Small Pelagics Fisheries Competition with Seabirds: Review and Application

William J. Sydeman and Sarah Ann Thompson

FARALLON INSTITUTE

Petaluma, California

Global landings of SPF and euphausiids, 2010-2014, FAO Catch Database

Species	2010	2011	2012	2013	2014	5-year average
Krill, planktonic crustaceans	215175	181010	188147	239950	316408	228138
Herrings, sardines, anchovies	17269000	21164496	17569534	17600048	15215458	17763707
Atlantic sandeels	423209	443604	107577	284138	270401	305786
Pacific sandlance	237938	187559	175892	161949	153433	183354
Atlantic saury	7436	5628	15329	8547	1560	7700
Pacific saury	432372	458954	460961	428390	628569	481849
Capelin	506897	853449	992491	763948	282833	679924
Total	19,092,027	23,294,700	19,509,931	19,486,970	16,868,819	19,650,489

unit = MT

THE ROYAL SOCIETY biology letters

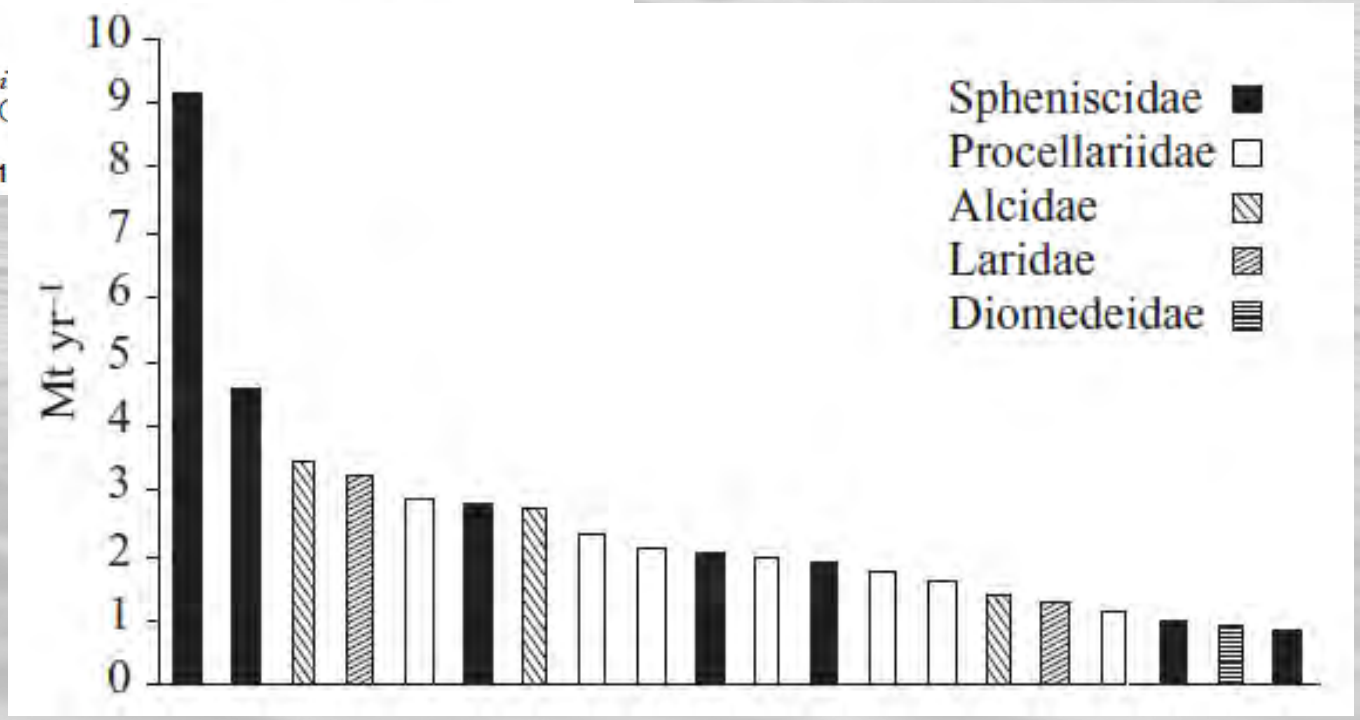
The food consumption of the world's seabirds

M. de L. Brooke

Department of Zoology, Uni
Cambridge CB2 3EJ, UK (

Recd 09.10.03; *Accptd* 01

- **Bioenergetic models indicate 55.9 – 83.7 MMT consumed yr^{-1} (krill, squid, forage fish)**



Given consumption/harvest, potential is high, but is there present exploitative competition?

From the seabird perspective, *do fisheries targeting SPF reduce/alter (thereby limit) food resources within critical foraging habitats to affect demography?*

Long-standing issue

TRANSACTIONS of the AMERICAN FISHERIES SOCIETY

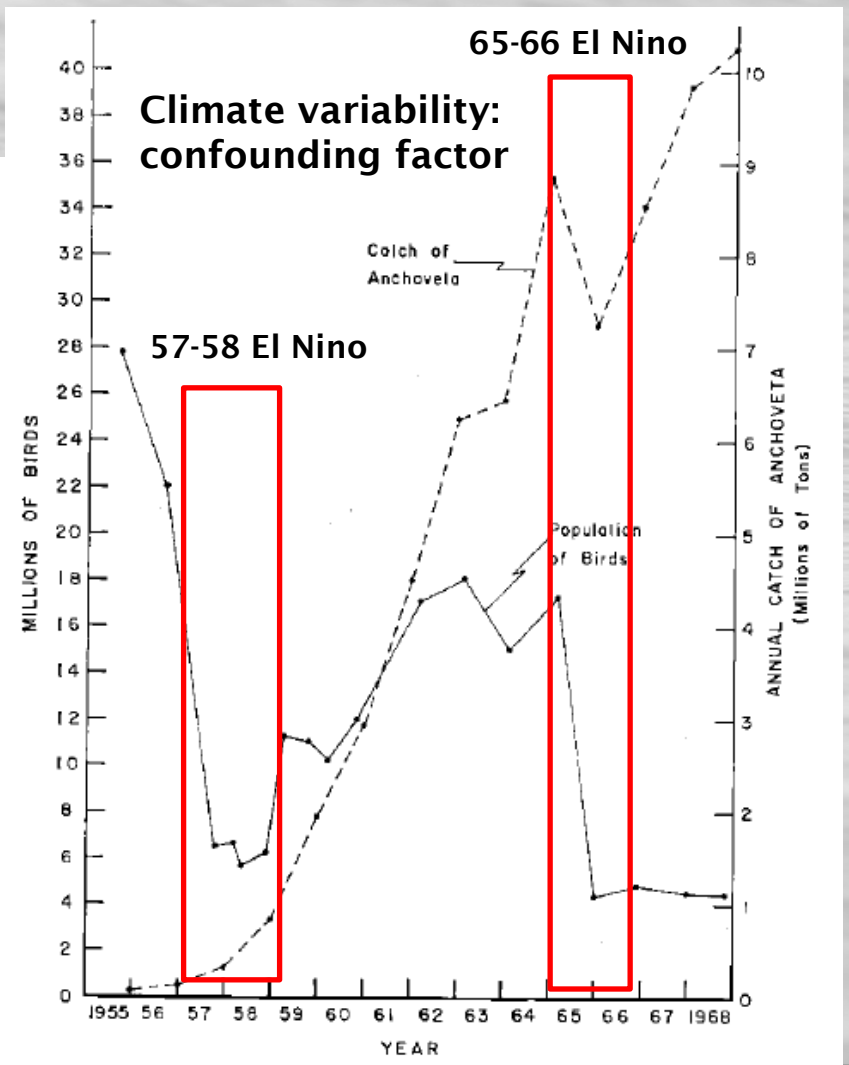
July 1970

VOLUME 99
NUMBER 3

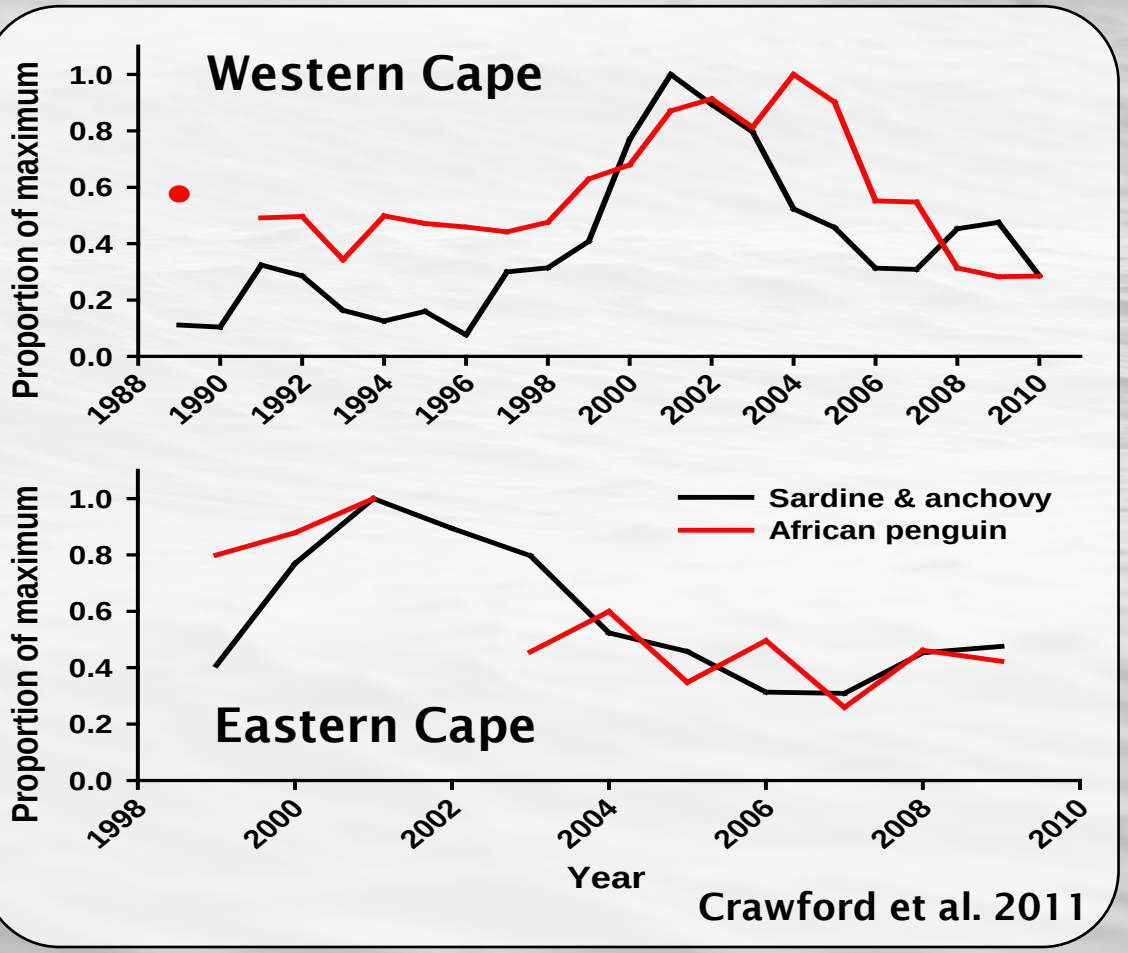
Men, Birds and Anchovies in the Peru Current—Dynamic Interactions

MILNER B. SCHAEFER
Institute of Marine Resources
University of California
La Jolla, California 92037

The fishery could, in principal, take the entire maximum sustainable catch if the birds were eliminated. This, however, is undoubtedly not desirable, because *some* population of guano birds needs to be maintained to preserve the species, since this genetic material may be of great future value.



Also, lags in seabird response



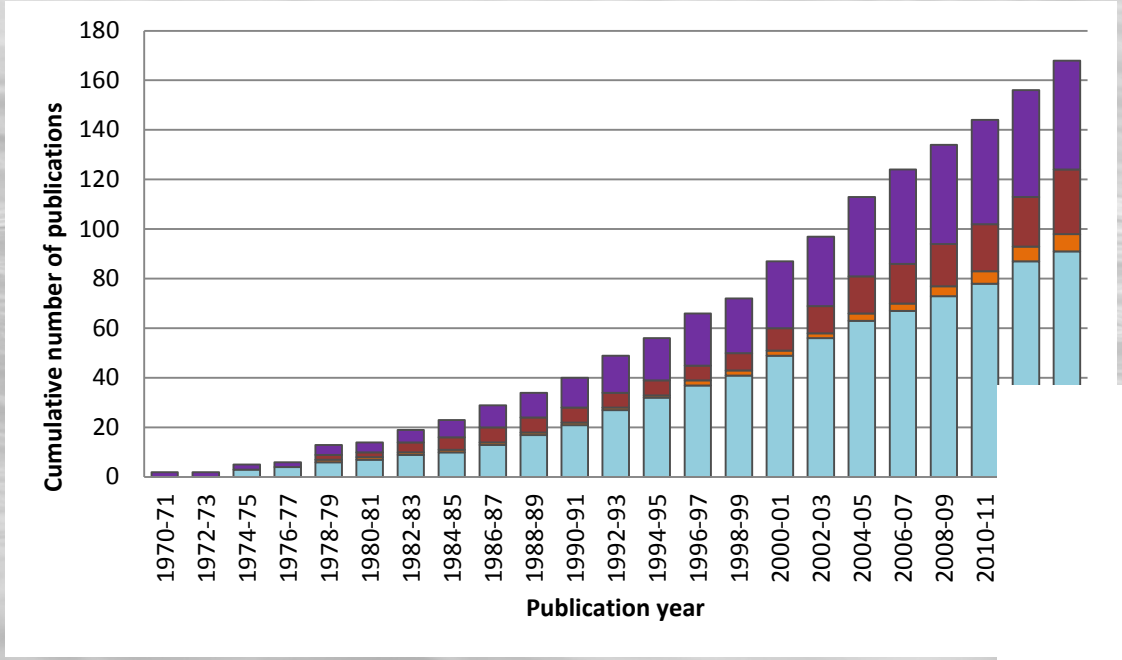
- Trends in penguins, forage fish, South Africa

Guidelines for Assessing Fisheries-Seabird Competition?

Funded by The Pew Charitable Trusts

Interdisciplinary workshops, Cape Town (10/2015) and Seattle (1/2016) (fisheries scientists, seabird ecologists, [old and young])

Literature review of approaches to date

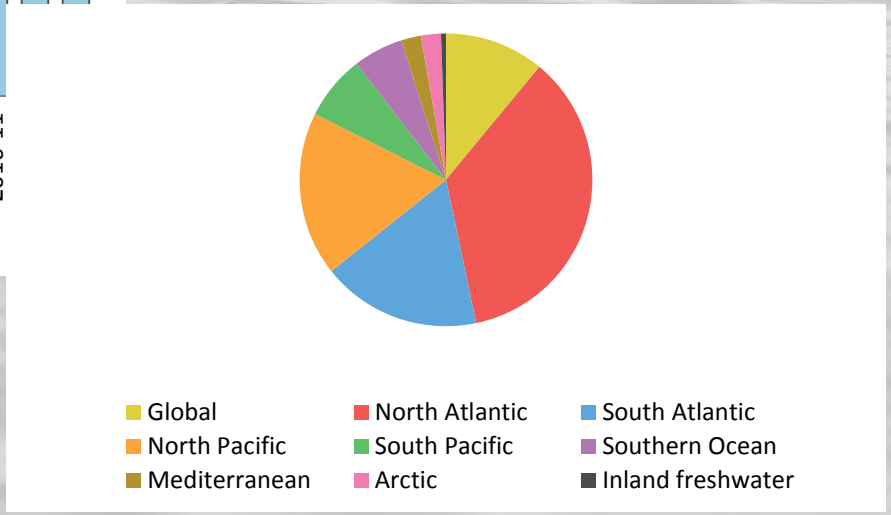


Reviews (no new data)

Numerical Experiments

Field Experiments (LPDE)

Observations



Conceptual framework

Within management control

Disturbance at the local scale (interference competition)

Fishery

Environment

Prey abundance

Managed stock scale

Spatial prey availability

Foraging success

Seabird productivity & survival

Out of management control

Exploitative competition

Sydeman et al. in review

Seabird characteristics affecting foraging success

- small body mass ~ high metabolic rates (~10-40% of body mass daily, more while provisioning offspring) - need a lot of food
- small body size also limits foraging ambits and prey selection

  i. foraging limited to surface to mid shelf depths (0 to ~200 m)

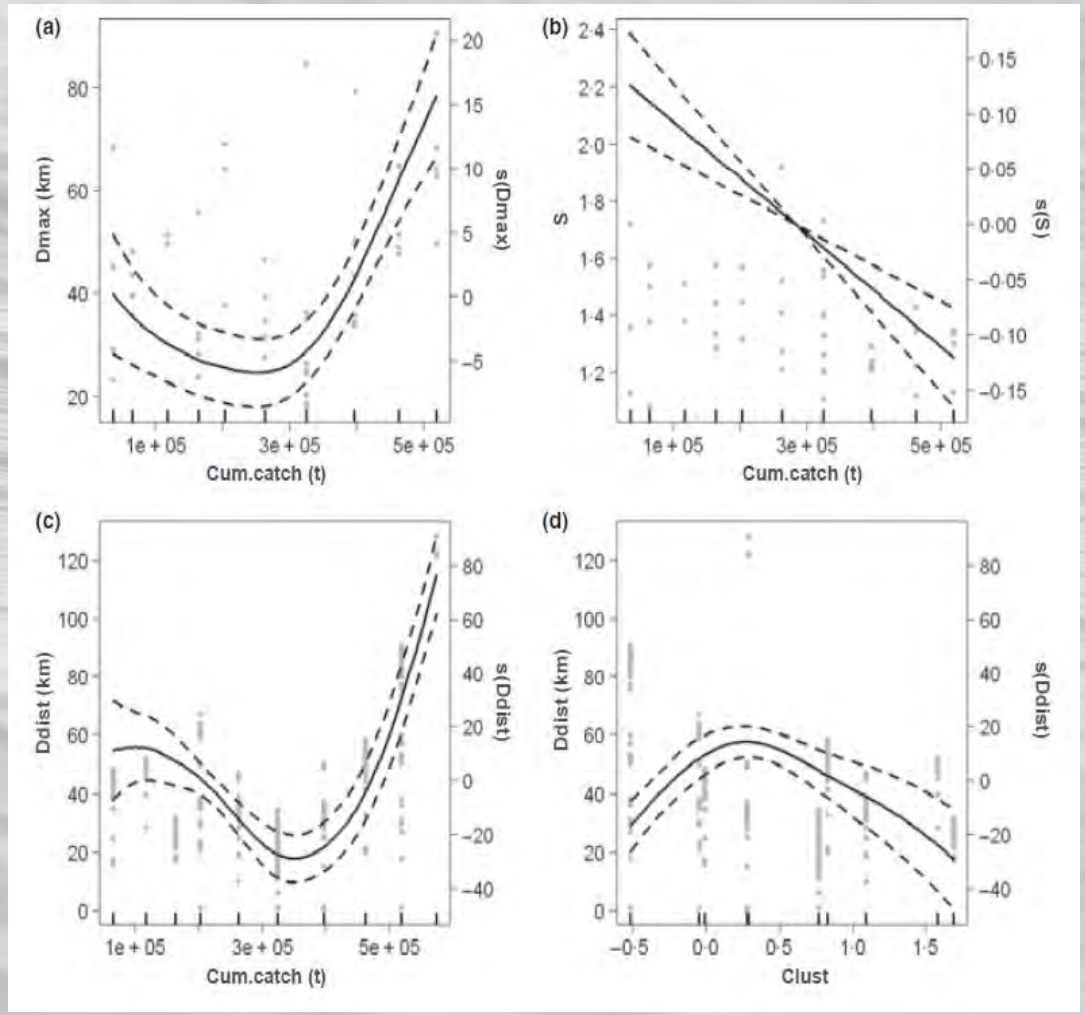
  ii. diet specialization, smaller pelagic fish (anchovy, sandeel, capelin), krill

  iii. during reproduction, "central place foragers"

<u>Spatial dynamics really matter</u>: seabirds are sensitive to local (sub-mesoscale) prey depletion, assessments of fisheries impacts must be both spatially-explicit and local; studies of fisheries - seabird competition on regional scales generally not appropriate -- at least for breeding seabirds

➢ Foraging effort increases relative to anchoveta fishery removals

S. Bertrand et al. 2012 J. Appl. Ecol.



Seabird characteristics affecting population dynamics

- Classic "k" – selected species:

  i. high survival and longevity (~10 – 100 yrs) (fisheries competition affecting survival would have stronger effects on populations)

  ii. deferred recruitment (3-10 yrs) (substantial lags in population responses to prey depletion, difficulties in modeling effects)

  iii. low reproductive rate (can withstand occasional breeding failure (e.g., El Nino), but not chronic failures)

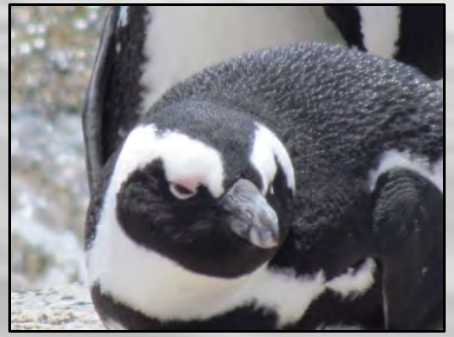
  iv. non-linear predator-prey relationships

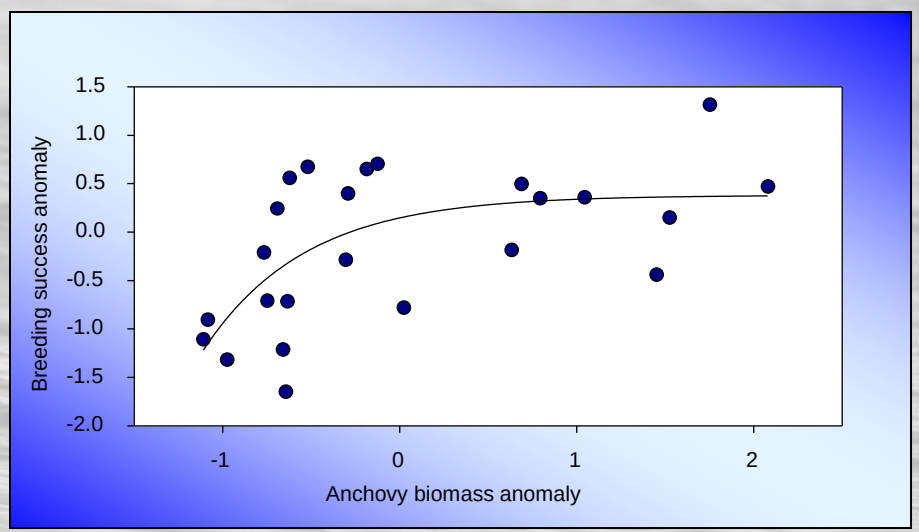
- Need long term studies, assessments focusing on key population parameters will be most productive

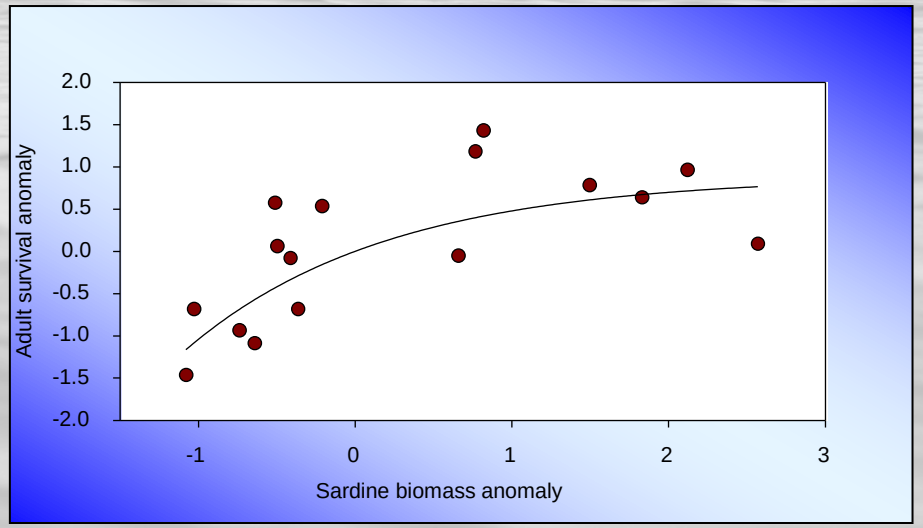
African penguin

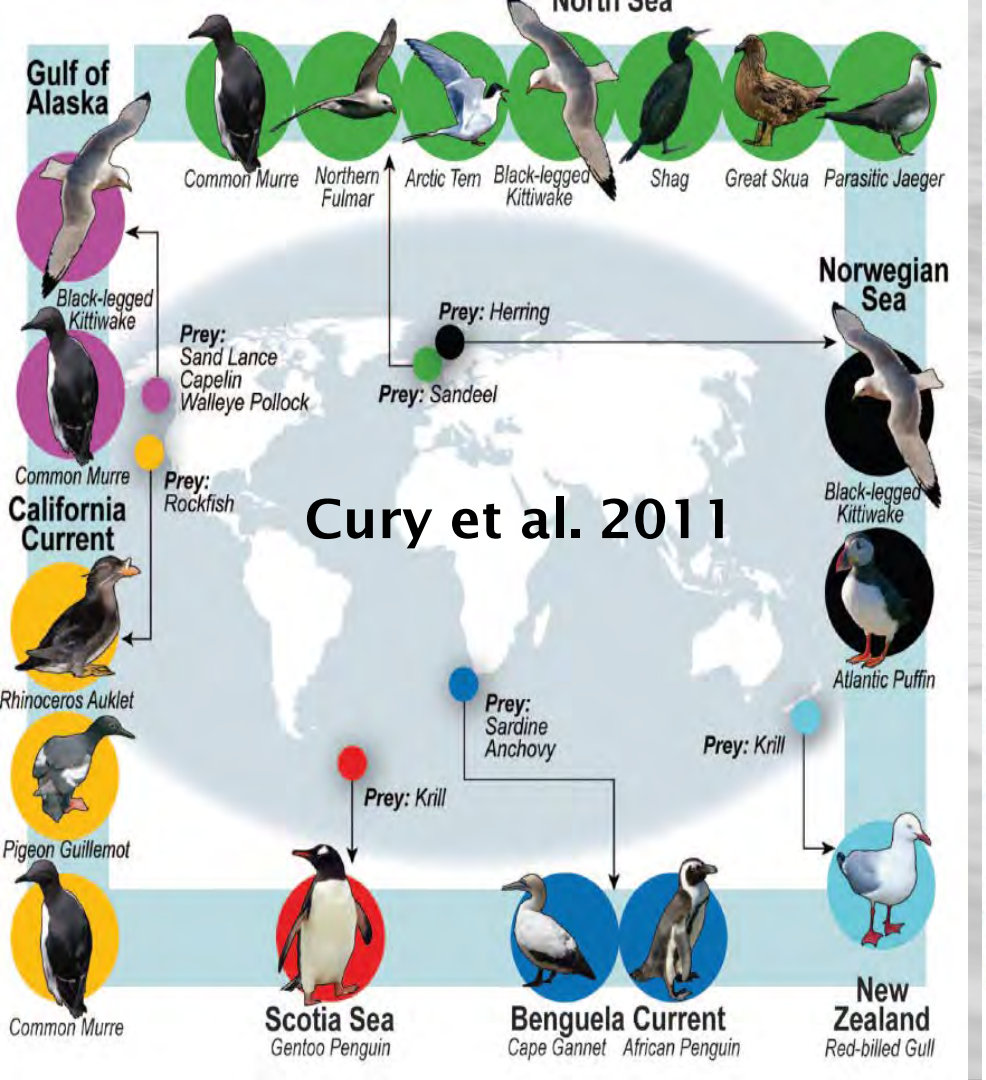
- breeding success related to anchovy
- survival (proportion surviving) related to sardine

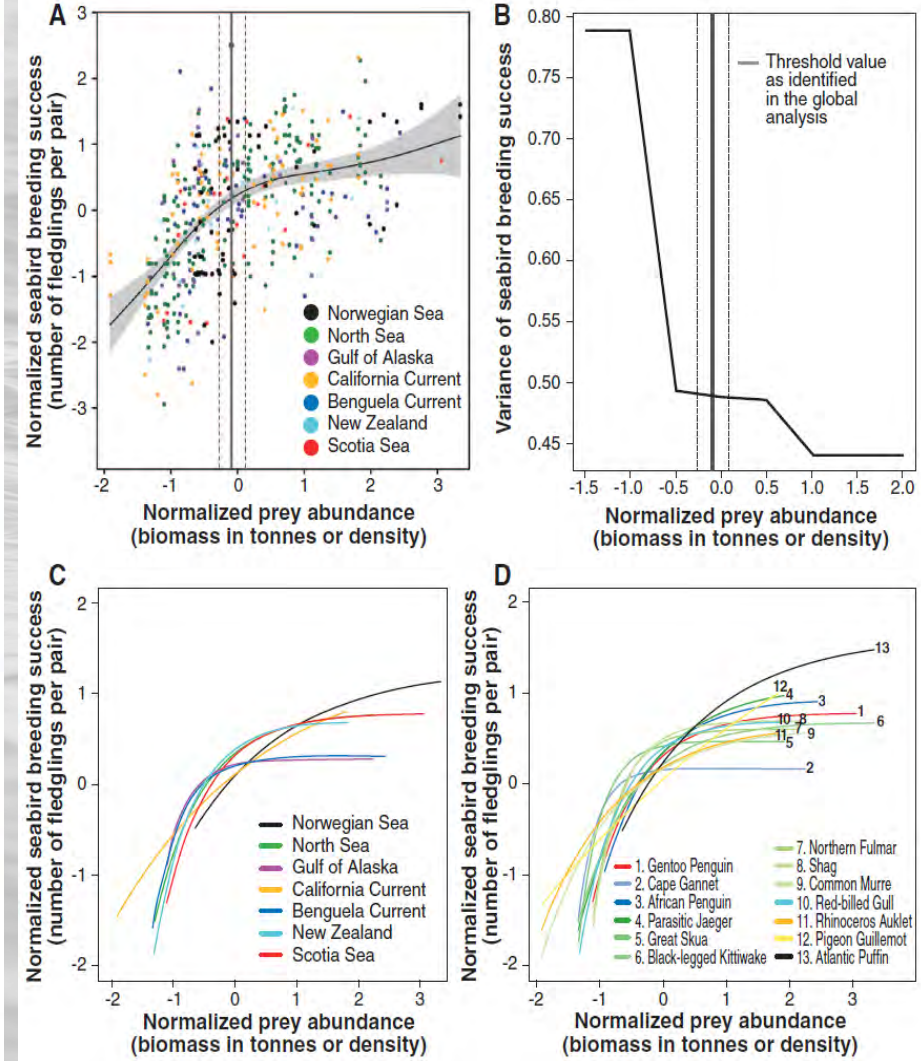
➢ Forage species and fisheries are not the same…








North Sea
Gulf of Alaska
Common Murre
Northern Fulmar
Arctic Tern
Black-legged Kittiwake
Shag
Great Skua
Parasitic Jaeger
Black-legged Kittiwake
Prey: Sand Lance
Capelin
Walleye Pollock
Prey: Herring
Prey: Sandeel
Norwegian Sea
Common Murre
California Current
Prey: Rockfish
Cury et al. 2011
Black-legged Kittiwake
Atlantic Puffin
Rhinoceros Auklet
Prey: Sardine
Anchovy
Prey: Krill
Prey: Krill
Pigeon Guillemot
Common Murre
Scotia Sea
Gentoo Penguin
Benguela Current
Cape Gannet
African Penguin
New Zealand
Red-billed Gull

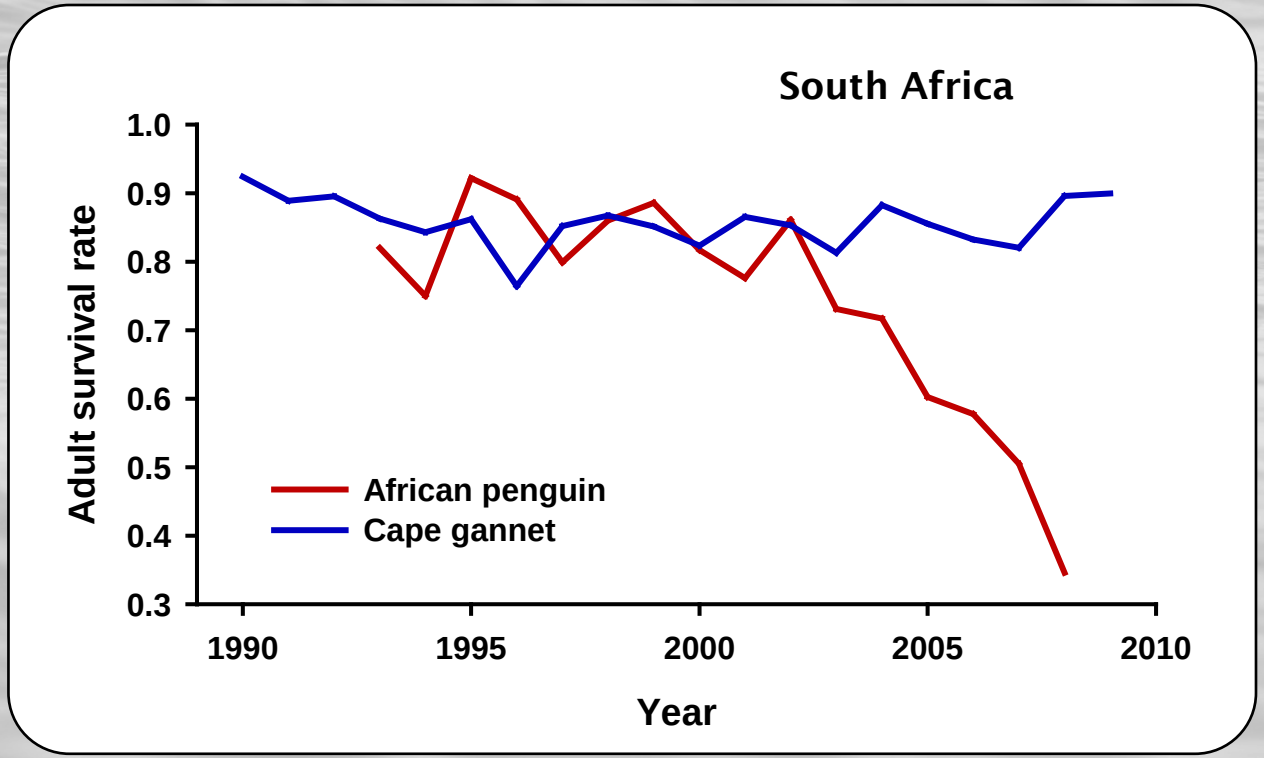

A
Normalized seabird breeding success (number of fledglings per pair)
Normalized prey abundance (biomass in tonnes or density)
Norwegian Sea
North Sea
Gulf of Alaska
California Current
Benguela Current
New Zealand
Scotia Sea
B
Variance of seabird breeding success
Threshold value as identified in the global analysis
Normalized prey abundance (biomass in tonnes or density)
C
Normalized seabird breeding success (number of fledglings per pair)
Normalized prey abundance (biomass in tonnes or density)
Norwegian Sea
North Sea
Gulf of Alaska
California Current
Benguela Current
New Zealand
Scotia Sea
D
Normalized seabird breeding success (number of fledglings per pair)
Normalized prey abundance (biomass in tonnes or density)
1. Gentoo Penguin
2. Cape Gannet
3. African Penguin
4. Parasitic Jaeger
5. Great Skua
6. Black-legged Kittiwake
7. Northern Fulmar
8. Shag
9. Common Murre
10. Red-billed Gull
11. Rhinoceros Auklet
12. Pigeon Guillemot
13. Atlantic Puffin

Implications of non-linear numerical response relationships

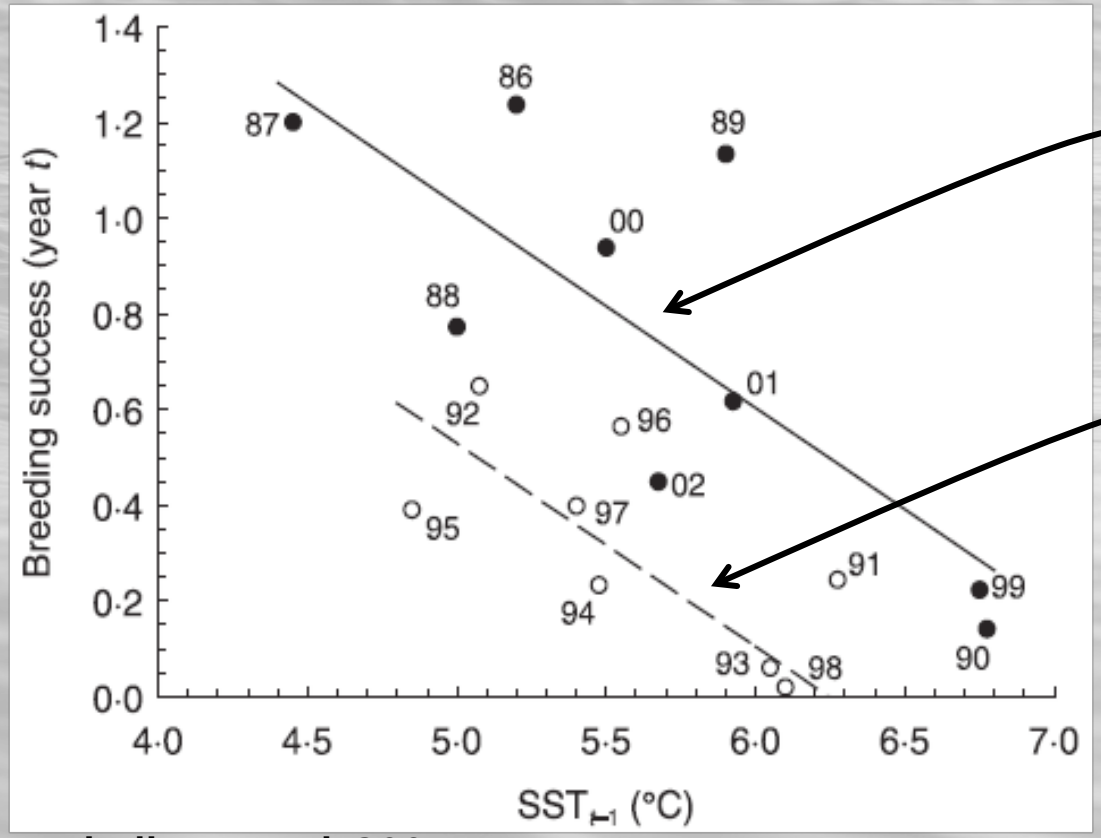
1. At low levels of prey abundance (from climate, etc.), fisheries prey depletion impacts will be greater

2. At high levels of prey abundance, fisheries impacts should be few, unless (a) availability reduced below threshold, (b) spatial distribution (horizontal or vertical) or organization (density, patchiness) is altered; abundance alone may not be enough to make predictions

3. Seabirds are buffered to varying prey availability to some extent (time budgets, they can work harder when prey is reduced), but at moderate levels of prey abundance/availability, when they show signals (e.g. declining survival), threshold may have been crossed.



Climate and fishery effects on breeding success, North Sea



Prior to sandeel fishery

During sandeel fishery

Frederiksen et al. 2004

Much correlative evidence, but how to test causation and mechanisms?

Long-term localized prey depletion experiments (LPDE) are needed, but are expensive, unpopular, and difficult to implement (substantial cooperation with industry is needed)

i. **Conduct numerical simulations with maximum likelihood or Bayesian methods to consider uncertainty in model parameters, environmental drivers of population dynamics, and functional forms of relationships**

ii. **Use spatial modeling to address likely effects of time/area fisheries closures and test appropriate experimental design (closures for x years, etc.?)**

iii. **replication, lack of real "controls", climate, and other demonic intrusions may limit effectiveness (North Sea and Benguela)**

Conclusions

1. While fisheries can affect the availability of forage fish within critical habitats, and seabirds have measurable foraging and demographic responses to changes in forage fish availability, establishing causal linkages from fisheries to seabird populations is difficult
2. For breeding seabirds, investigations of these linkages must be localized and spatially-explicit, but few field experiments have been successfully implemented (North Sea and Benguela)
3. To fully understand seabird population dynamics, seabird-fisheries competition should be examined in the non-breeding season

Application

1. Time-area closures around seabird breeding colonies may serve to resolve fisheries competition concerns during reproductive periods
2. For non-reproductive periods when the seabirds are not constrained to forage near a colony, “set asides” or “cutoffs” in HCR could be used to leave sufficient SPF in the sea to maintain trophic relationships
    - Benchmarks for ecosystem-scale, top predator community-based (seabirds, marine mammals, large predatory fish) forage fish protection could be developed using a synthesis of bioenergetic and multi-species numeric response models…next talk

Seabirds as Indicators of SPF (Cairns 1987)

100s of papers

FISHERIES OCEANOGRAPHY

FISHERIES OCEANOGRAPHY Fish. Oceanogr.

Puffins reveal contrasting relationships between forage fish and ocean climate in the North Pacific

WILLIAM J. SYDEMAN,[1]* JOHN F. PIATT,[2]
SARAH ANN THOMPSON,[1,3]
MARISOL GARCÍA-REYES,[1]
SCOTT A. HATCH,[2,4]
MAYUMI L. ARIMITSU,[2] LESLIE SLATER,[5]
JEFFREY C. WILLIAMS,[5] NORA A. ROJEK,[5]
STEPHANI G. ZADOR[6] AND
HEATHER M. RENNER[5]

Research

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Modeling spatiotemporal dynamics of krill aggregations: size, intensity, persistence, and coherence with seabirds

Jarrod A. Santora, Jeffrey G. Dorman and William J. Sydeman

J. A. Santora (jsantora@ucsc.edu), Dept of Applied Mathematics and Statistics, Center for Stock Assessment Research, Univ. of California at Santa Cruz, Santa Cruz, CA, USA. – J. G. Dorman, W. J. Sydeman and JAS, Farallon Inst. for Advanced Ecosystem Research, Petaluma, CA, USA.

Workshop Participants: Alec MacCall, Alejandro Simeone, Amanda Gladics, Andre Punt, Ashley Bennison, Carl van der Lingen, Charlotte Boyd, Claire Saraux, Dilek Sahin, Dimas Gianuca, Elizabeth (Libby) Logerwell, Elizabeth Phillips, Francis Daunt, Heather Renner, Herman Oosthuizen, Jaimie Cleeland, James Grecian, Jennifer Lang, Jennifer Provencher, Jennifer Roberts, Jim Mills, Julia Parrish, Julie Thayer, Ken Morgan, Laura Koehn, Lynne Shannon, Mayumi Arimitsu, Nicole Bransome, Olaf Olsson, Philipp Boersch-Supan, Ricardo Amoroso, Richard Sherley, Robert Crawford, Robert Furness, Robert Suryan, Ross Wanless, Sarah Ann Thompson, Sophie Bertrand, Stephani Zador, Taryn Morris, Tom Good, Thomas Mattern, William Sydeman, Yuna Kim

THANK YOU!