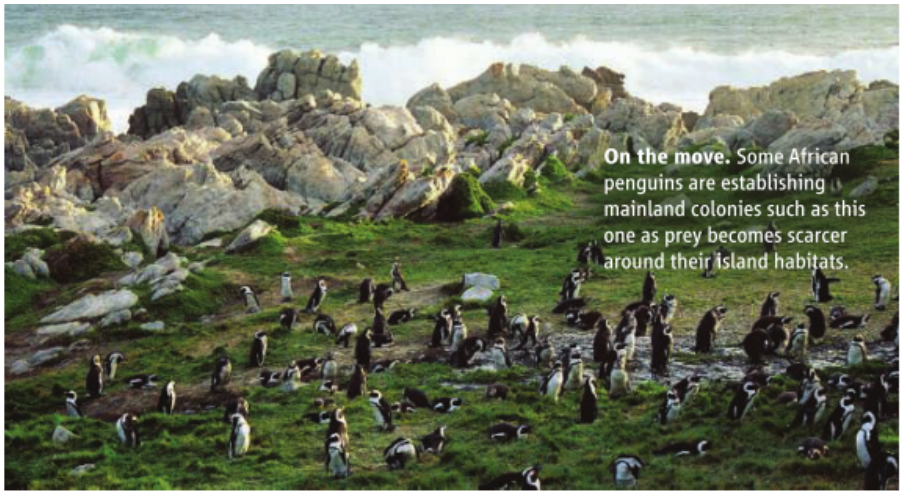


African penguins in a puzzling decline

Koenig (2007) *Science*



On the move. Some African penguins are establishing mainland colonies such as this one as prey becomes scarcer around their island habitats.

ZOOLOGY

African Penguin Populations Reported in a Puzzling Decline

PRETORIA, SOUTH AFRICA—African penguin populations, on the upswing since the mid-1990s, appear to have gone into a surprising nosedive. New data indicate that their numbers may have dropped in the past few years by as many as 50,000—40% of the population. And the birds, which normally breed on island colonies, have puzzled scientists by establishing a growing number of new colonies on the mainland.

Cape Town's avian demography unit, agrees that the new colonies reflect a trend of penguins moving eastward toward the current fish biomass center, near Mossel Bay.

African penguins, called jackass penguins because of their braying, once numbered more than 1.5 million on islands off South Africa's western coast. But guano and egg harvesting a century ago led to a 90% decline in the population; oil spills in 1994 and 2000

...the birds' prime food sources—sardines and anchovies—are becoming scarce around established colonies... overfishing may be part of the problem... the biomass of those fish species in the region near the penguins' largest breeding islands west of Cape Town fell sharply after 2002.

Penguins moulting at Robben Island

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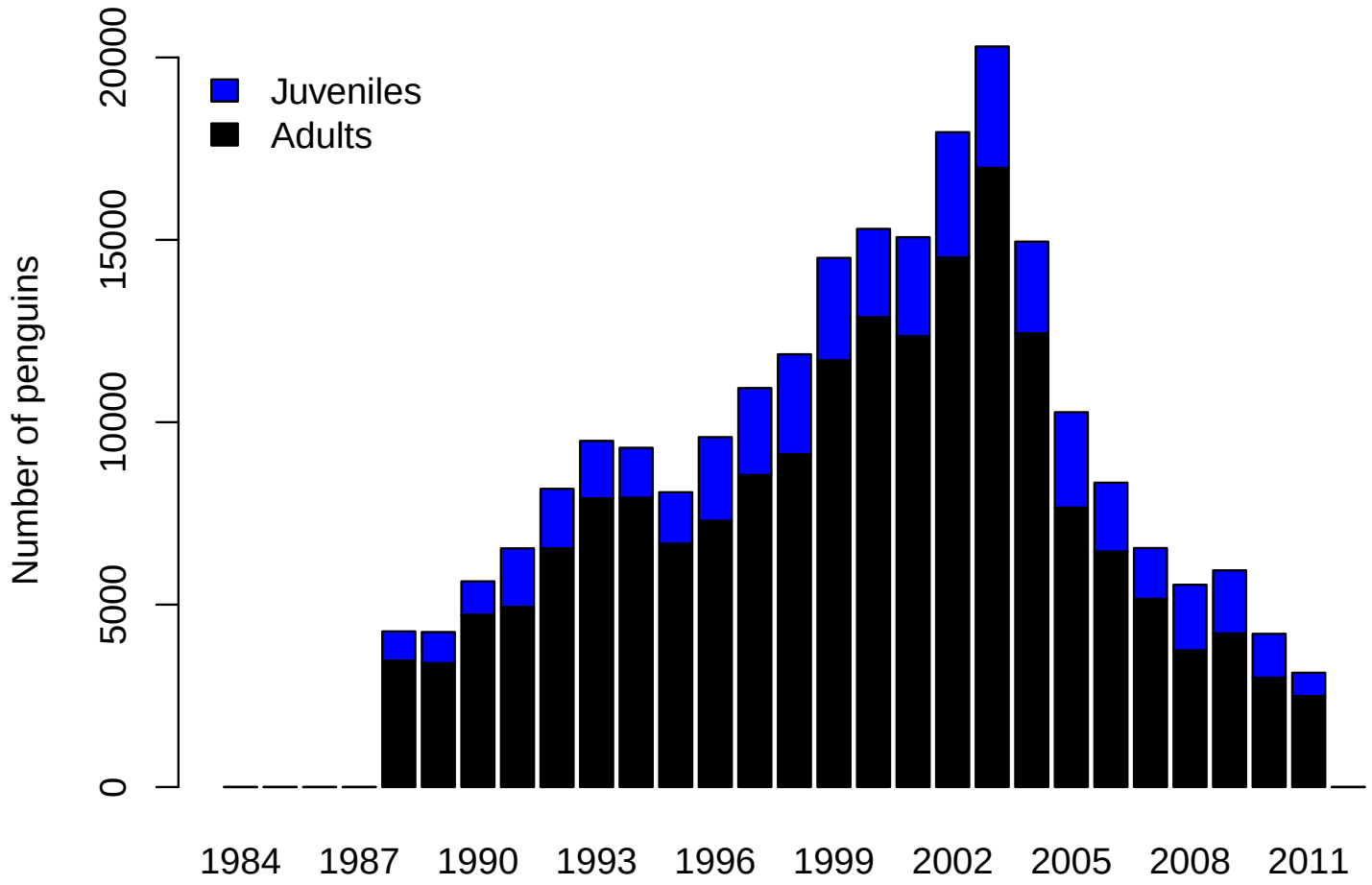
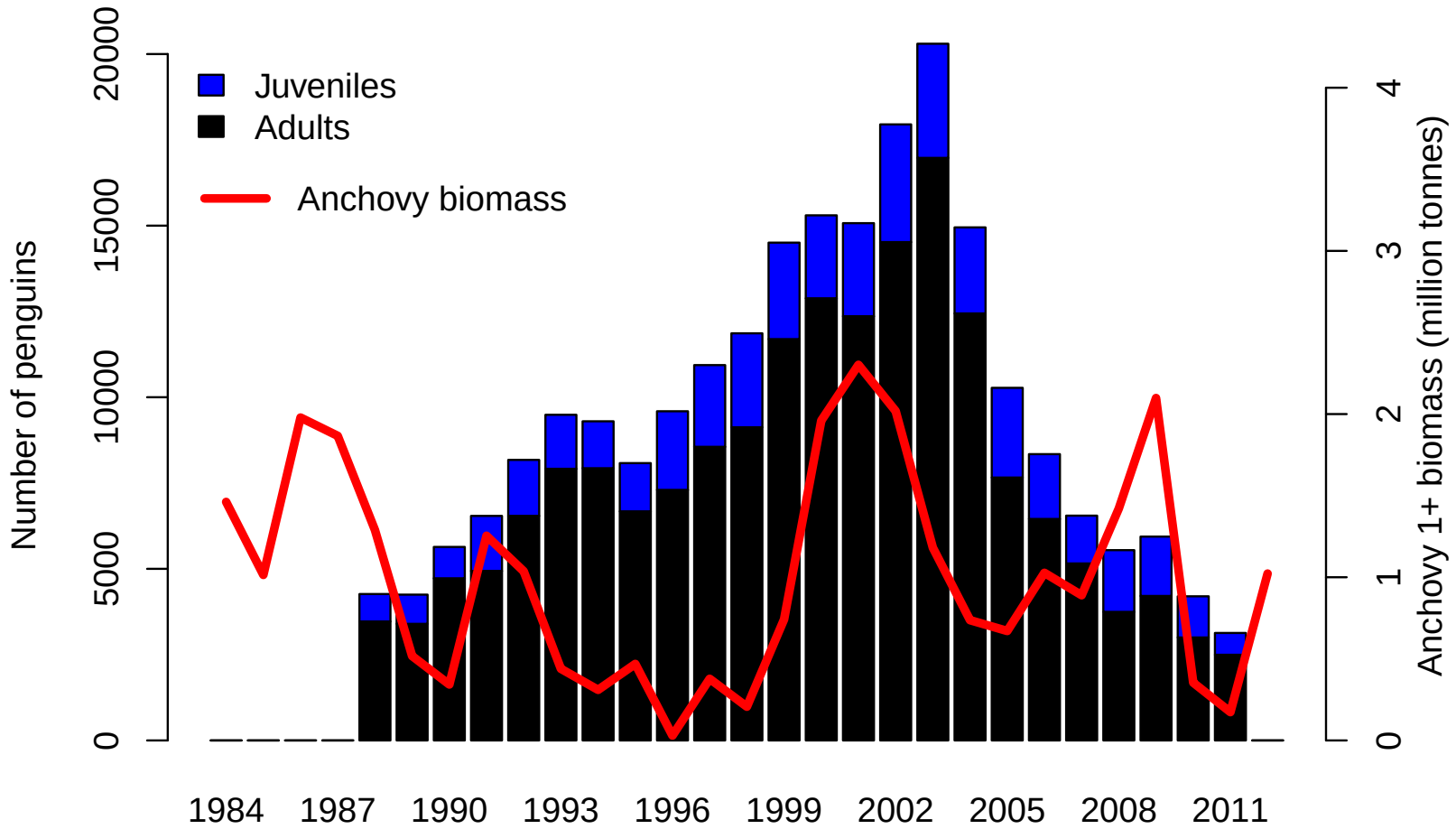


Penguins moulting at Robben Island

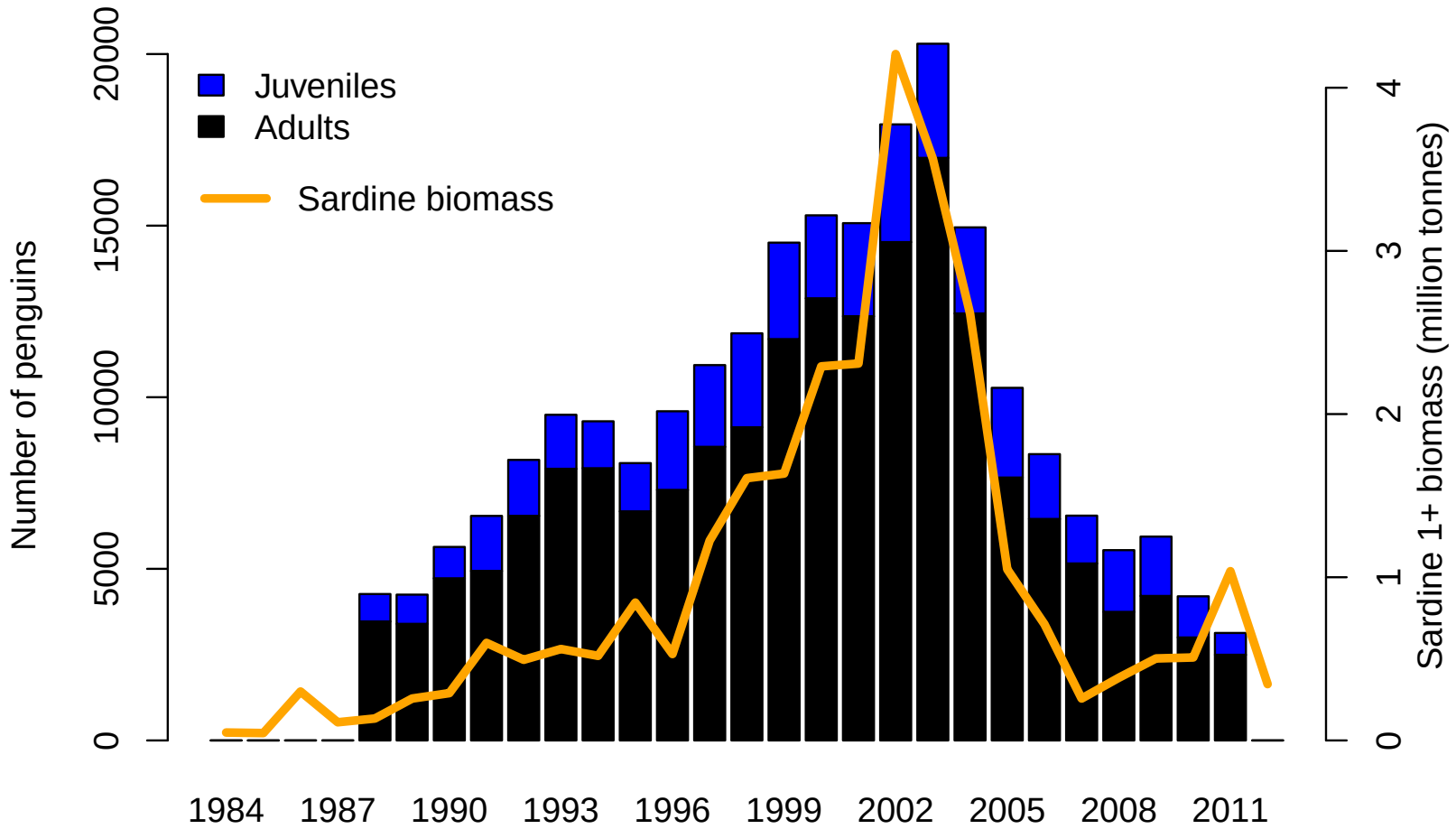
Compared with anchovy biomass



$r = 0.34, p > 0.1$

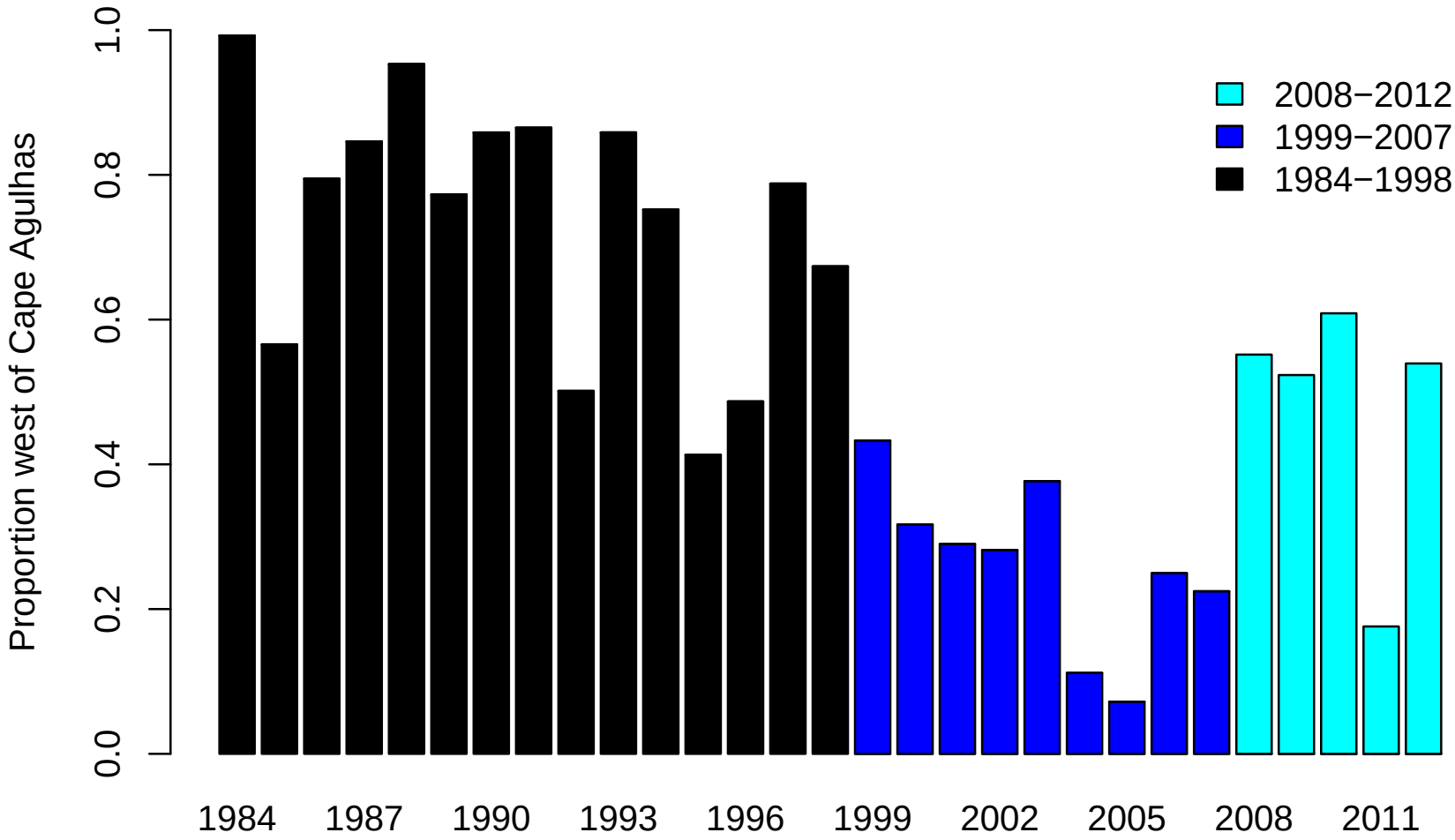
Penguins moulting at Robben Island

Compared with sardine biomass



$r = 0.89, p < 0.001$

Proportion of sardine west of Cape Agulhas



Collapse of South Africa's penguins

Crawford *et al.* (2011) *AJMS*

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Collapse of South Africa's penguins in the early 21st century

RJM Crawford[1,2,3*], R Altwegg[2,3,4], BJ Barham[5], PJ Barham[2,3,6], JM Durant[7], BM Dyer[1], D Geldenhuys[8], AB Makhado[1], L Pichegru[9], PG Ryan[9], LG Underhill[2,3], L Upfold[1], J Visagie[8], LJ Waller[2,3,8] and PA Whittington[10,11]

[1] Oceans and Coasts, Department of Environmental Affairs, Private Bag X2, Rogge Bay 8012, South Africa
[2] Animal Demography Unit, University of Cape Town, Rondebosch 7701, South Africa
[3] Marine Research Institute, University of Cape Town, Rondebosch 7701, South Africa
[4] South African National Biodiversity Institute, Private Bag X7, Claremont 7735, South Africa
[5] Penguin Datasystems, 2 Cotham Place, Bristol, BS6 6QS, UK
[6] HH Wills Physics Laboratory, University of Bristol, Tyndall Avenue, Bristol BS8 1TL, UK
[7] Centre for Ecological and Evolutionary Synthesis (CEES), Department of Biology, University of Oslo, PO Box 1066, Blindern, 0316 Oslo, Norway
[8] Cape Nature, Private Bag X29, Rondebosch 7701, South Africa
[9] Percy FitzPatrick Institute of African Ornithology, University of Cape Town, Rondebosch 7701, South Africa
[10] East London Museum, PO Box 11021, Southernwood 5213, South Africa
[11] Department of Zoology, Nelson Mandela Metropolitan University, PO Box 77000, Port Elizabeth 6031, South Africa
** Corresponding author, e-mail: crawford@environment.gov.za*

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The number of African penguins *Spheniscus demersus* breeding in South Africa collapsed from about 56 000 pairs in 2001 to some 21 000 pairs in 2009, a loss of 35 000 pairs (>60%) in eight years. This reduced the global population to 26 000 pairs, when including Namibian breeders, and led to classification of the species as Endangered. In South Africa, penguins breed in two regions, the Western Cape and Algoa Bay (Eastern Cape), their breeding localities in these regions being separated by c. 600 km. Their main food is anchovy *Engraulis encrasicolus* and sardine *Sardinops sagax*, which are also the

Collapse of South Africa's penguins

Crawford *et al.* (2011) *AJMS*

In the Western Cape, numbers decreased from a mean of 35 000 pairs in 2001–2005 to 11 000 pairs in 2009.

The example of the African penguin emphasises the need for fisheries management, in accounting for the food requirements of dependent species, to consider not only the overall abundance of prey, but also its local availability.

Penguins facing extinction

www.timeslive.co.za (19 February 2013)

Penguins facing extinction

MHLABUNZIMA MEMELA | 19 February, 2013 00:14

Times LIVE

African penguins on the Cape coast could be driven into extinction due to overfishing, marine biologists have warned

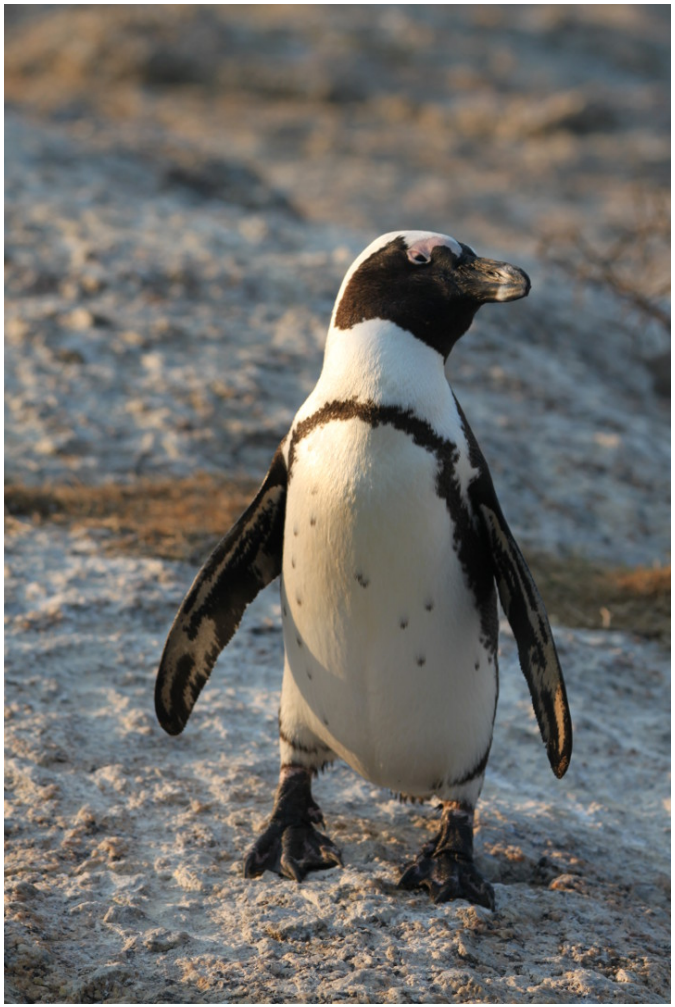
Image by: NARDUS ENGELBRECHT/GALLO IMAGES

Endangered
African penguins on
the Cape coast could become
extinct in the next 15 years.

...the penguin
population has dropped
by at least 70% since 2004
due to the ongoing competition
with commercial fishermen
for sardines and anchovies.

Globally, the African penguin population has shrunk from two million pairs to 26 000 pairs.

Questions



1. How do penguin demographics depend on forage fish abundance?
2. What is the projected impact of small pelagic catches on the penguin population?

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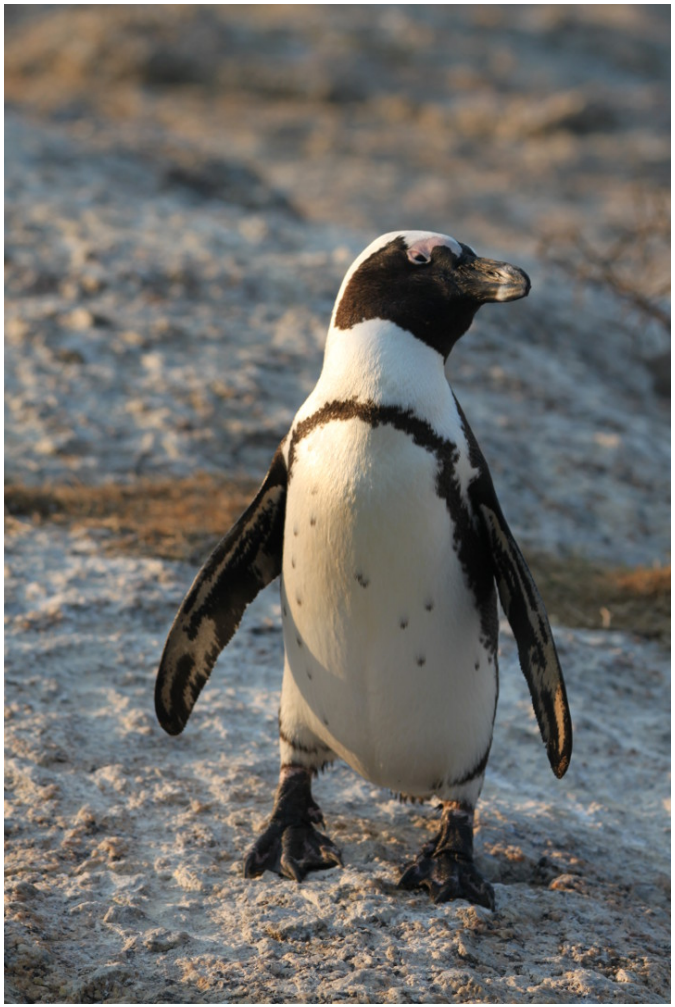

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Basic model structure

- Robben Island penguin colony
- Age-structured model
- Allows for immigration
- Incorporates two independent types of data:
  1. Moult counts
  2. Sightings of banded penguins
- Annual adult survival related to sardine abundance

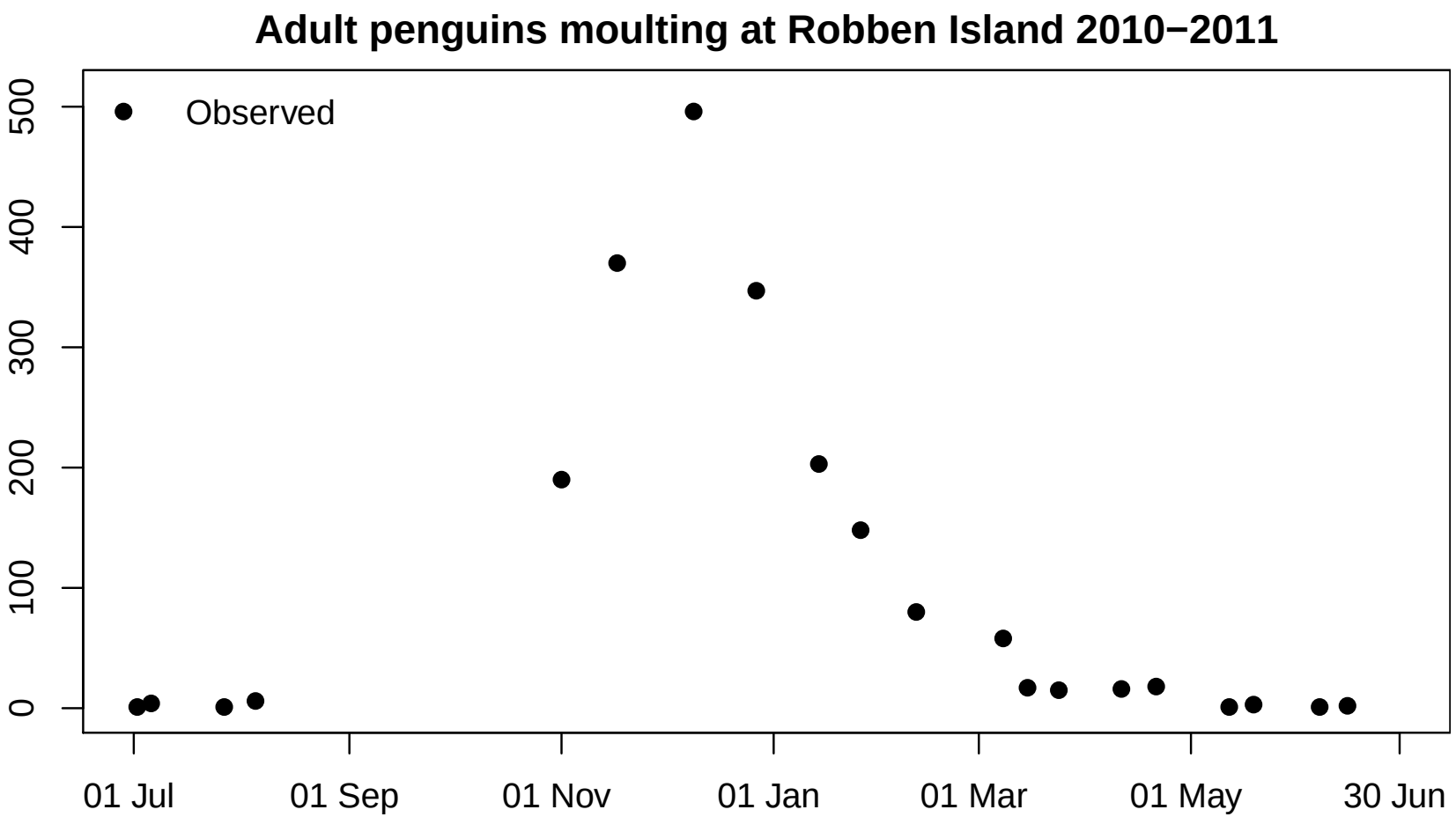
Moult counts

- All penguins must moult annually
- Feather-shedding takes about 12 days
- Counts are conducted every couple of weeks on average
- Most penguins moult during spring and summer
- Aggregate for each year (July–June) is calculated by interpolation

Counting moulting penguins

Adult and juvenile penguins

Interpolation of moult counts



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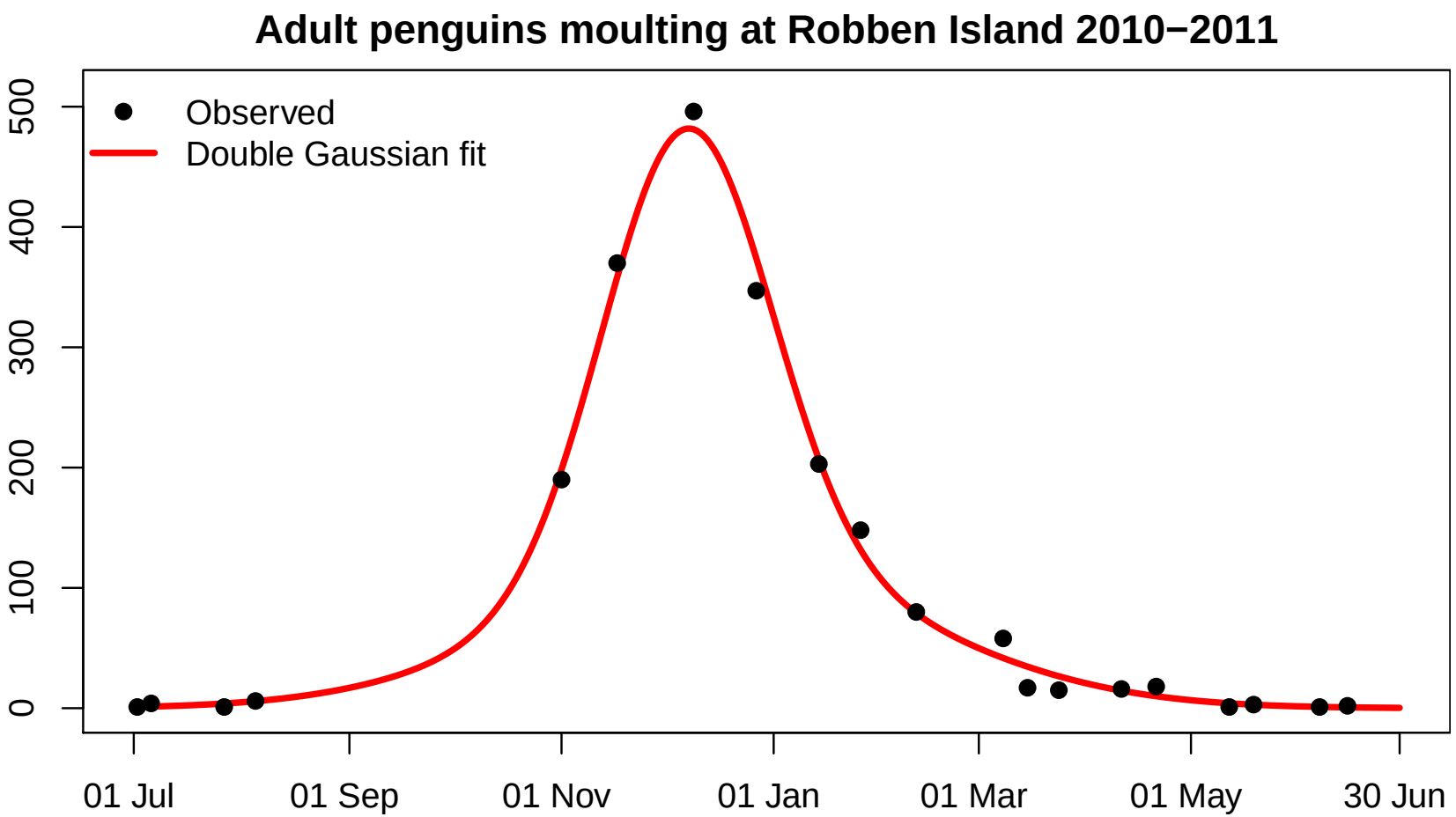
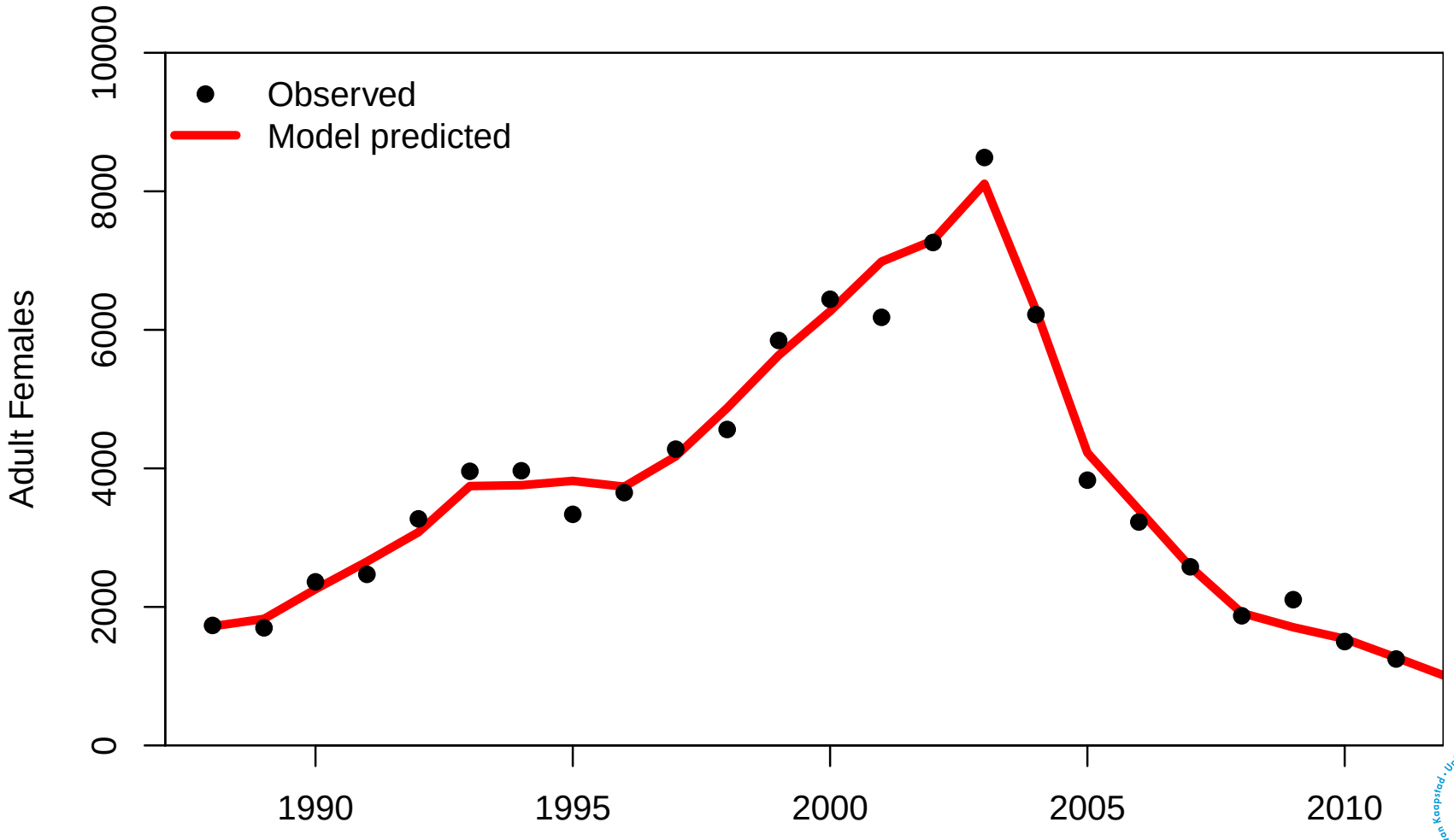


Fit to Robben Island moult count series



Example of a sighting-history table

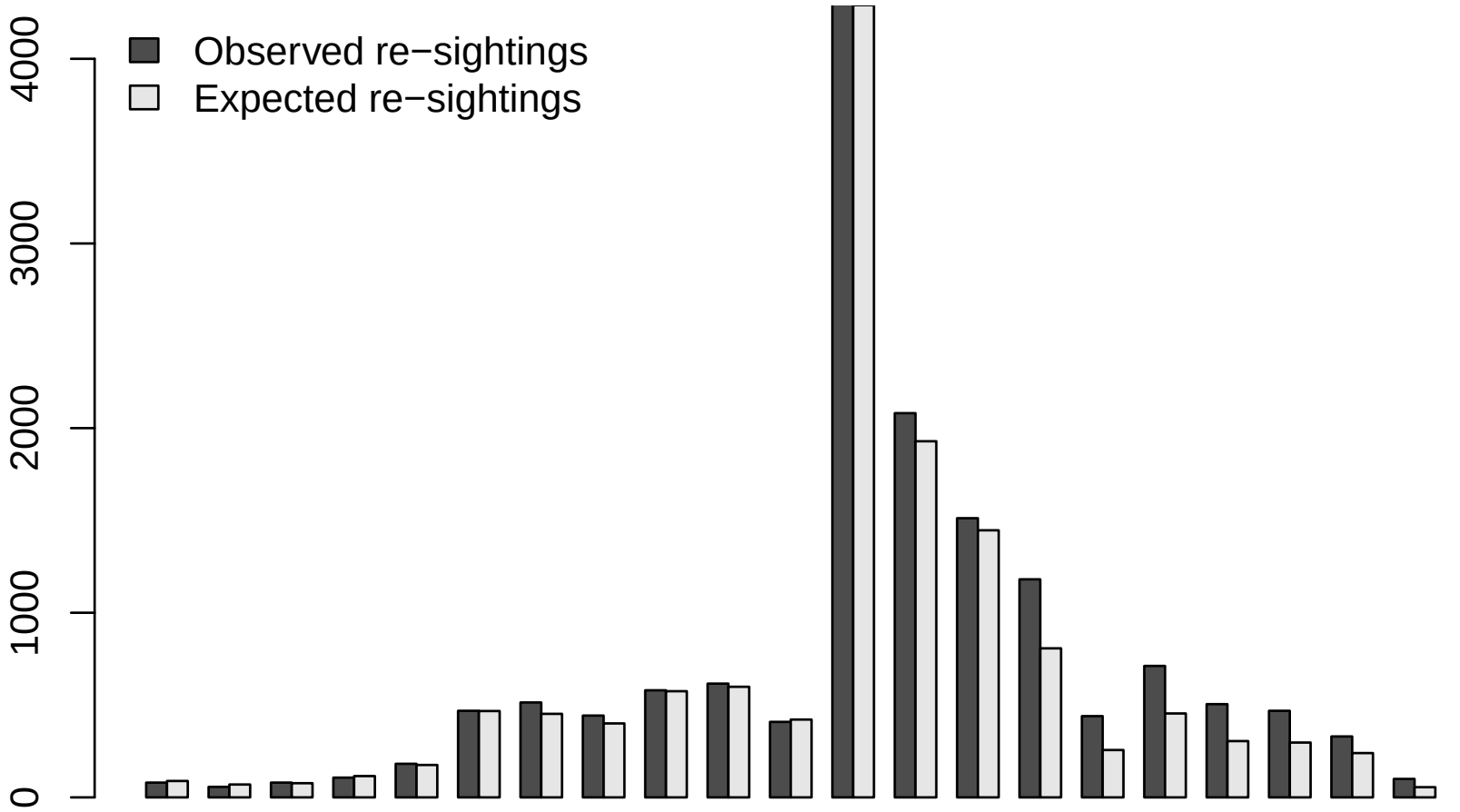
	89		91		93		95		97		99		01		03		05	...
R00188	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	
R00217	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	
S02990	0	0	0	1	0	1	1	1	0	0	0	0	0	0	0	0	0	
S02991	0	0	0	1	0	1	0	1	0	0	1	0	0	0	0	0	0	
S02992	0	0	0	1	0	1	0	1	1	0	0	0	0	0	0	0	0	
S12633	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1	0	0	
S12652	0	0	0	0	1	0	0	0	1	1	0	1	0	0	0	0	0	
S18572	0	0	0	0	0	1	0	1	1	1	1	0	0	0	0	0	0	
S18577	0	0	0	0	0	1	1	0	1	1	1	0	0	0	0	0	0	
S14755	0	0	0	0	0	0	1	0	1	1	0	1	1	0	0	0	0	
S14861	0	0	0	0	0	0	1	0	1	0	0	1	0	0	1	1	0	
S19970	0	0	0	0	0	0	1	1	0	1	1	1	0	0	0	0	0	
S19774	0	0	0	0	0	0	0	1	1	1	1	0	1	0	0	0	0	

Tag-recapture data

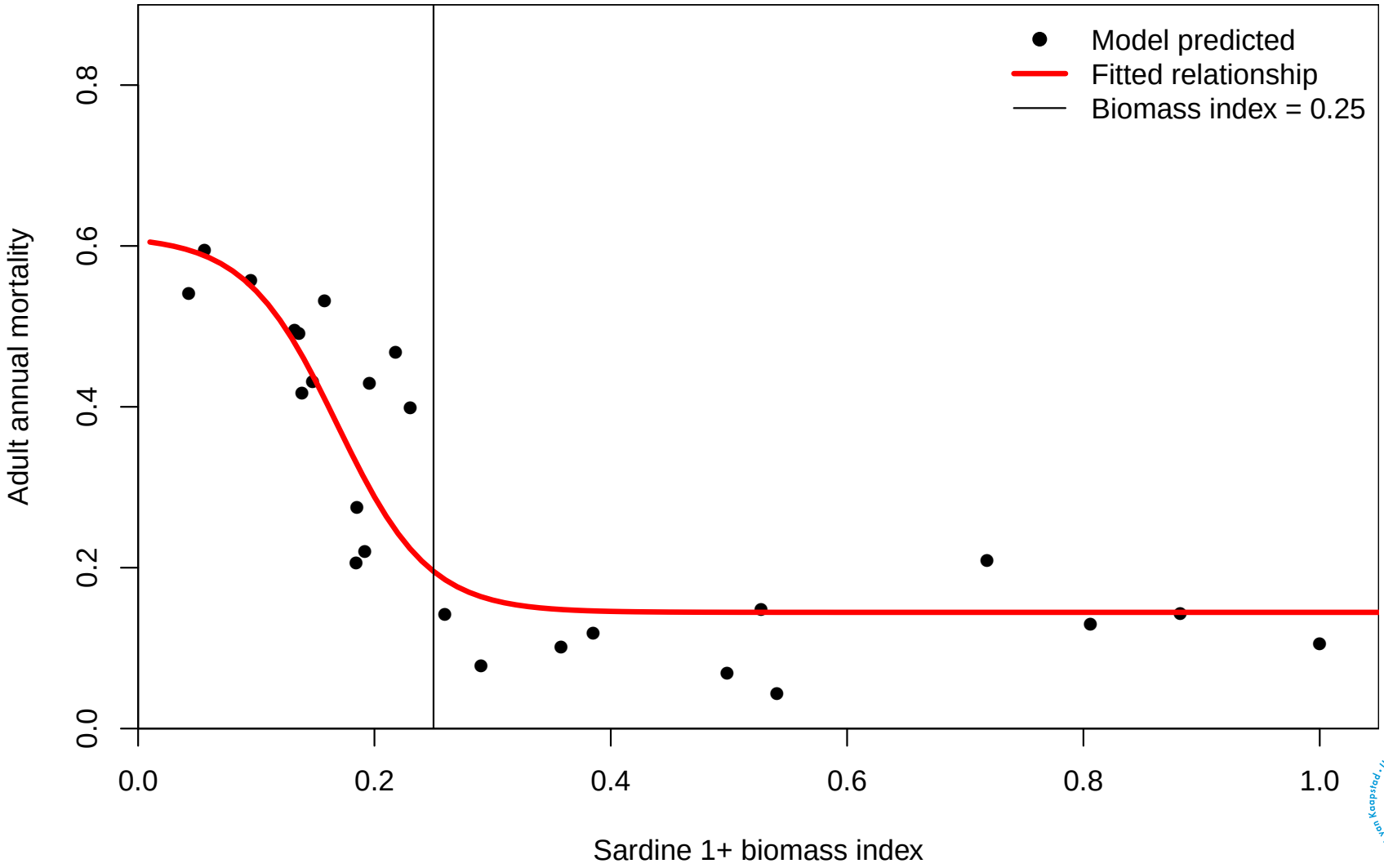
- Expected numbers of re-sightings can be modelled
- Two estimable parameters for each time-step:
  - Probability of survival from year i to year $i + 1$
  - Probability of re-sighting in year i
- Each unique capture history is a mutually exclusive event
- Observed numbers of capture histories are multinomially distributed

Fit to tag data

Observed and expected re-sightings of banded penguins

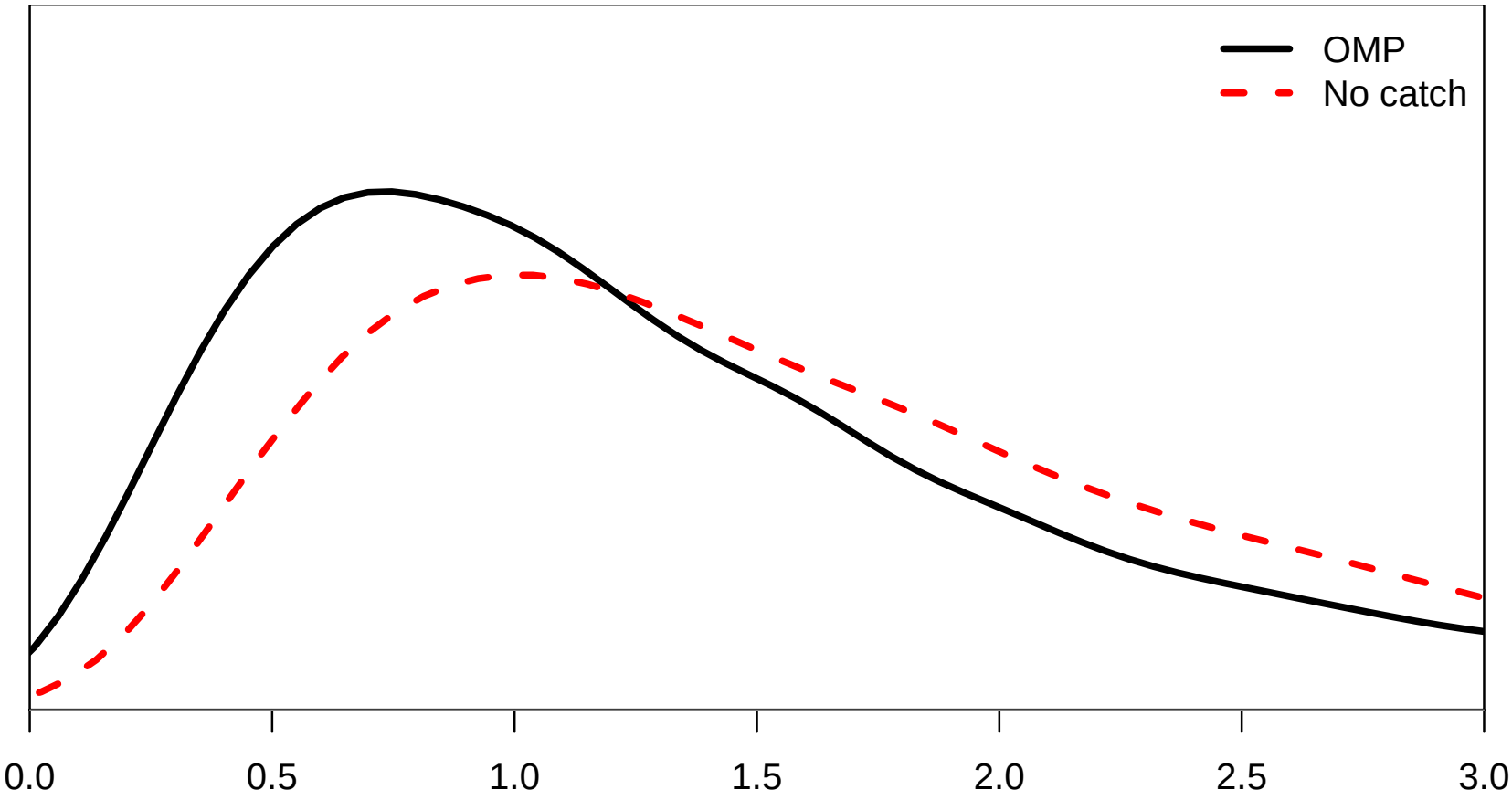


Penguin survival–sardine biomass relationship



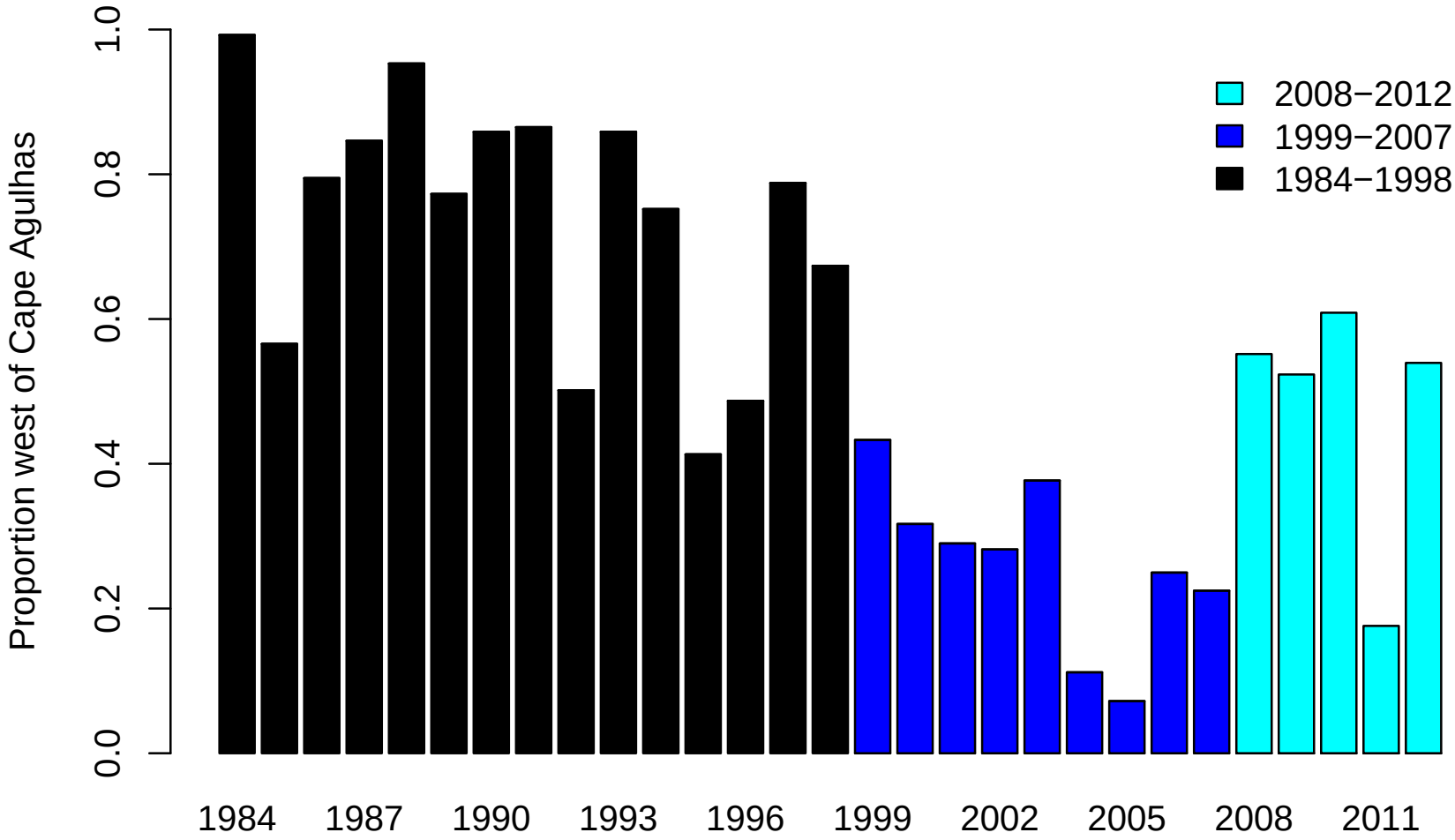
Projected sardine abundance (2013–2022)

Total November survey 1+ biomass



Proportion of sardine west of Cape Agulhas

In the November 1+ biomass survey



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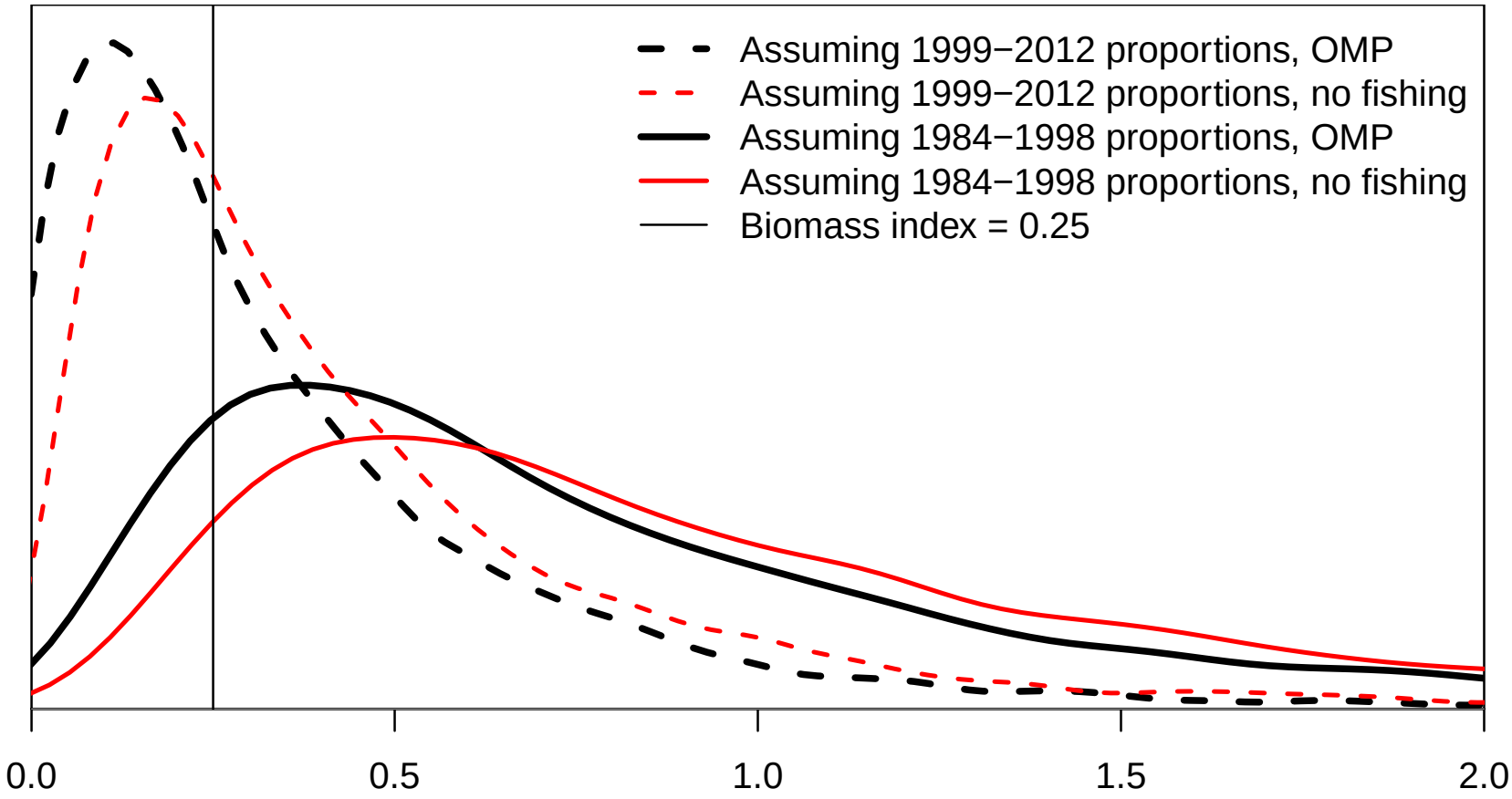
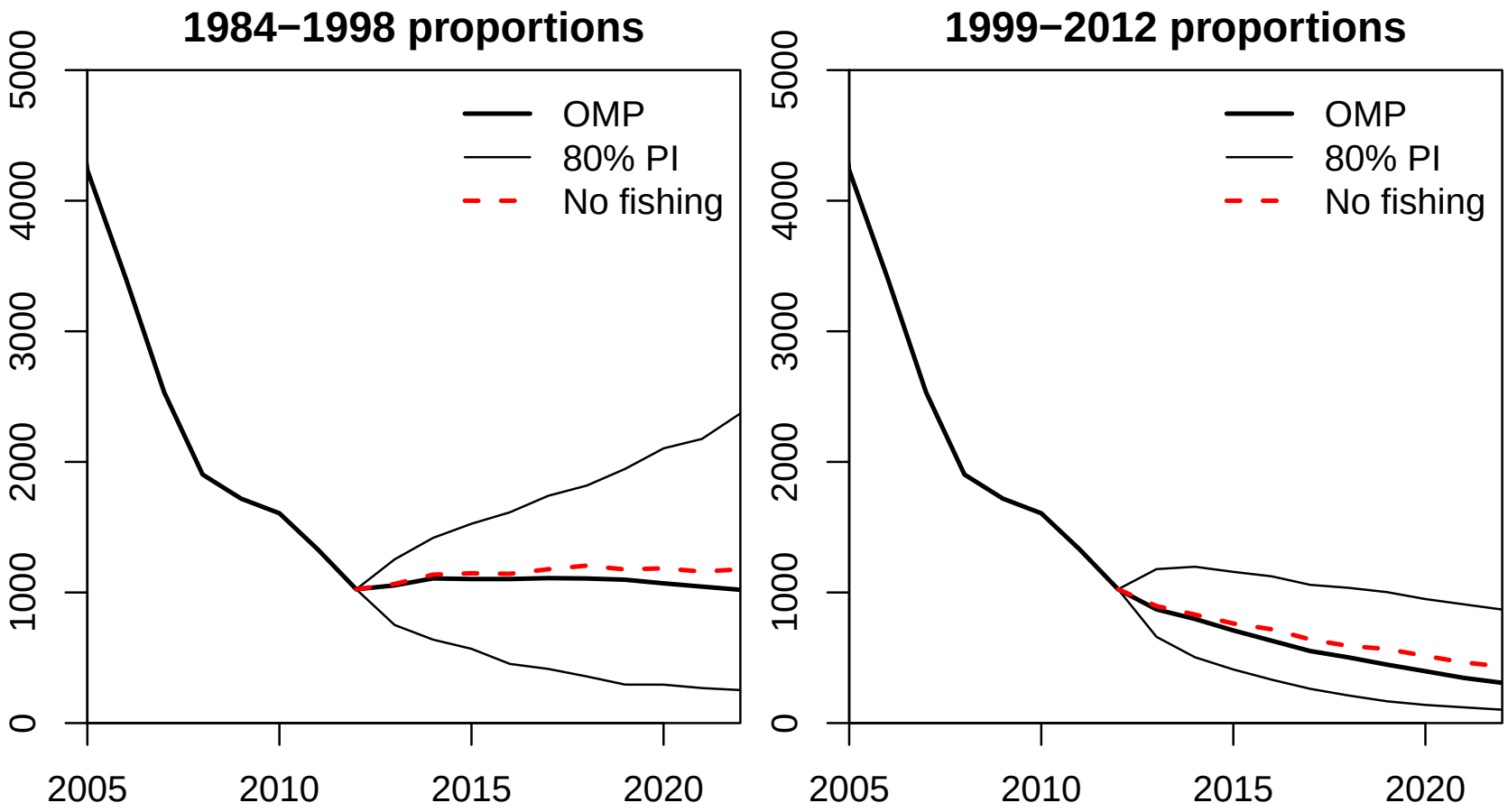


Projected penguin abundance (2013–2022)

Robben Island adult female moulters



Summary

- The sardine biomass–penguin mortality relationship predicts that mortality increases when sardine biomass drops below one-quarter of the maximum observed.
- The levels of fishing permitted by the OMP tested are unlikely to have a substantial effect on penguin abundance.
- Changes in the spatial distribution of sardine are likely to be far more influential.

- Lesson: Don't make assumptions about complicated ecosystem interactions!

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Further reading

Pikitch EK, Boersma PD, Boyd IL, Conover DO, Cury PM, Essington TE, Heppell SS, Houde ED, Mangel M, Pauly D, Plagányi ÉE, Sainsbury KJ, and Steneck RS. (2012)

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Optimization Methods and Software, 27: 233–249.

Operational Management Procedure steps

1. Identify management objectives
2. Develop operating model (stock assessment)
3. Identify management strategies
4. Simulate management strategies:
   - Project population dynamics for 10–20 years
   - Replicate each projection (accounting for uncertainties)
     1. Generate "observable" data (from operating model)
     2. Apply the management strategy being tested
     3. Update the operating model dynamics (1 year time-step)
5. Summarize simulation results (performance measures)
   - Include penguin performance

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