Seabirds as Environmental Indicators: Climate Variability, Phenology, Prey Availability, and Tests of the "Integrator" Hypothesis

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Outline

- review evidence for seabirds as ecosystem indicators "near-globally"
- address role as "integrators" (and amplifiers) in end-to-end food web studies
- consider potential applications in monitoring and management

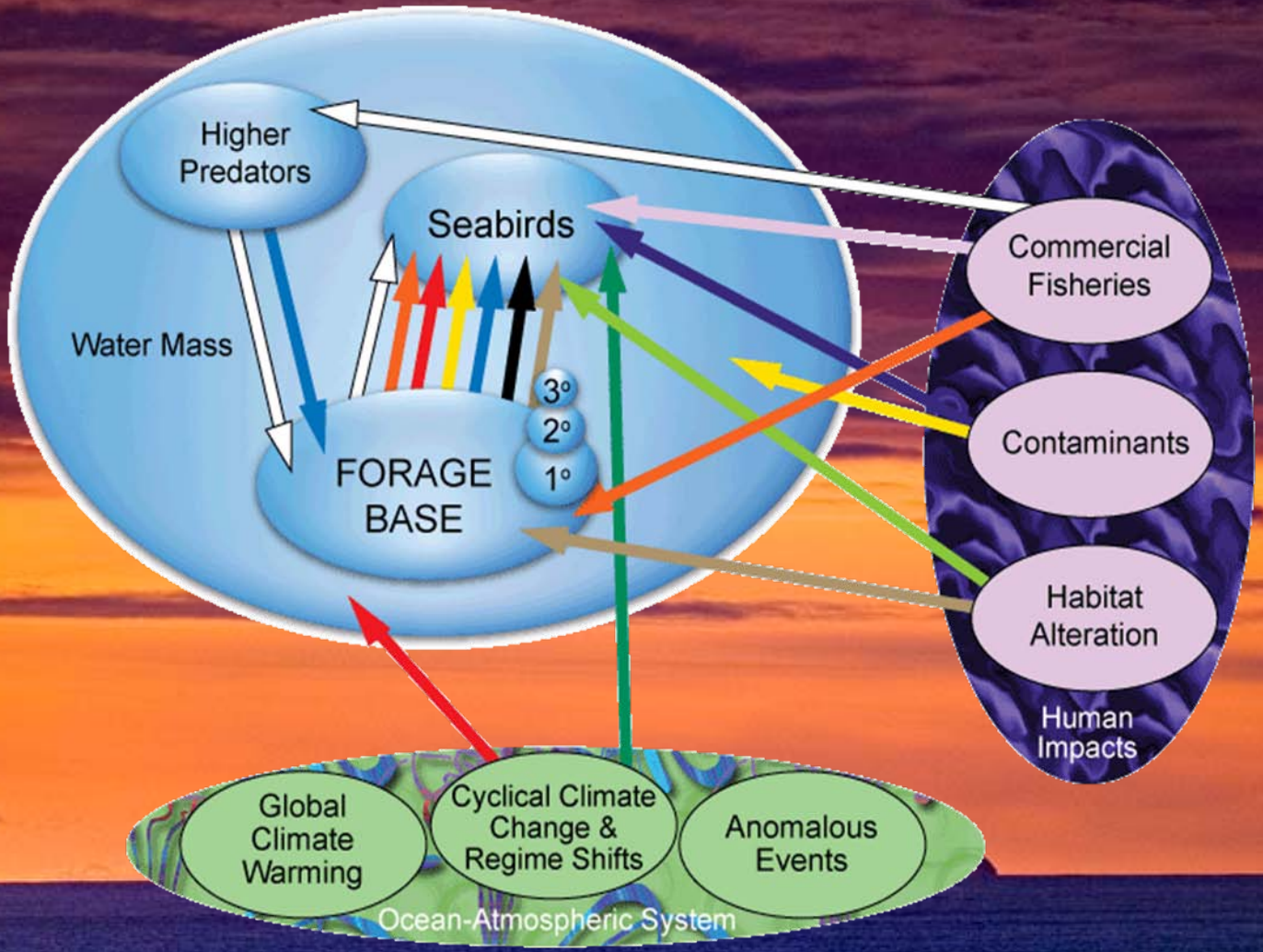
On colonies

At sea

Climate-Food Web Indicators

I. Cannot measure everything
II. Signals may be unclear
III. Prediction and for forecasting

H_o: Changes in Seabird Parameters Reflect Changes in Prey Resources Linked to Climate and Anthropogenic Influences



Piatt et al. 2006 Rpt to NPRB


Ron LeValley

Seabirds at colony

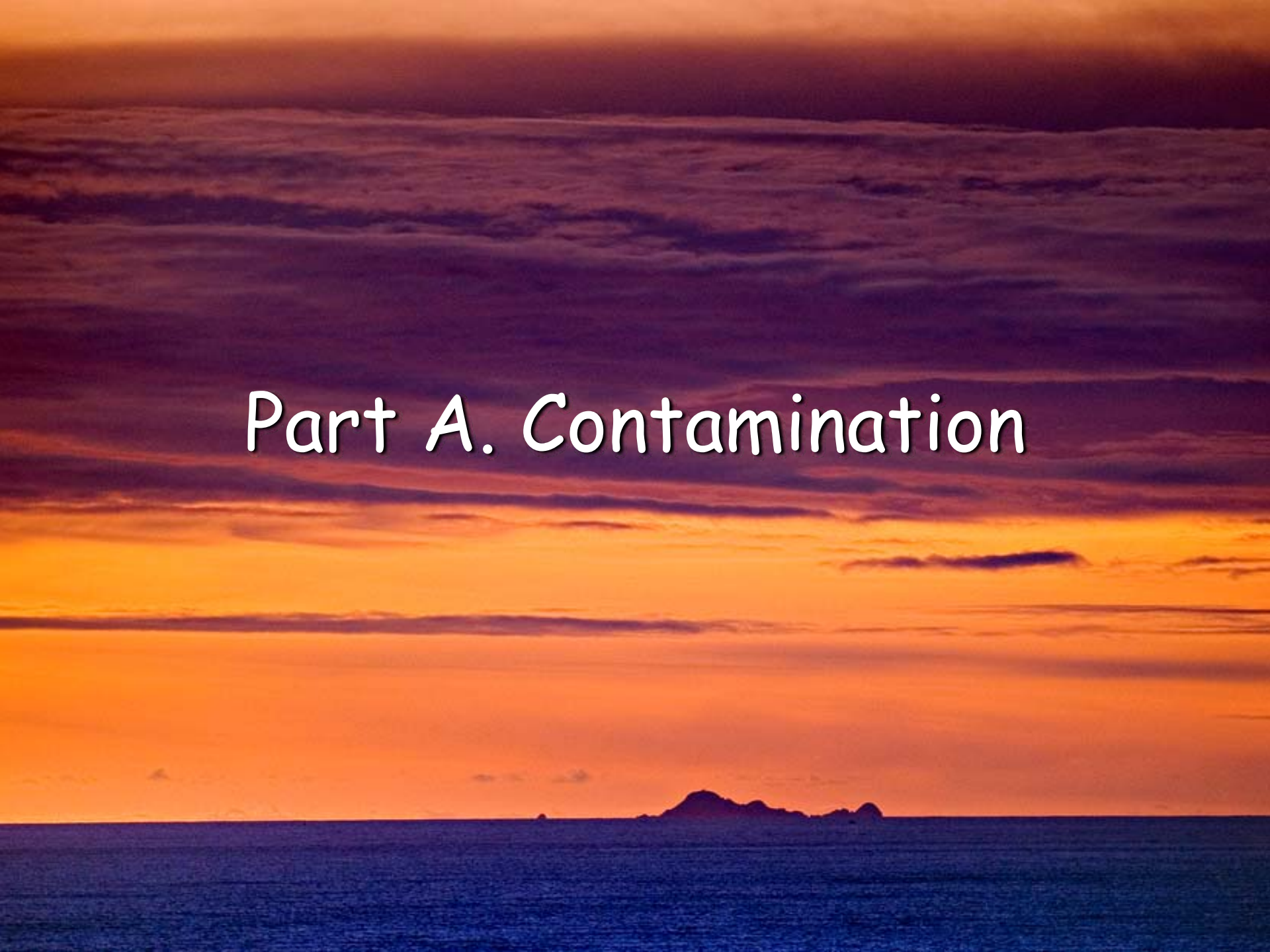
Demographic	Behavioral	Physiological	Adult + chick diet
Juvenile survival	Time at colony	Energy Expenditure- (DLW)	**Direct measures**
Adult survival	Chick feeding rates	Metabolic rate (oxygen consumption)	Chick meal collection
Site fidelity	Forage trip durations	Corticosterone levels	Adult regurgitation
Breeding probability	Contamination- side effects	Body condition • Body mass • Plasma yolk precursors • Total Body electrical conductivity (TOBEC) • Haematocrit • Fat scoring • Total body water (TBW)	Adult stomach pumping
Recruitment	Siblicide		Visual chick meal ID
Immigration/emigration from colony	Intraspecific aggression		
Age structure of population	Mating success		
Population trend			**Indirect measures**
			Stable isotope analysis
			Fatty acid analysis
Reproductive Biology • Chronology • Laying success • Clutch/brood size • Hatching success • Fledging success • **Reproductive variation** • Brood sex ratio		Contaminants: blood, liver, fat, eggs	
		Chick growth	
		Fledging mass	
		Fledging age	
		Blood parasite levels	
		Ectoparasite load	
		Immune capacity	

Today: Examples of Seabirds as Indicators of...

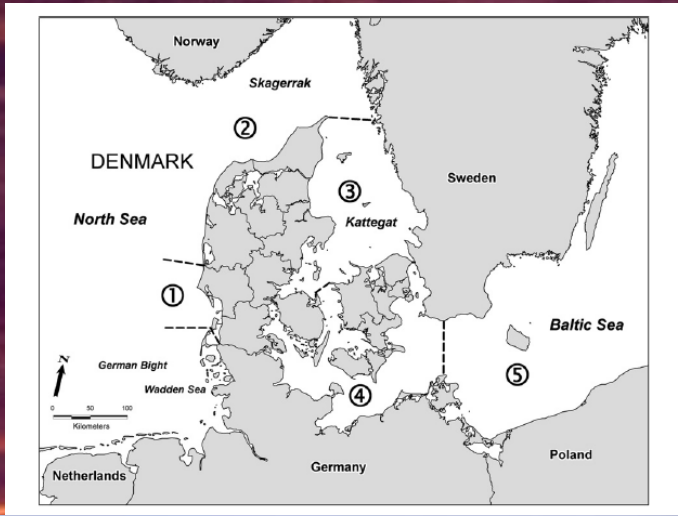
A. contaminants (chronic oil);

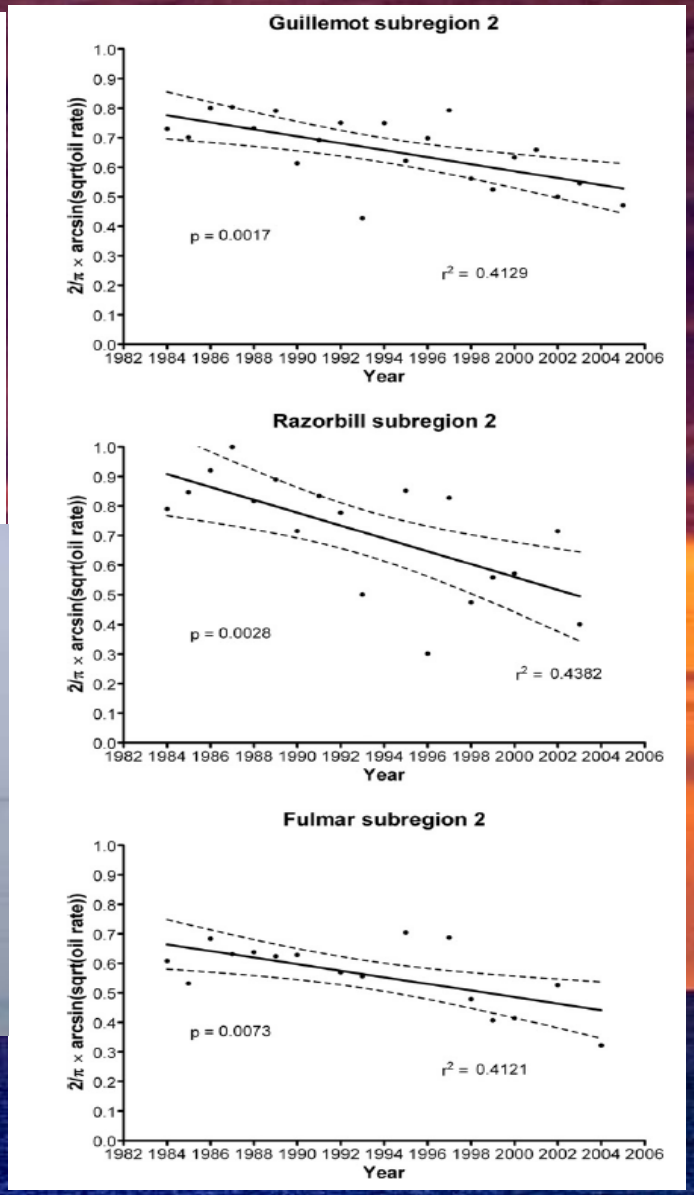
B. ecosystem-food web variation (prey resources, size/age of fish, squid, macrozooplankton), ecosystem controls;

C. fisheries issues


Part A. Contamination

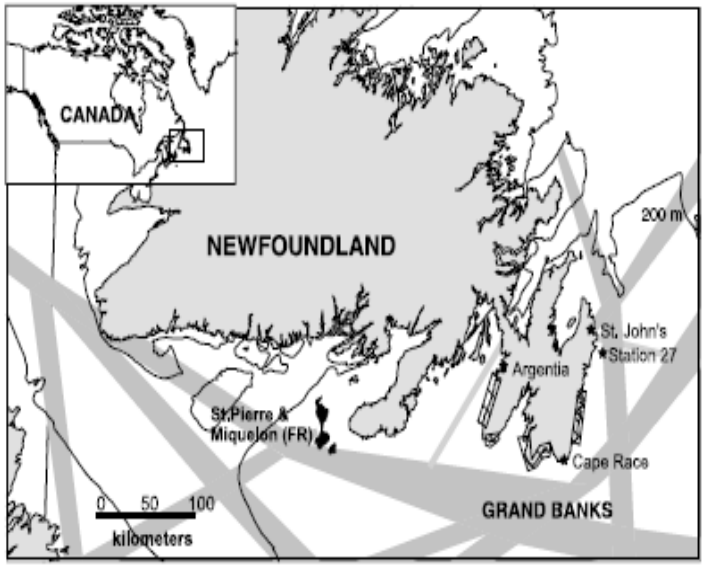
Seabirds as Indicators of Chronic Oil Pollution (North Sea)

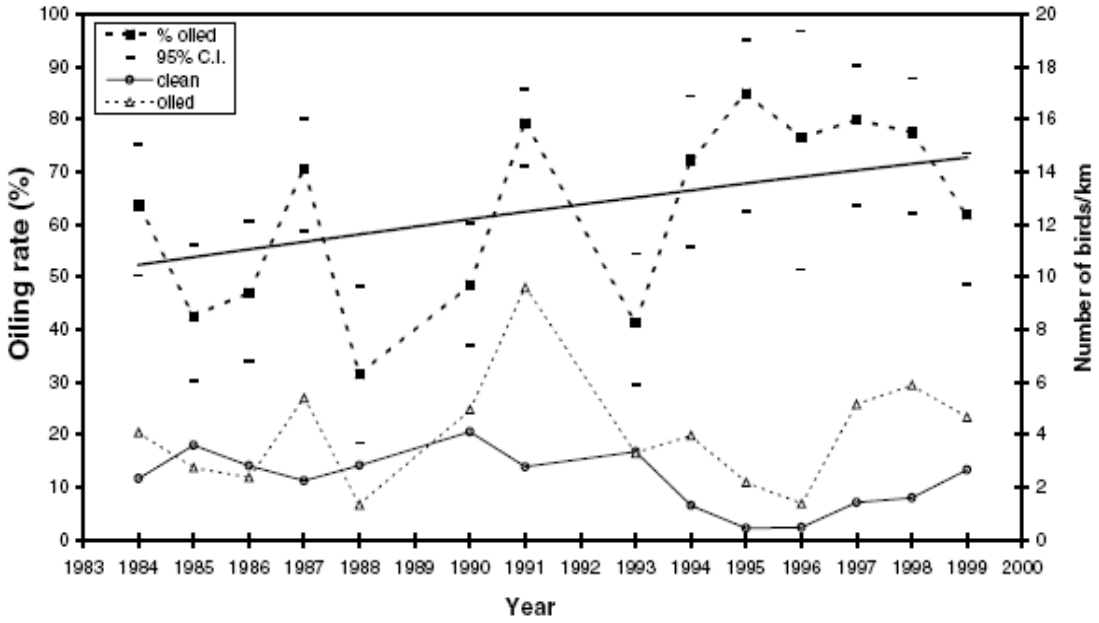


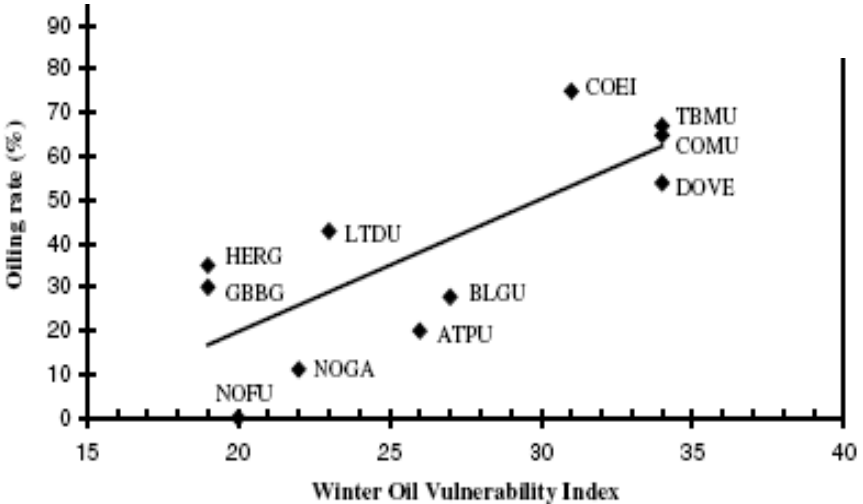


Larsen et al. 2007

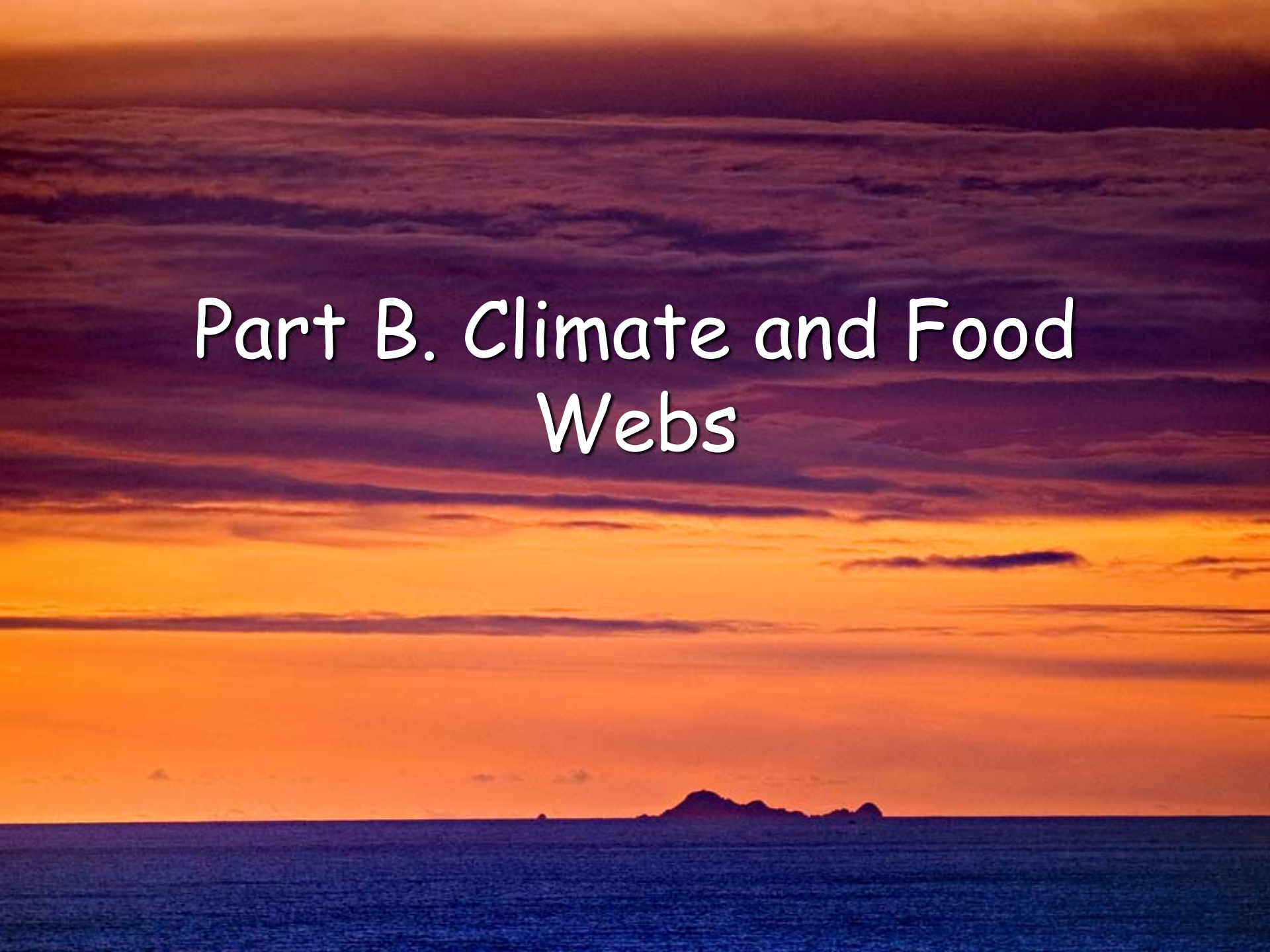
Seabirds as Indicators of Chronic Oil Pollution (NW Atlantic) – Species Variability

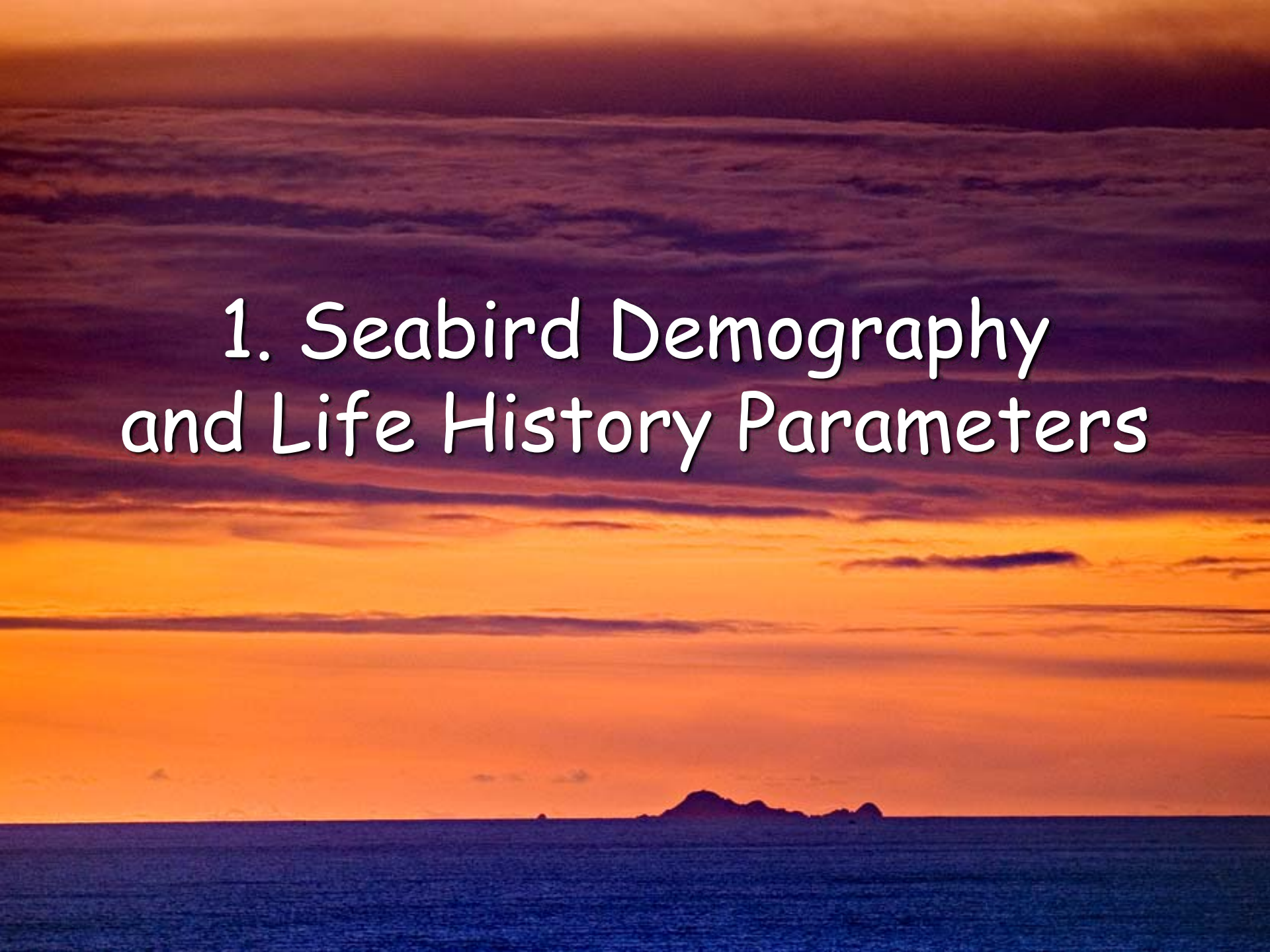




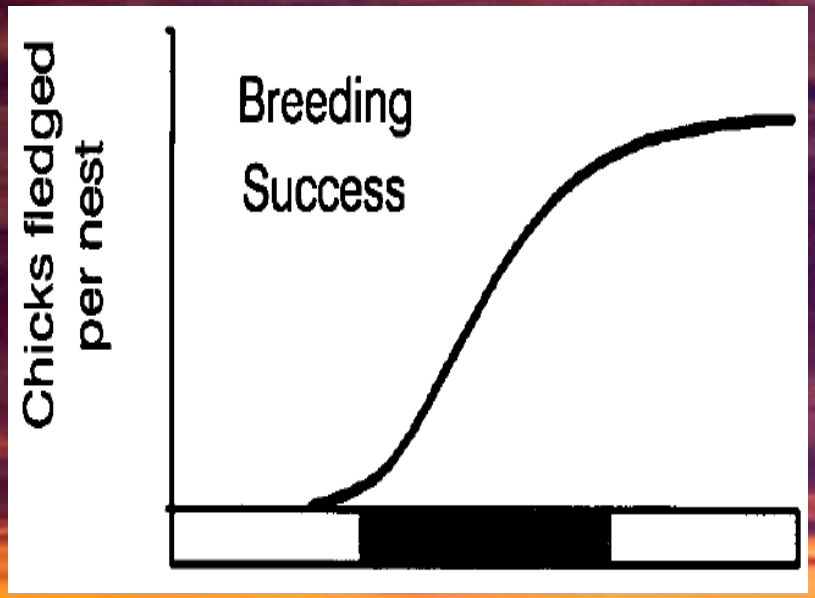


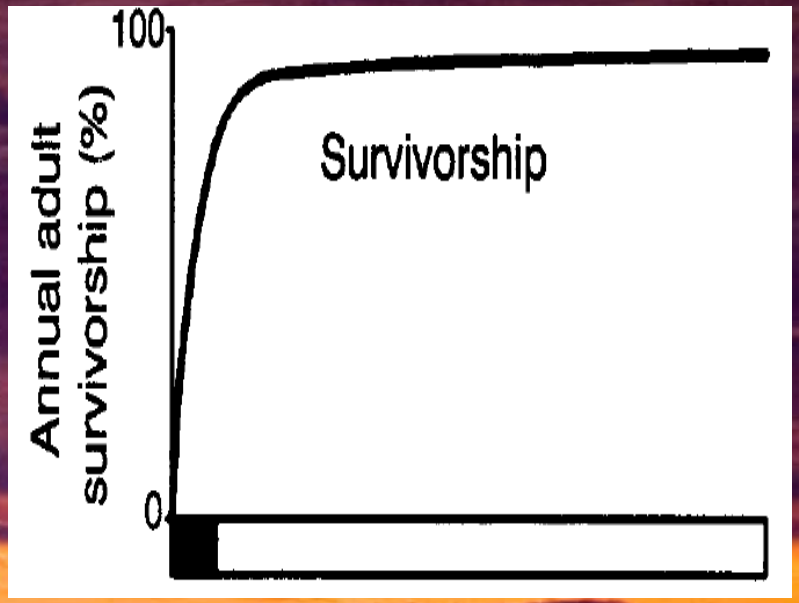
Wiese and Ryan 2003 MPB

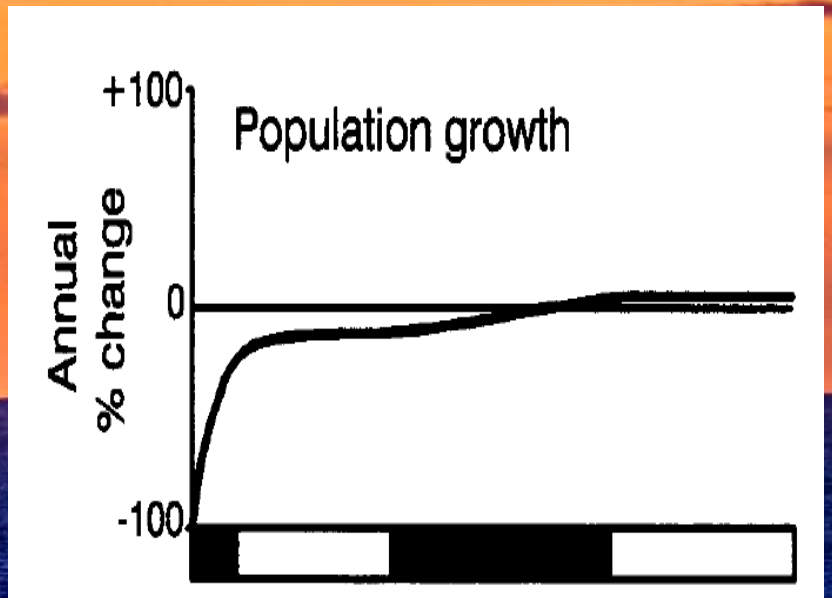

Part B. Climate and Food Webs


1. Seabird Demography
and Life History Parameters

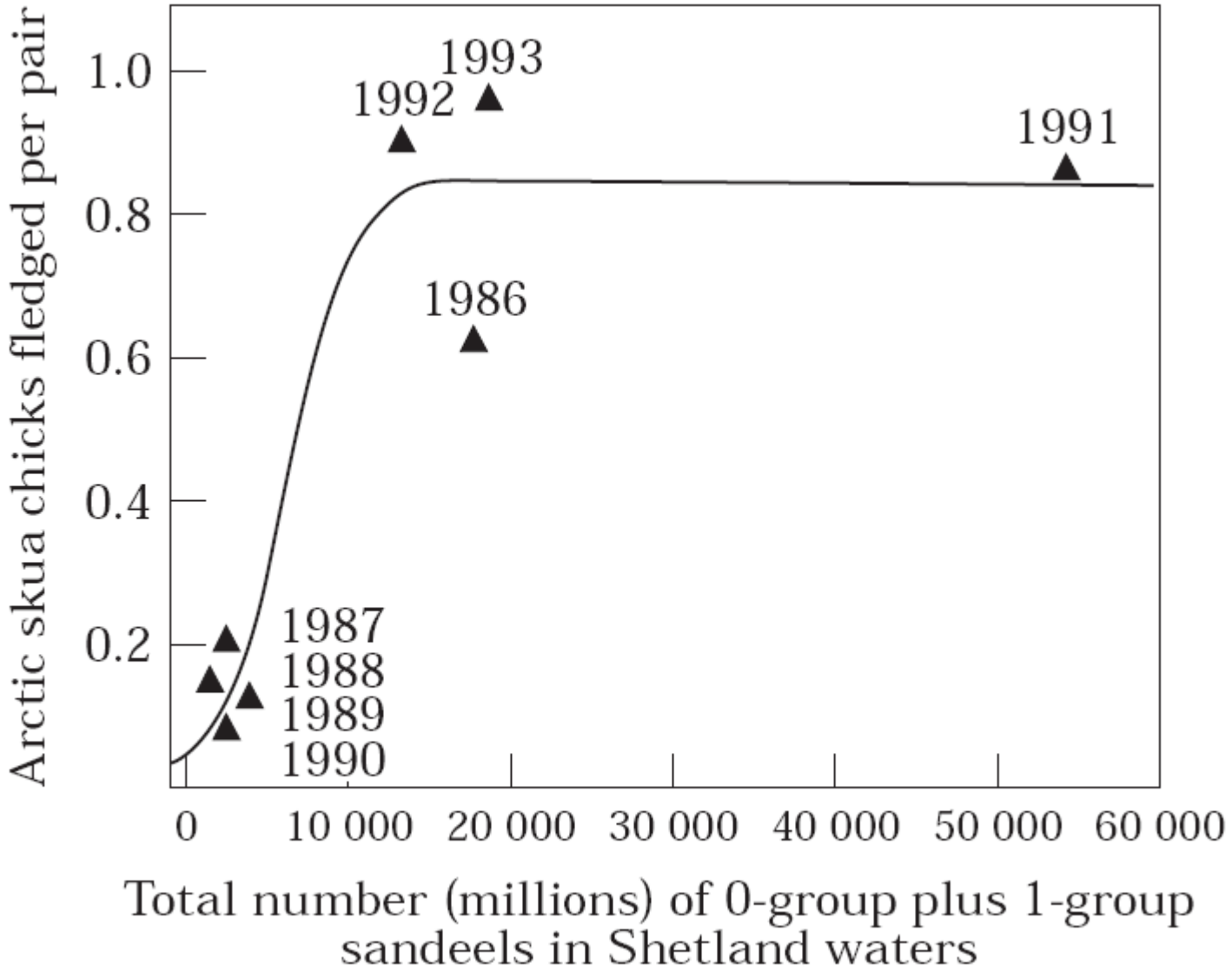
Variation in Utility of Demographic Traits as Indicators





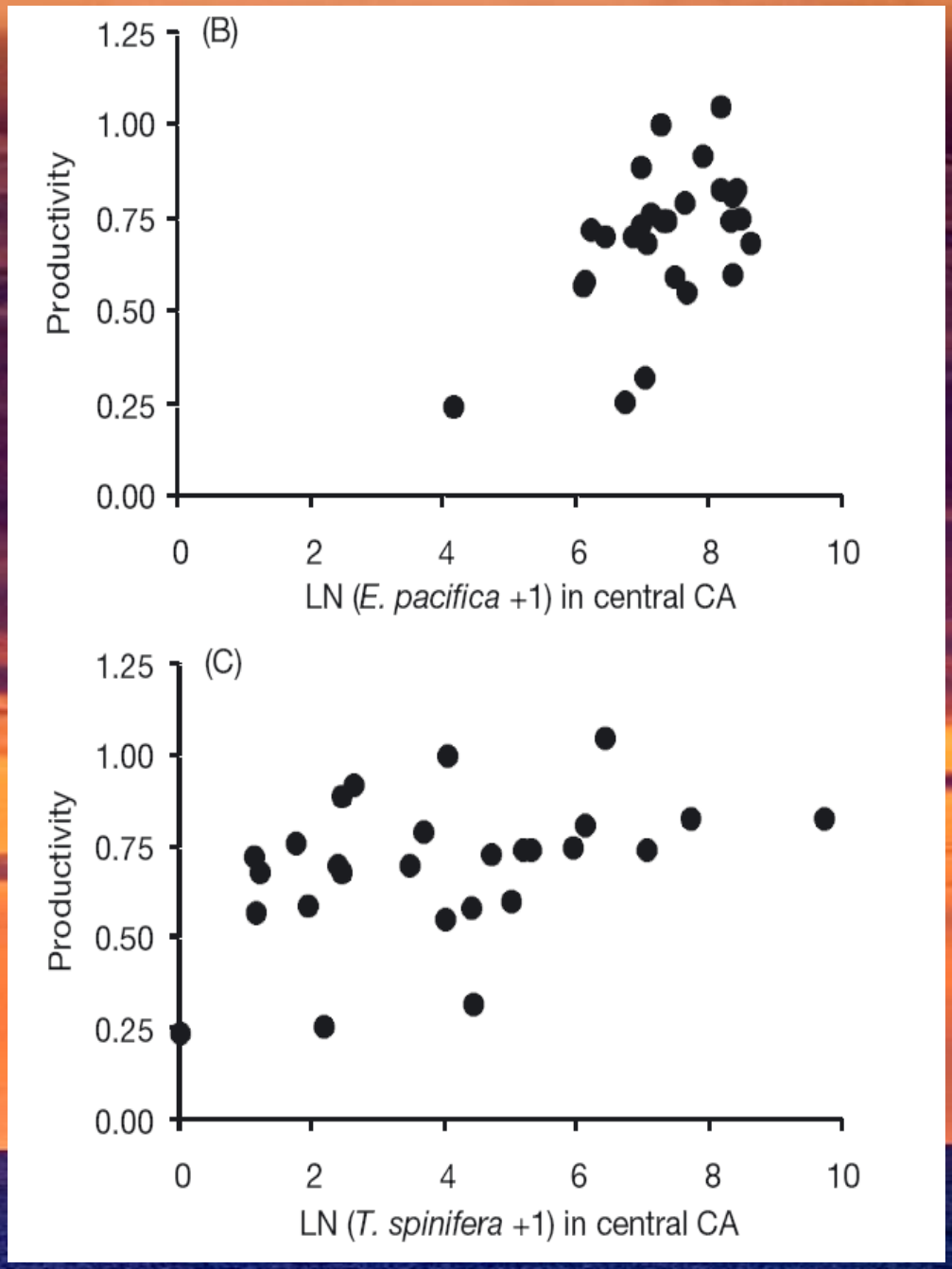


Cairns 1987

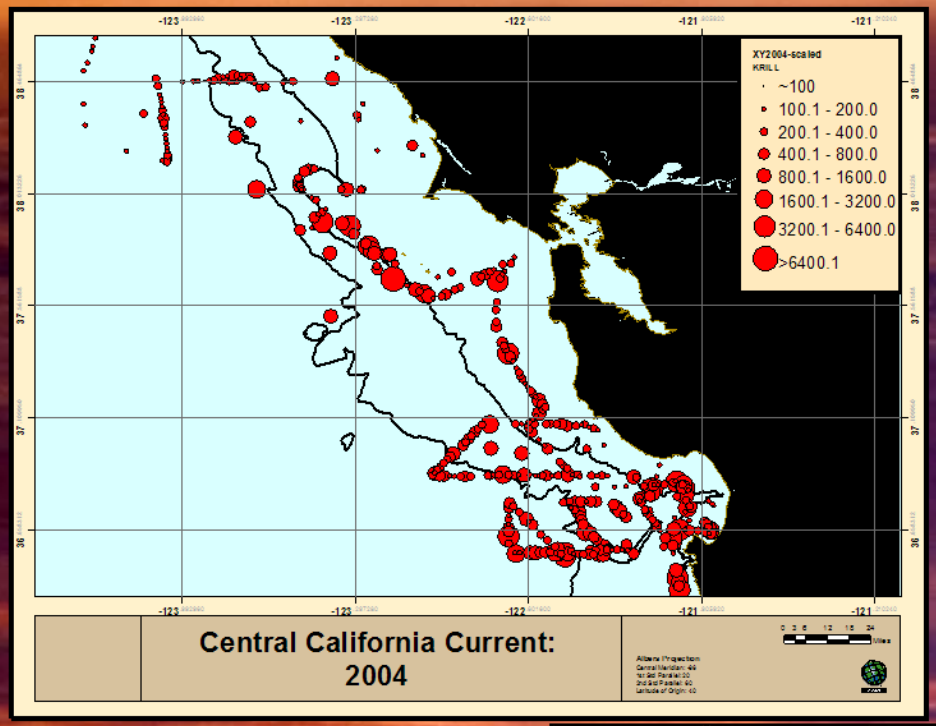

Arctic skua chicks fledged per pair
1.0
0.8
0.6
0.4
0.2
1993
1992
1991
1986
1987
1988
1989
1990
0
10 000
20 000
30 000
40 000
50 000
60 000
Total number (millions) of 0-group plus 1-group sandeels in Shetland waters

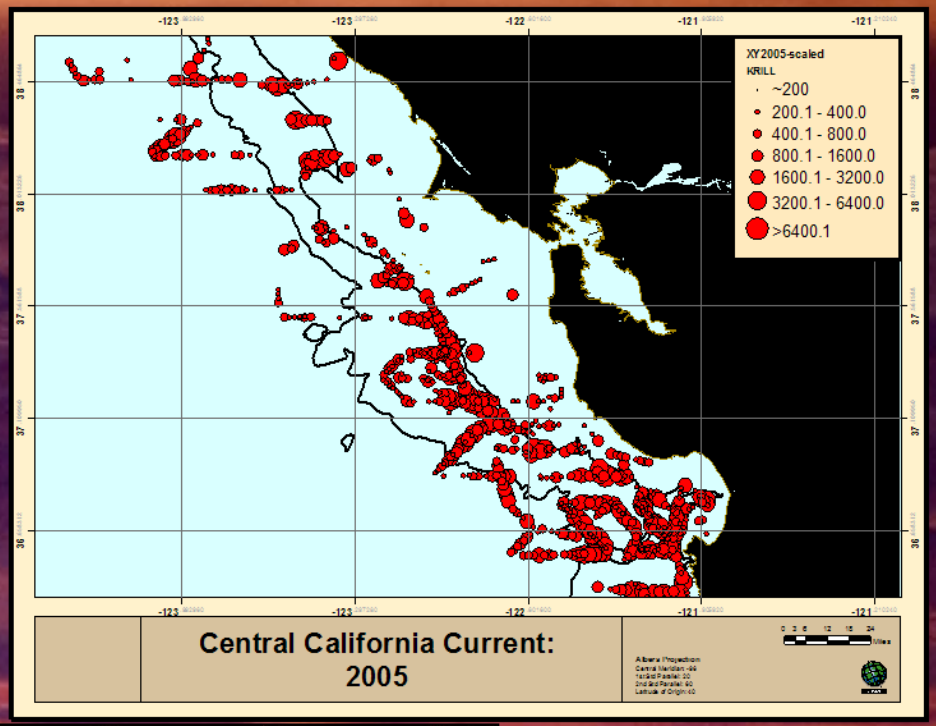
Seabird Breeding Success and Behavior Reveals Climate Variability on Multiple Time Scales

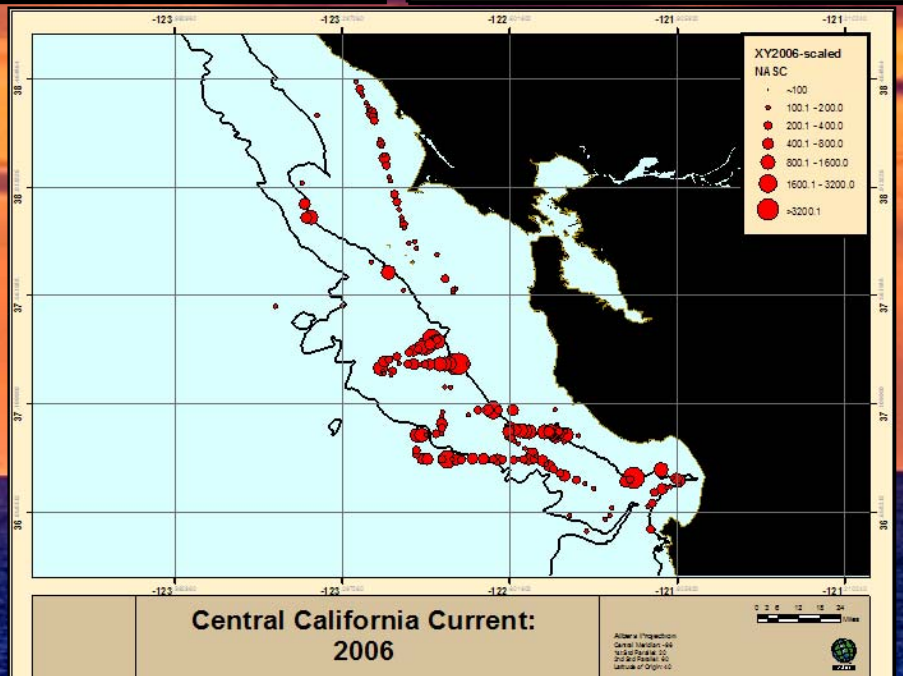
Sydeman et al. (2006), updated



Abraham and Sydeman 2004 MEPS

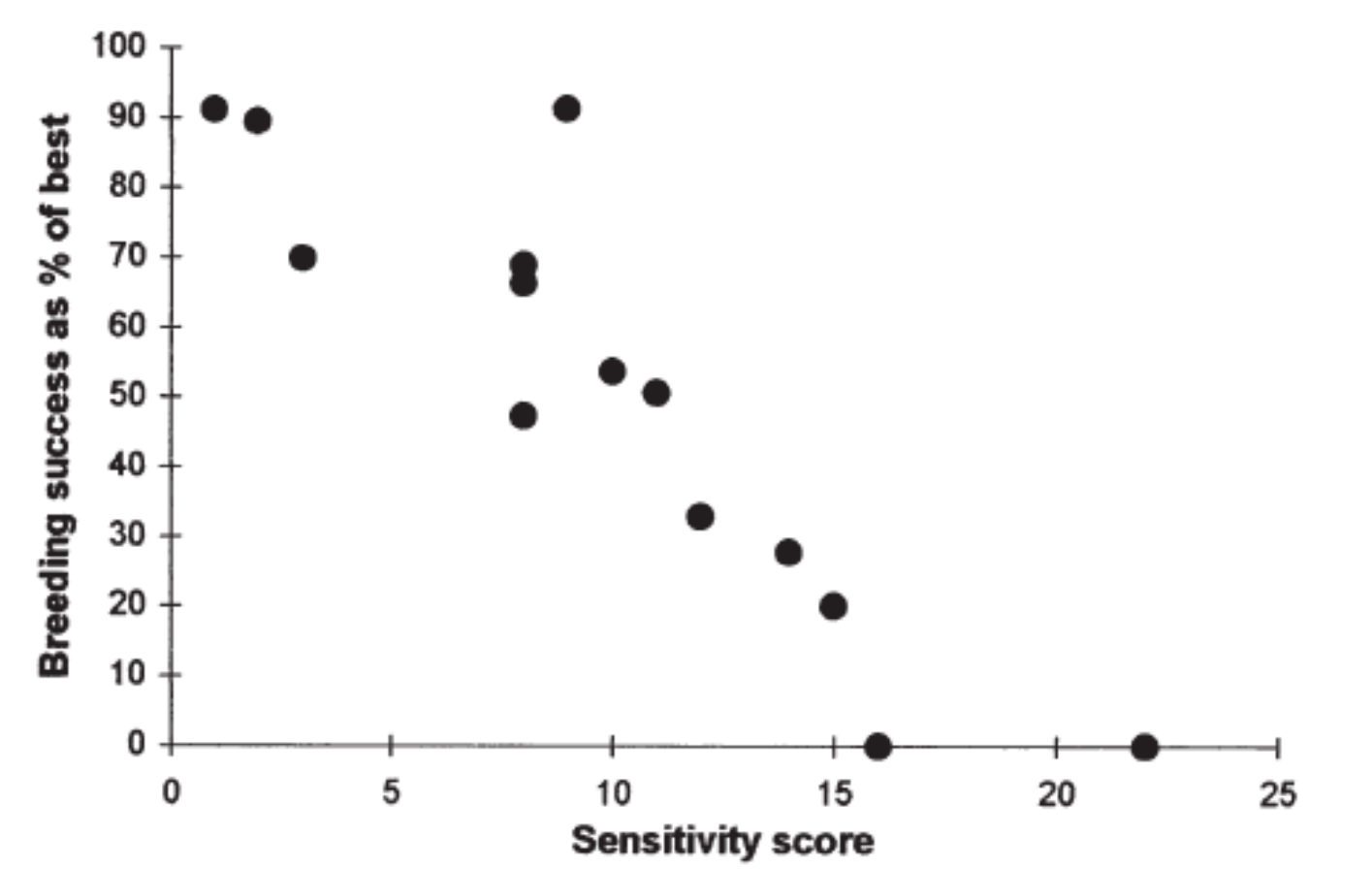






Krill Patches

Different Species (varying life histories) – Different Response (= indicator value)

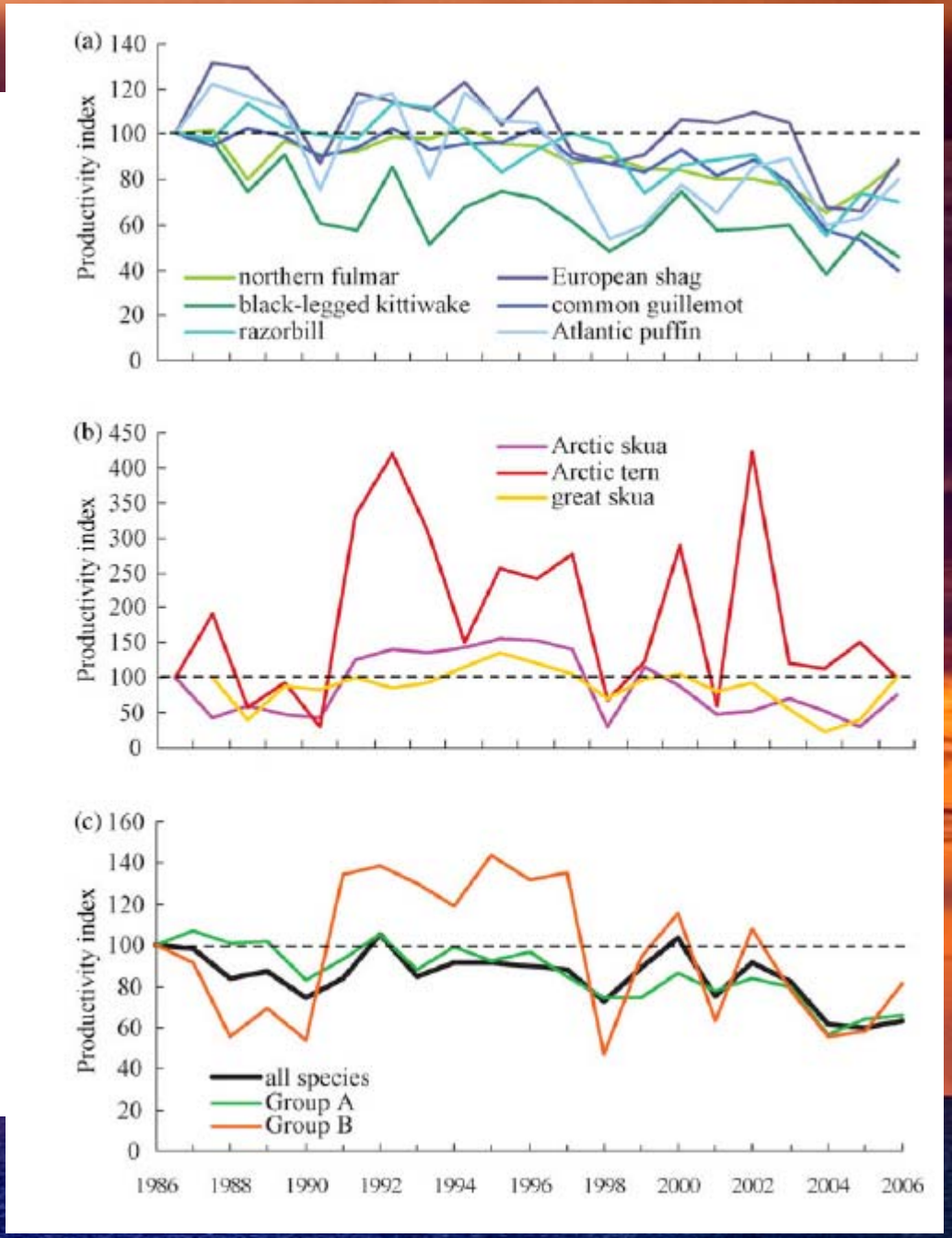


Furness and Tasker 2000 MEPS

Table 3. Results of the GLMM in respect to the year effect in the productivity of 16 seabird species breeding in Scotland, 1986–2006 (n.s., not significant; $*p < 0.05$, $***p < 0.001$).

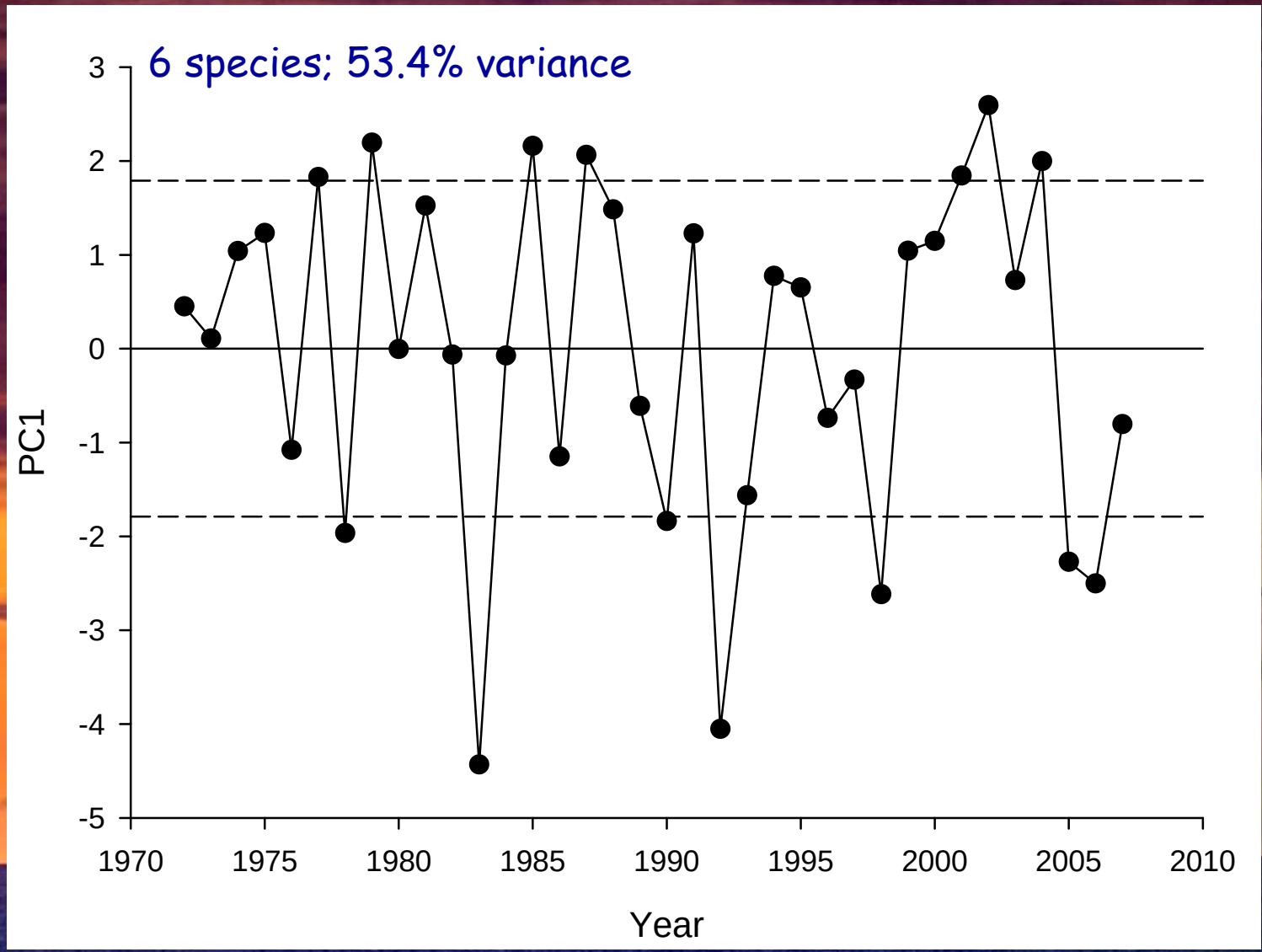
Species	Degrees of freedom		*F*-value	*p*-value
	Numerator	Denominator		
Northern fulmar	20	329	3.61	***
Manx shearwater[a]	20	7.7	0.53	n.s.
Northern gannet	20	64.5	0.70	n.s.
Great cormorant	15	55.2	3.75	***
European shag	20	189	1.92	*
Arctic skua	20	263	7.59	***
Great skua	19	143	3.35	***
Black-legged kittiwake	20	457	10.3	***
Sandwich tern	20	22.7	5.69	***
Arctic tern	20	629	8.81	***
Common tern	20	570	3.24	***
Little tern	20	130	2.68	***
Common guillemot	20	64.2	12.8	***
Razorbill	20	31.9	1.49	n.s.
Atlantic puffin[b]	20	23.7	2.22	*
Black guillemot[c]	19	31.3	0.46	n.s.

[a] *Puffinus puffinus.*
[b] *Fratercula arctica.*
[c] *Cepphus grylle.*



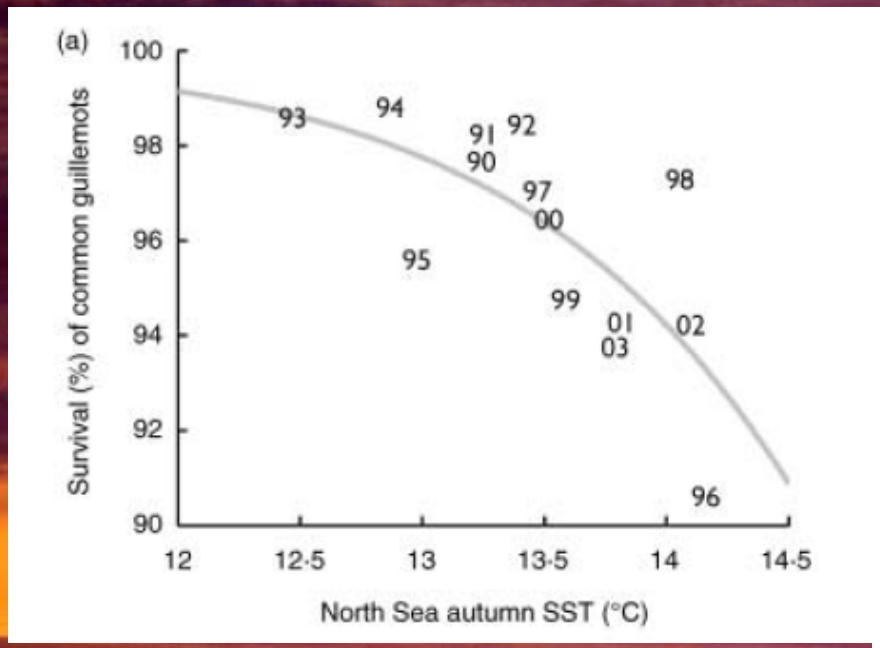
Parsons et al. 2008

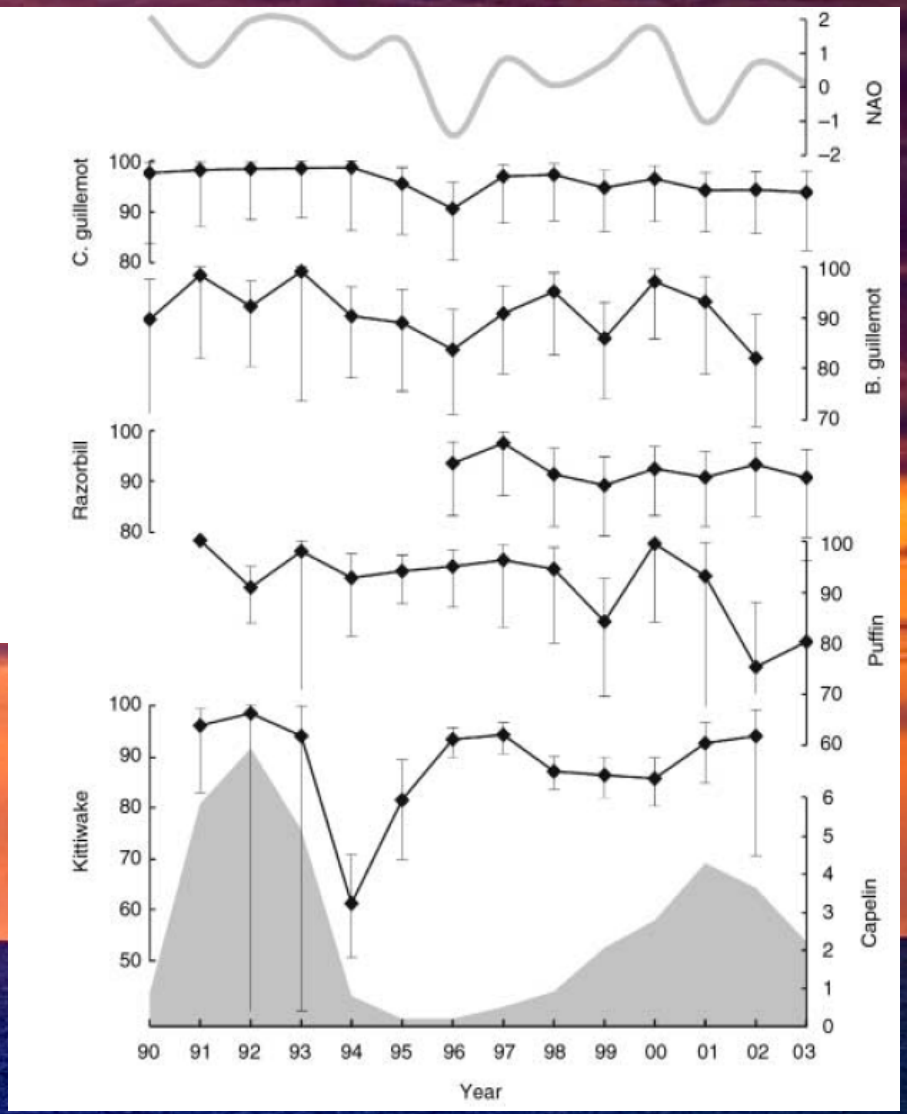
Seabird Multivariate Productivity Index



Sydeman et al. 2001 PiO, updated

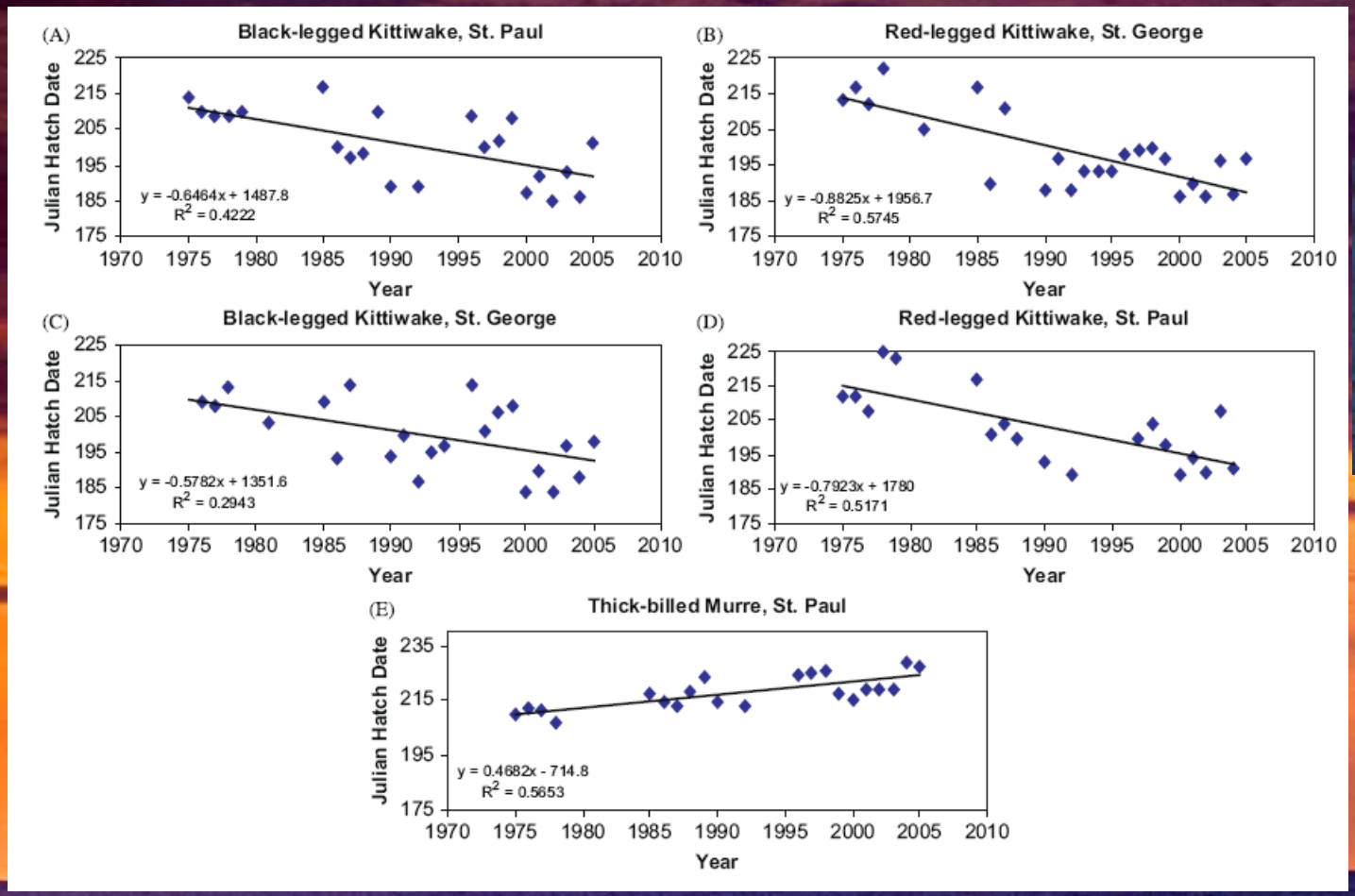
Seabird Adult Survival, Climate & Capelin (Barents Sea)



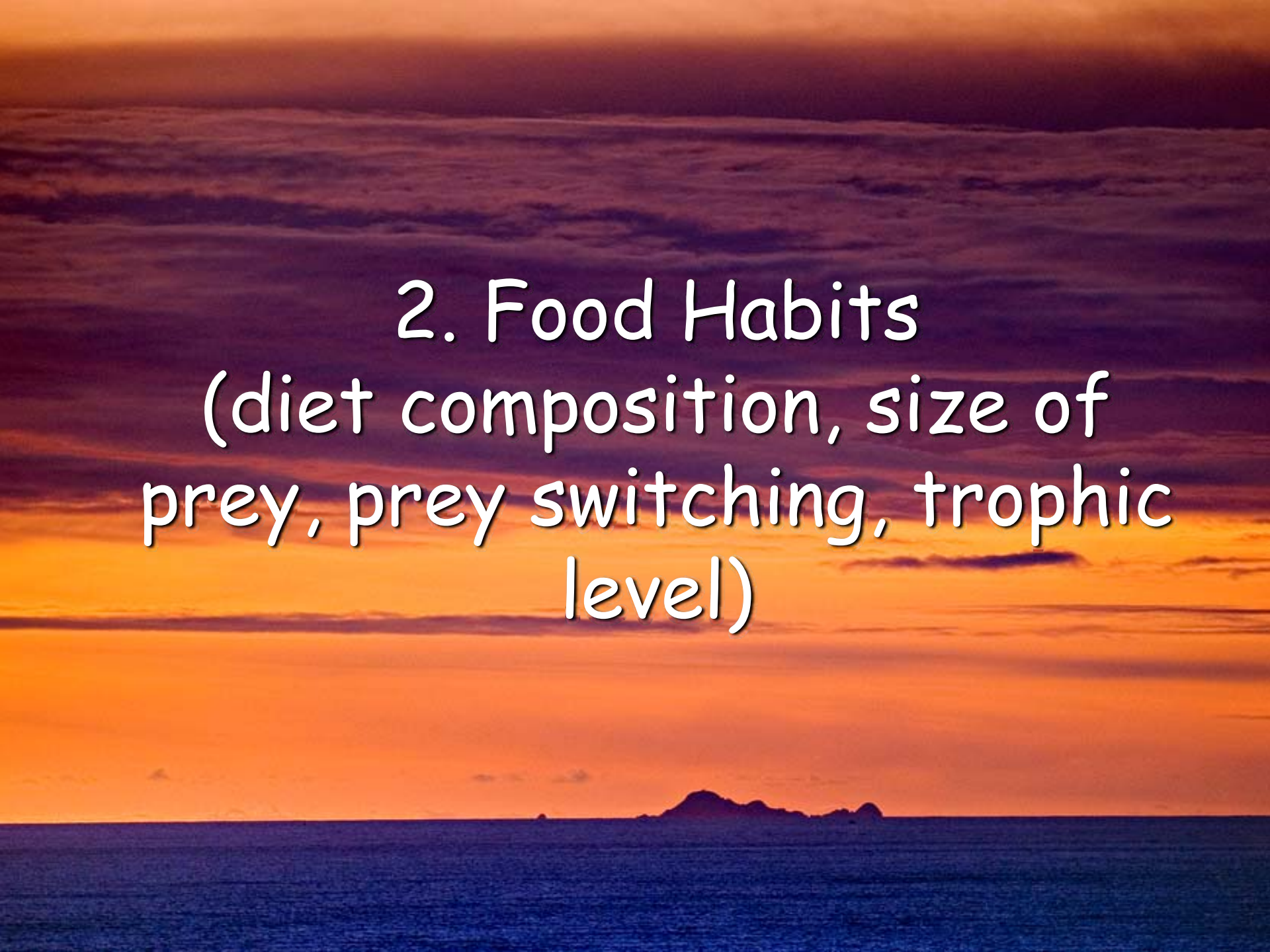


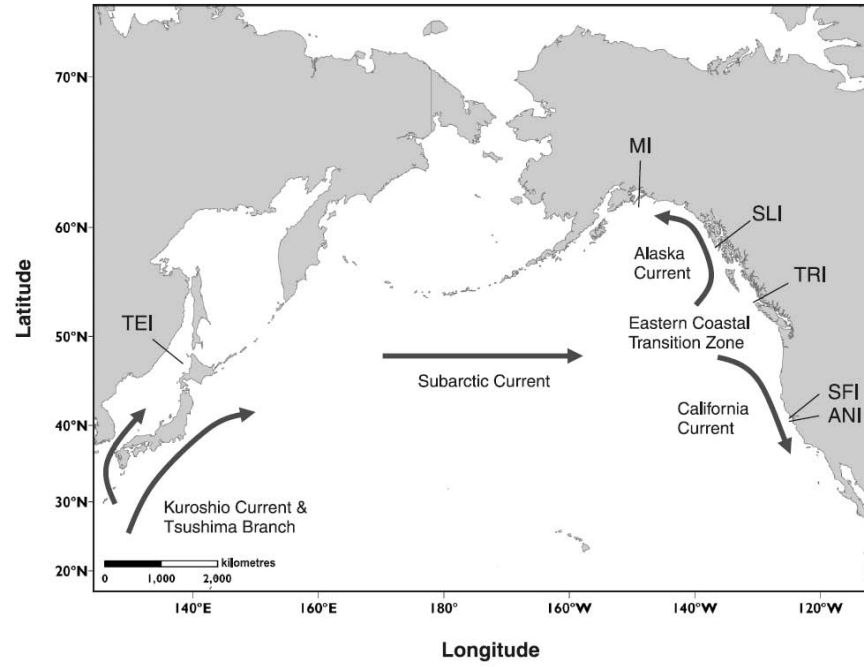
Sandvik et al. 2005 JAE

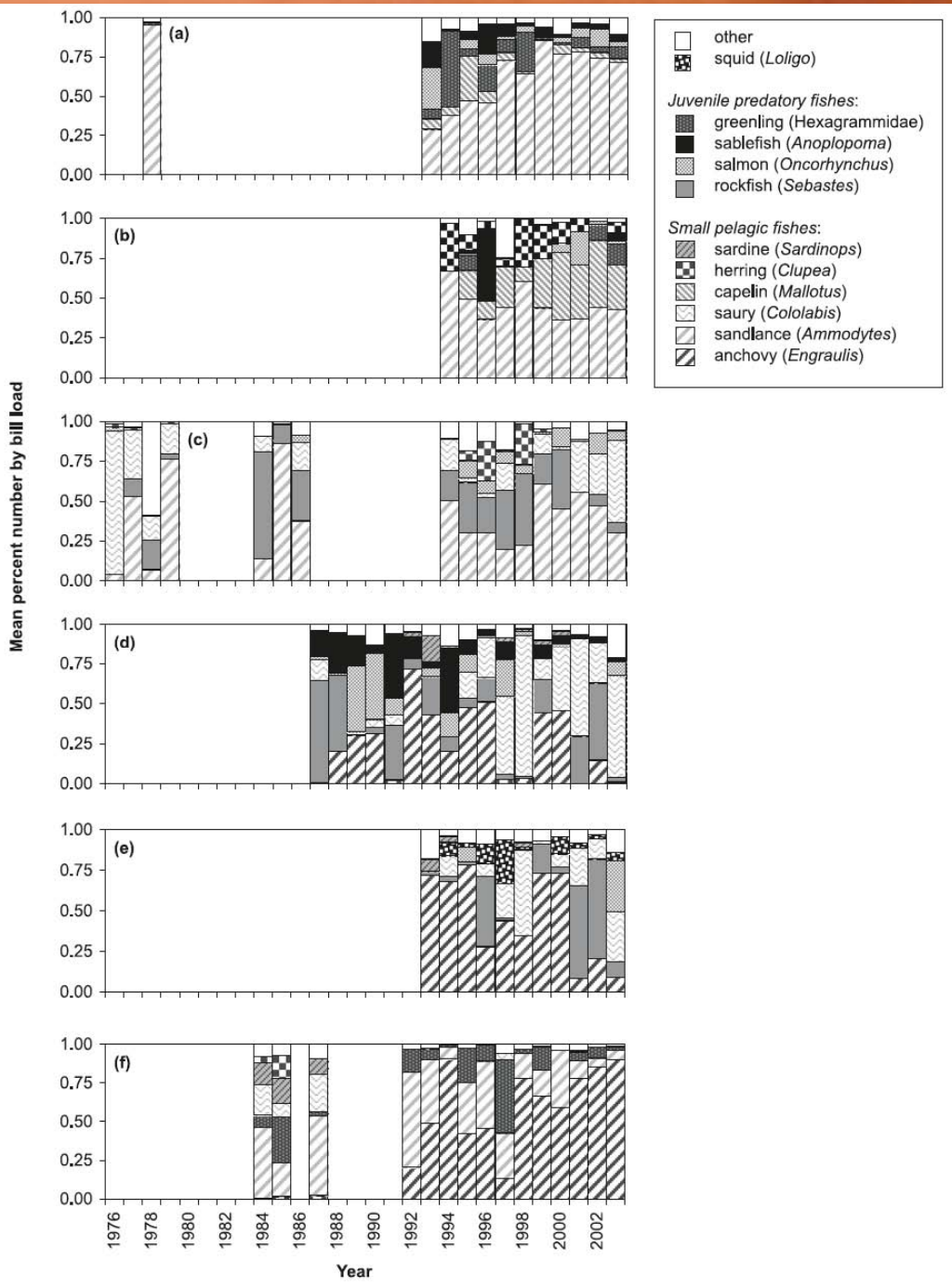
Seabird Phenology (Timing of Hatching) – Climate Change, Bering Sea



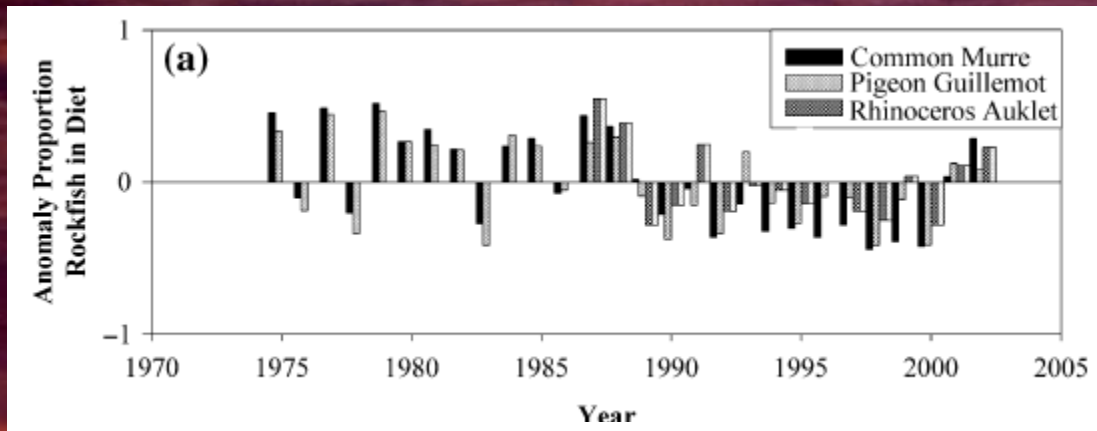
Byrd et al. 2008 DSR II

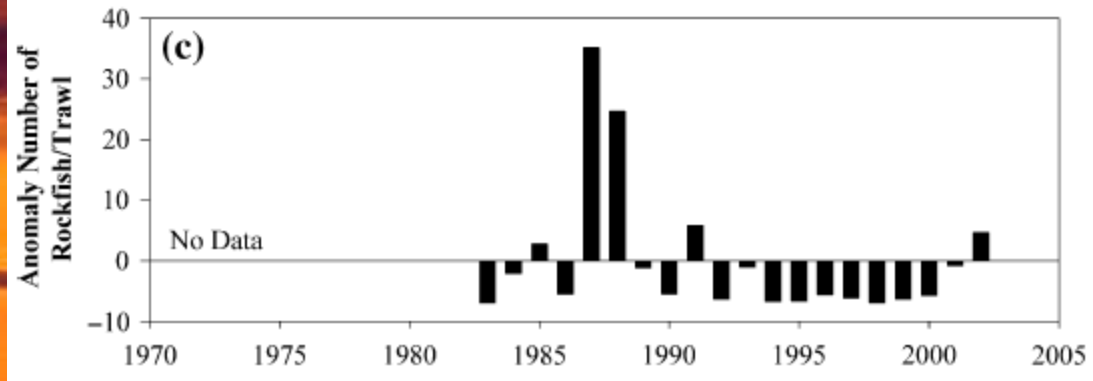

2. Food Habits
(diet composition, size of prey, prey switching, trophic level)

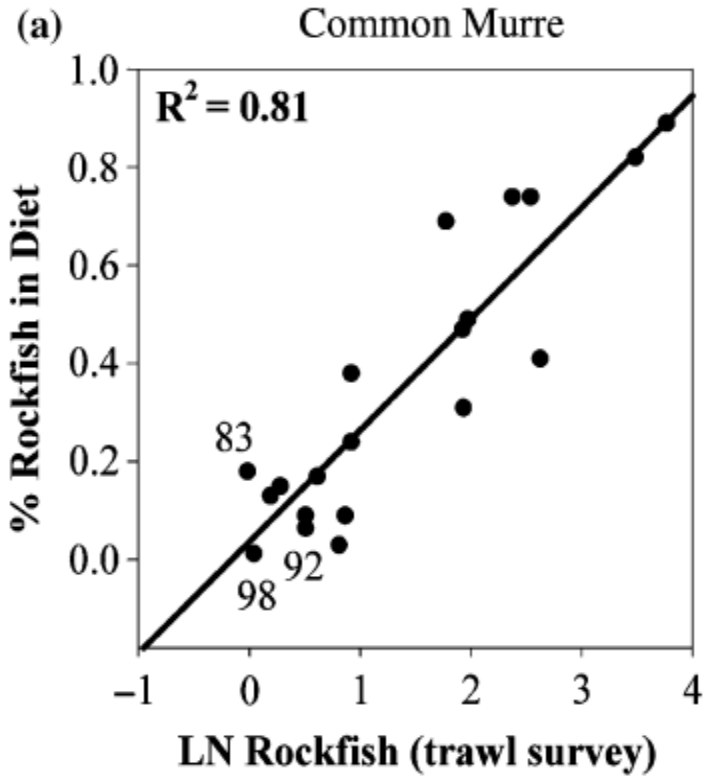


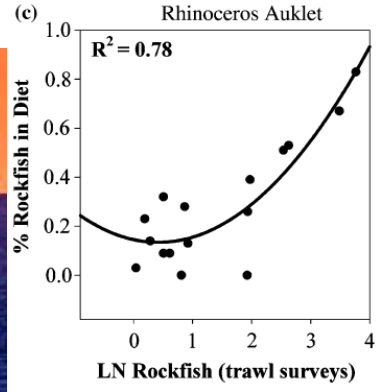


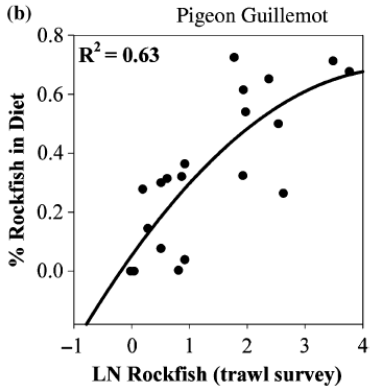
Thayer et al. 2008 CJFAS



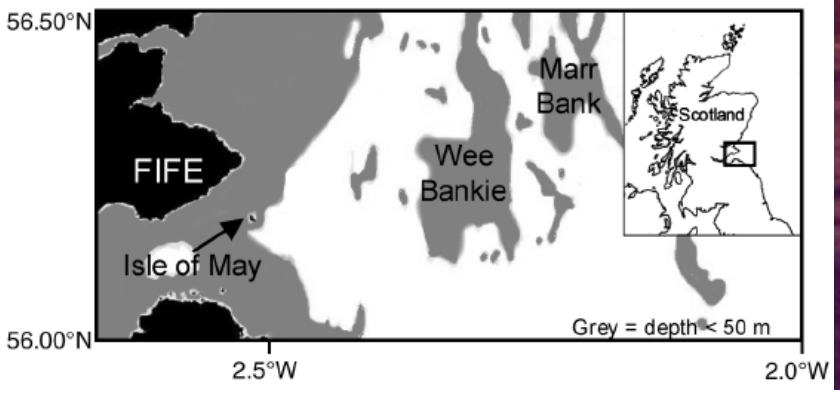


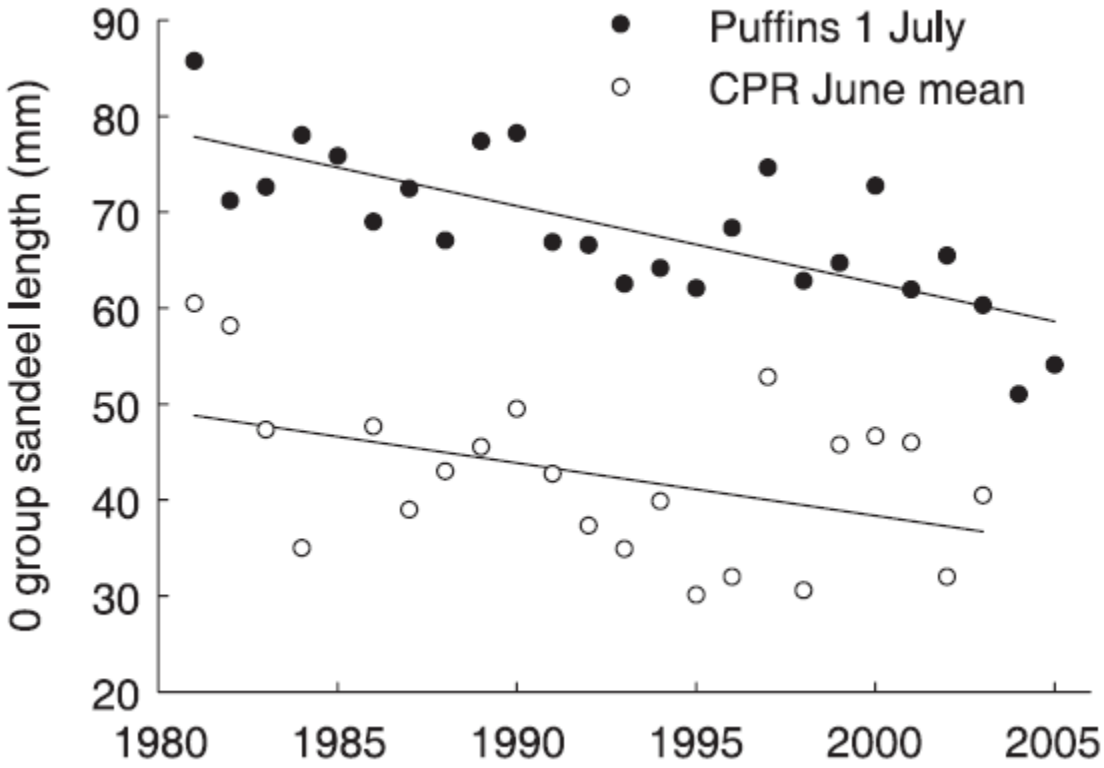


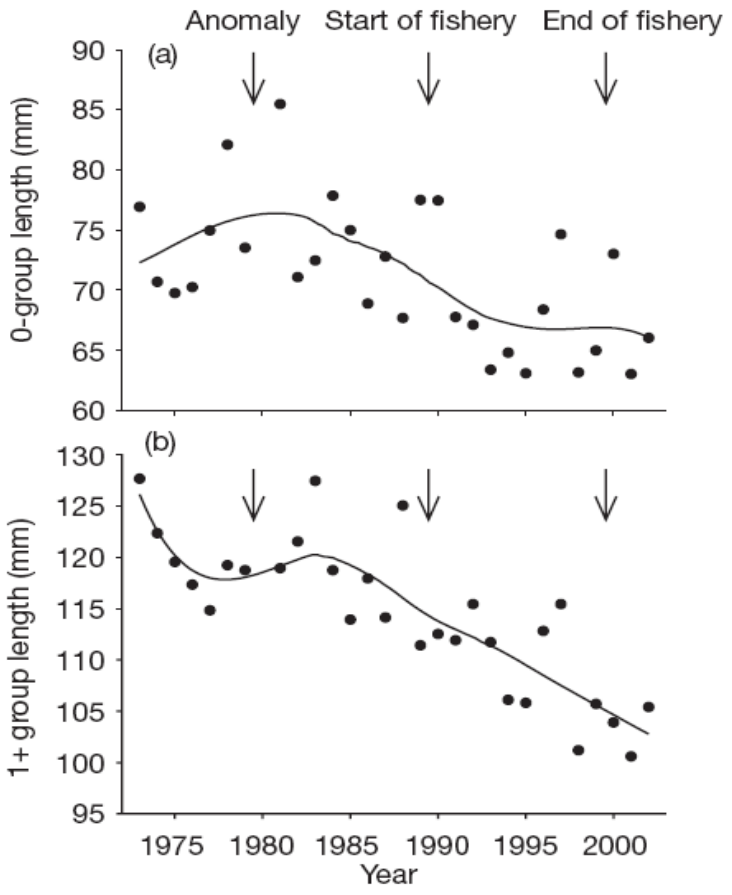




Mills et al. 2007 FOG

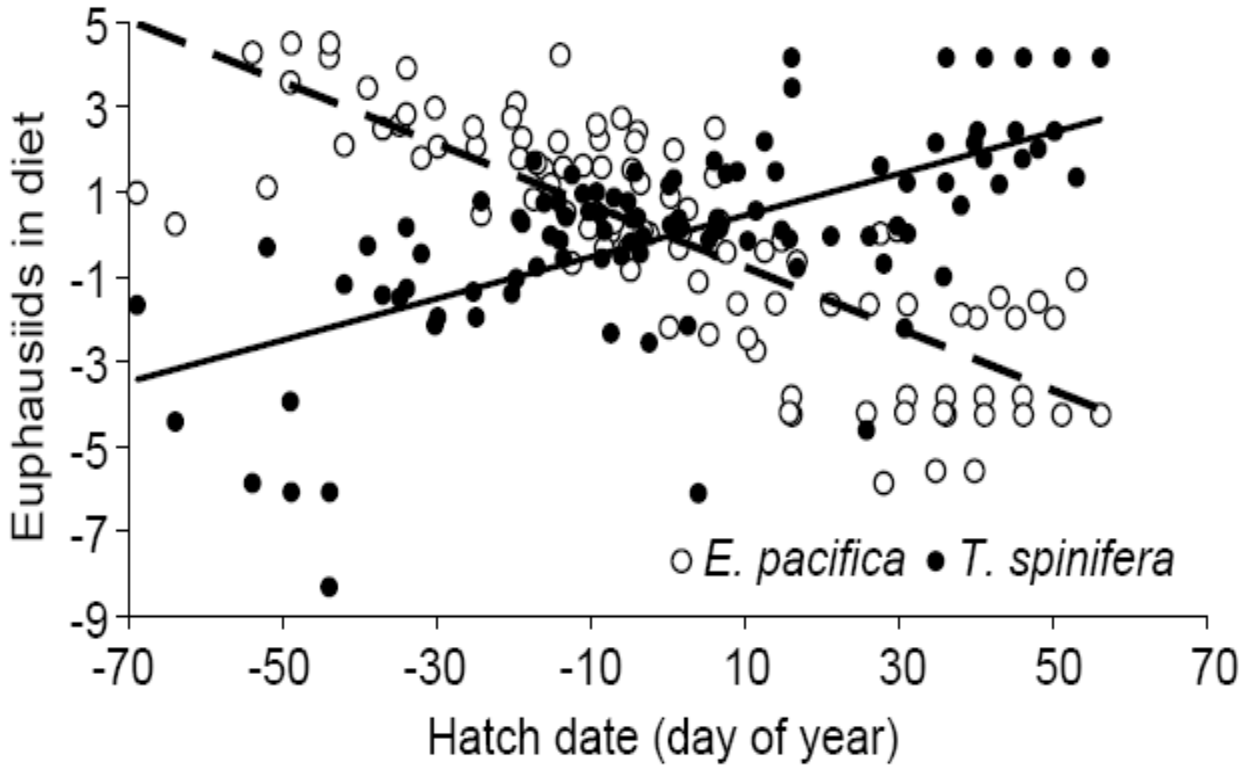


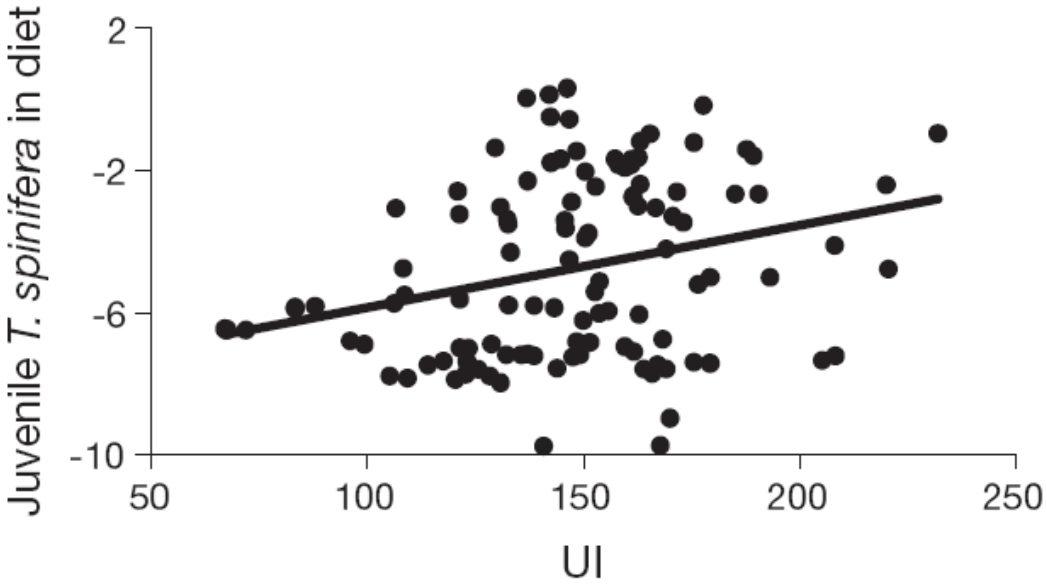




Wanless et al. 2004 MEPS, updated

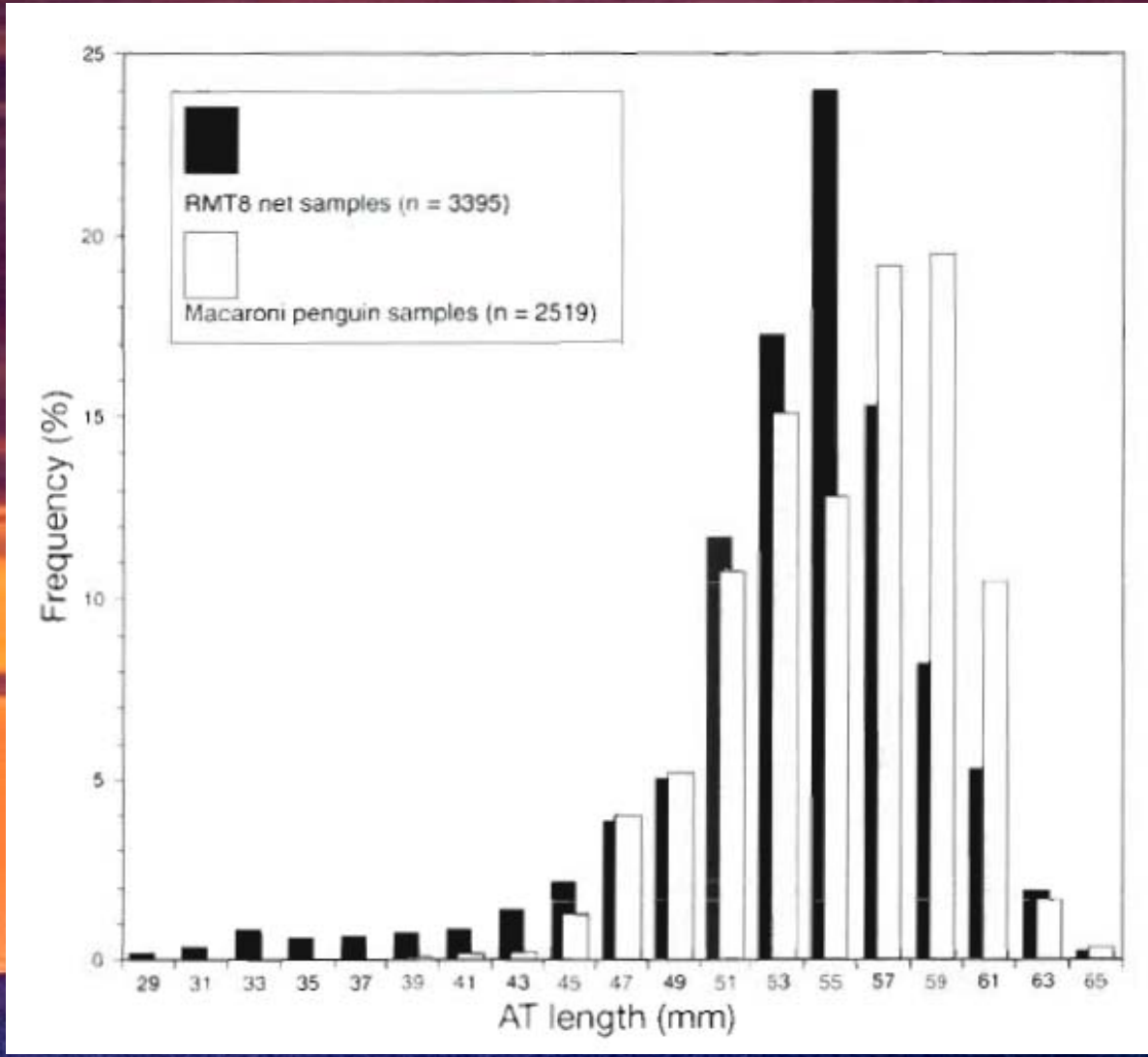
Complexity: Prey Switching





Abraham and Sydeman 2006 MEPS

Complexity: Prey Size Selectivity

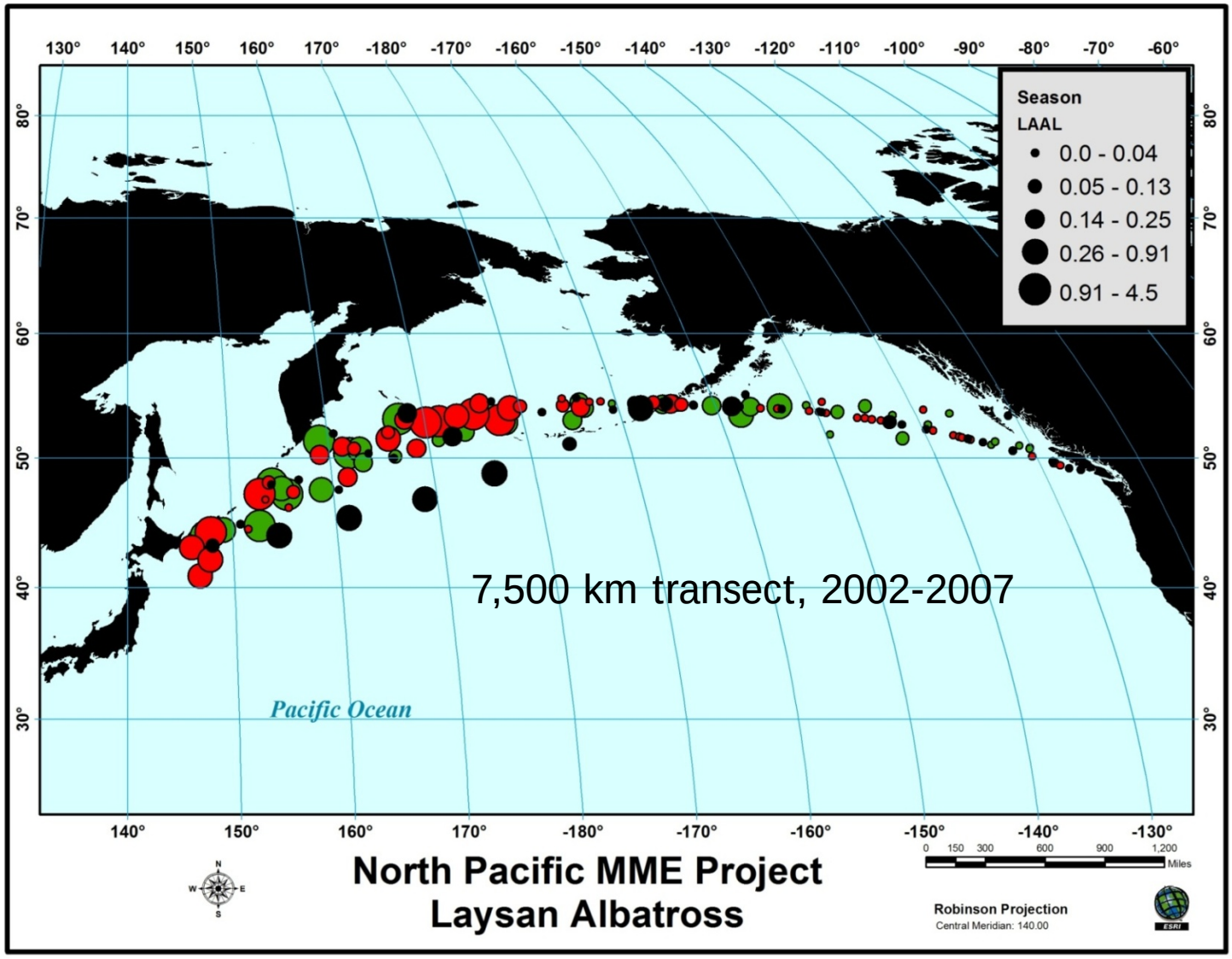


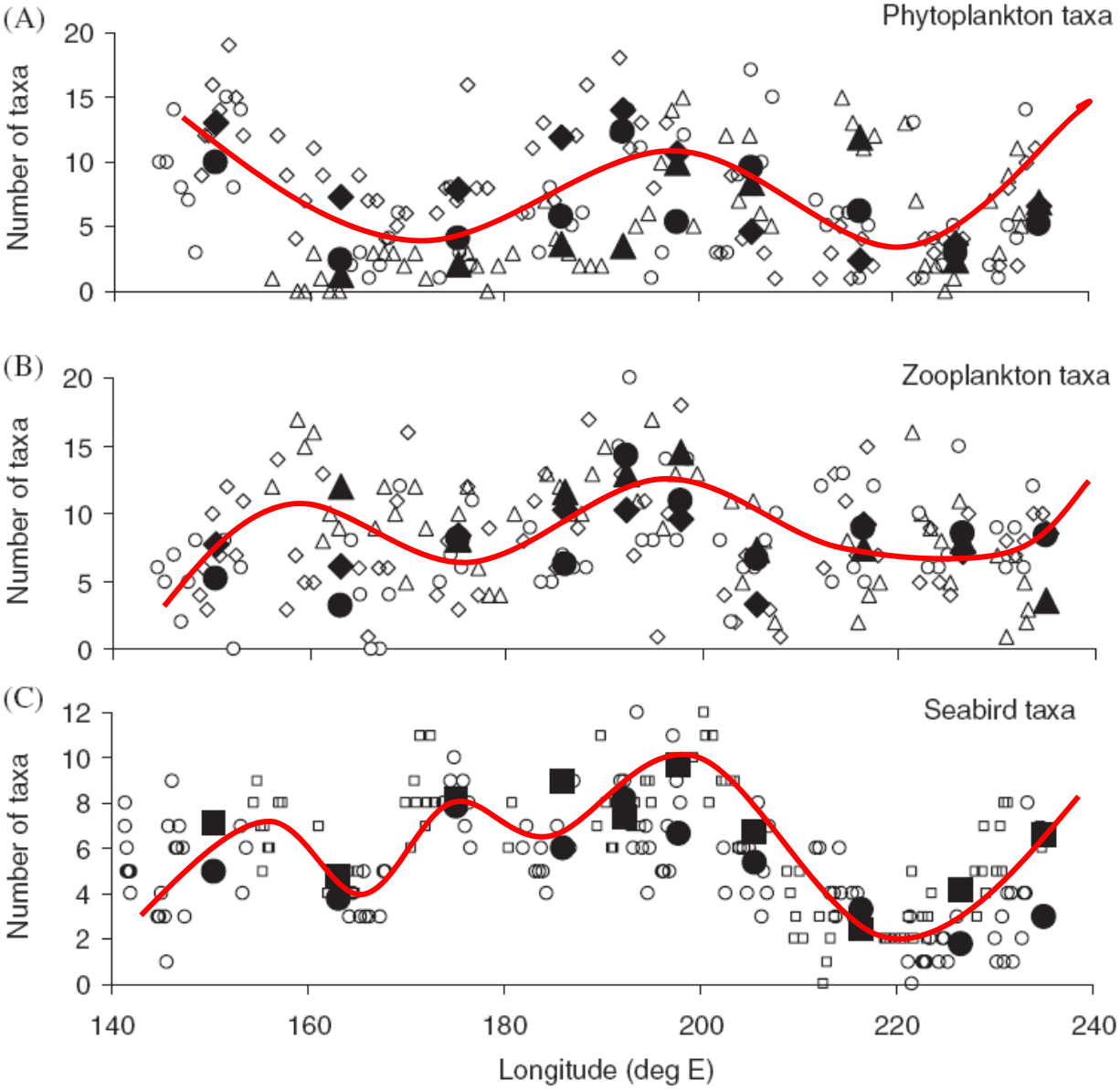
Hill et al. 1996 MEPS

3. Spatio-Temporal Integrators?

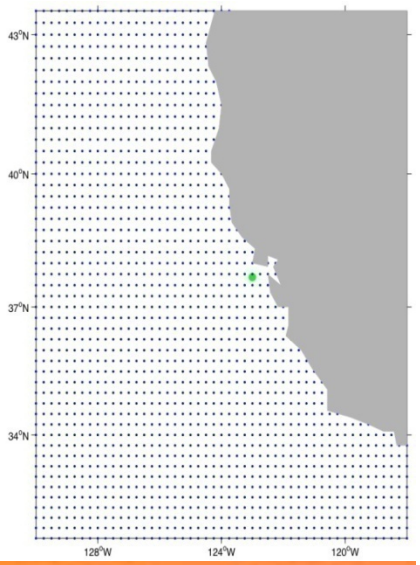
Spatial Integrators?

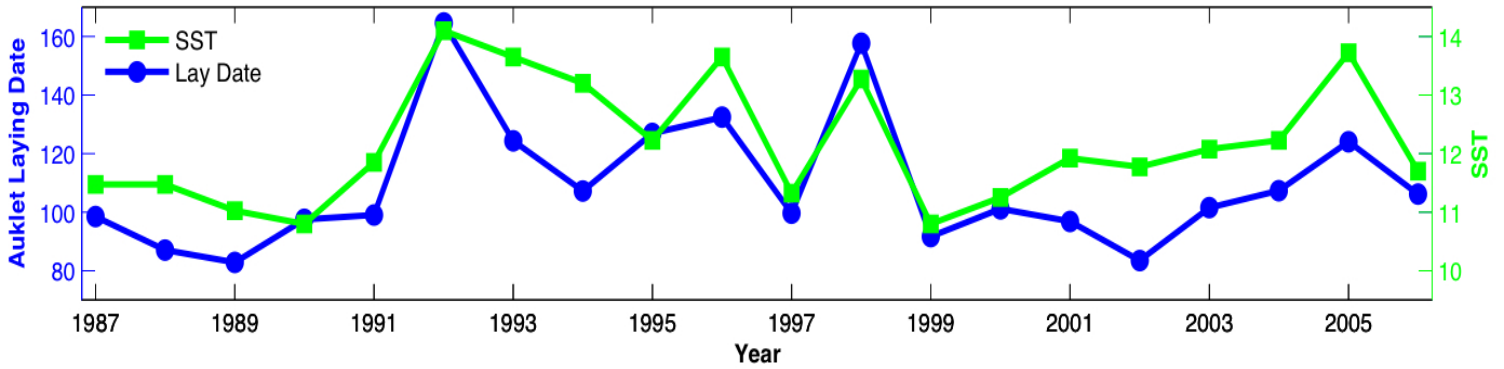
North Pacific CPR Marine Birds and Mammals

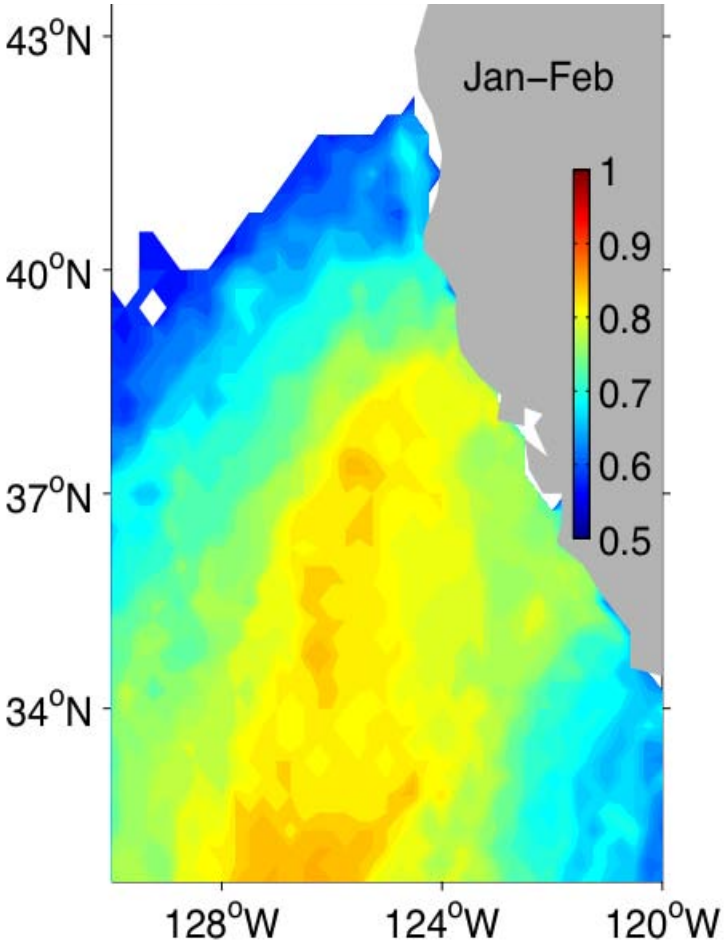


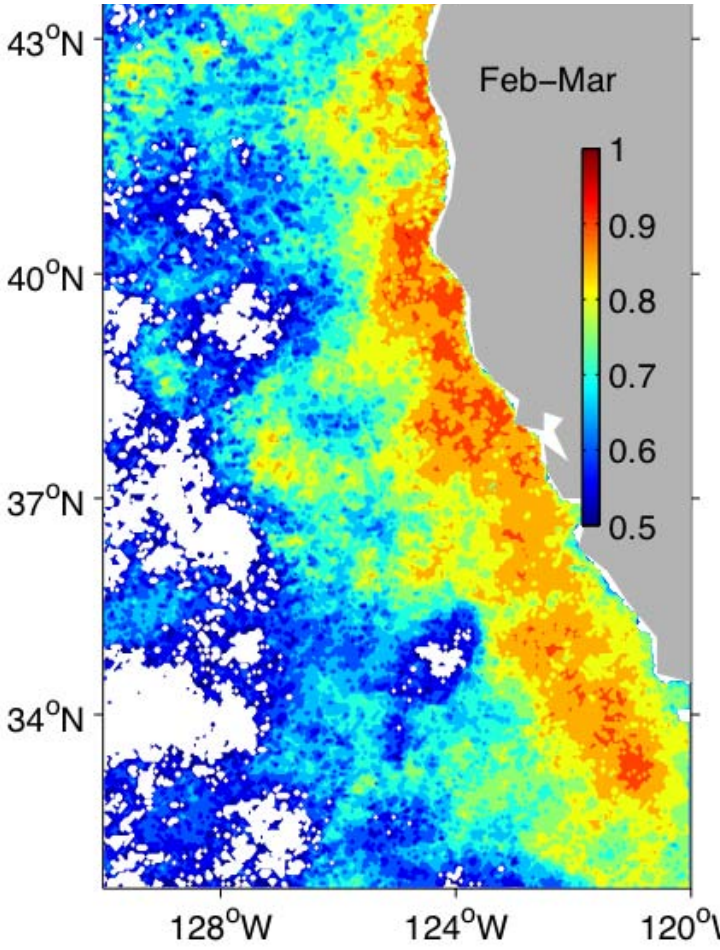


Batten et al. 2006 DSR II





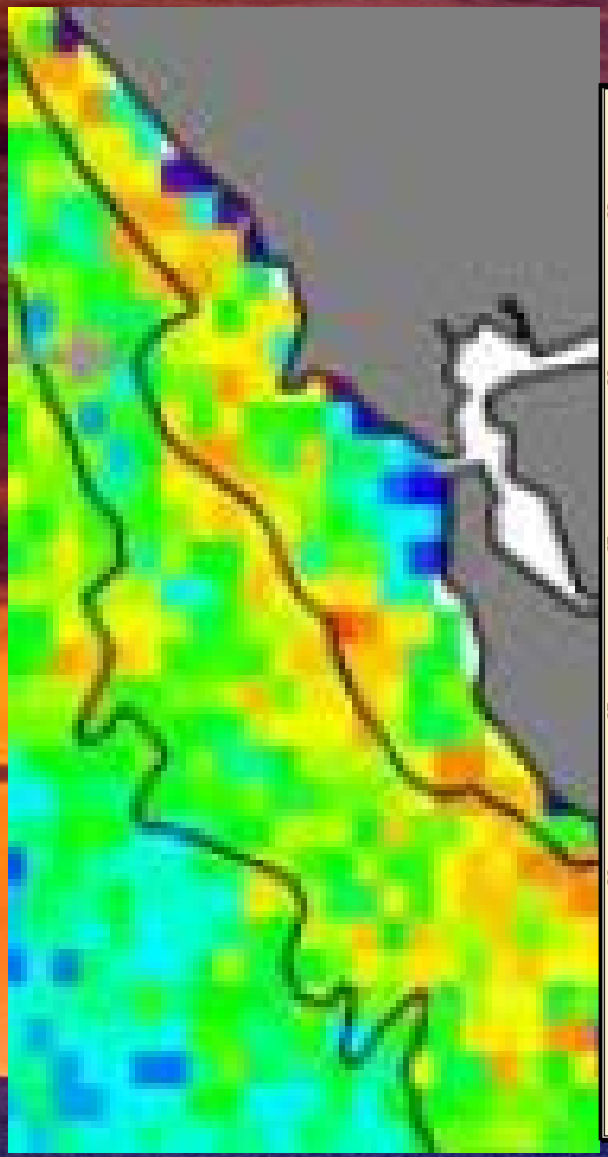


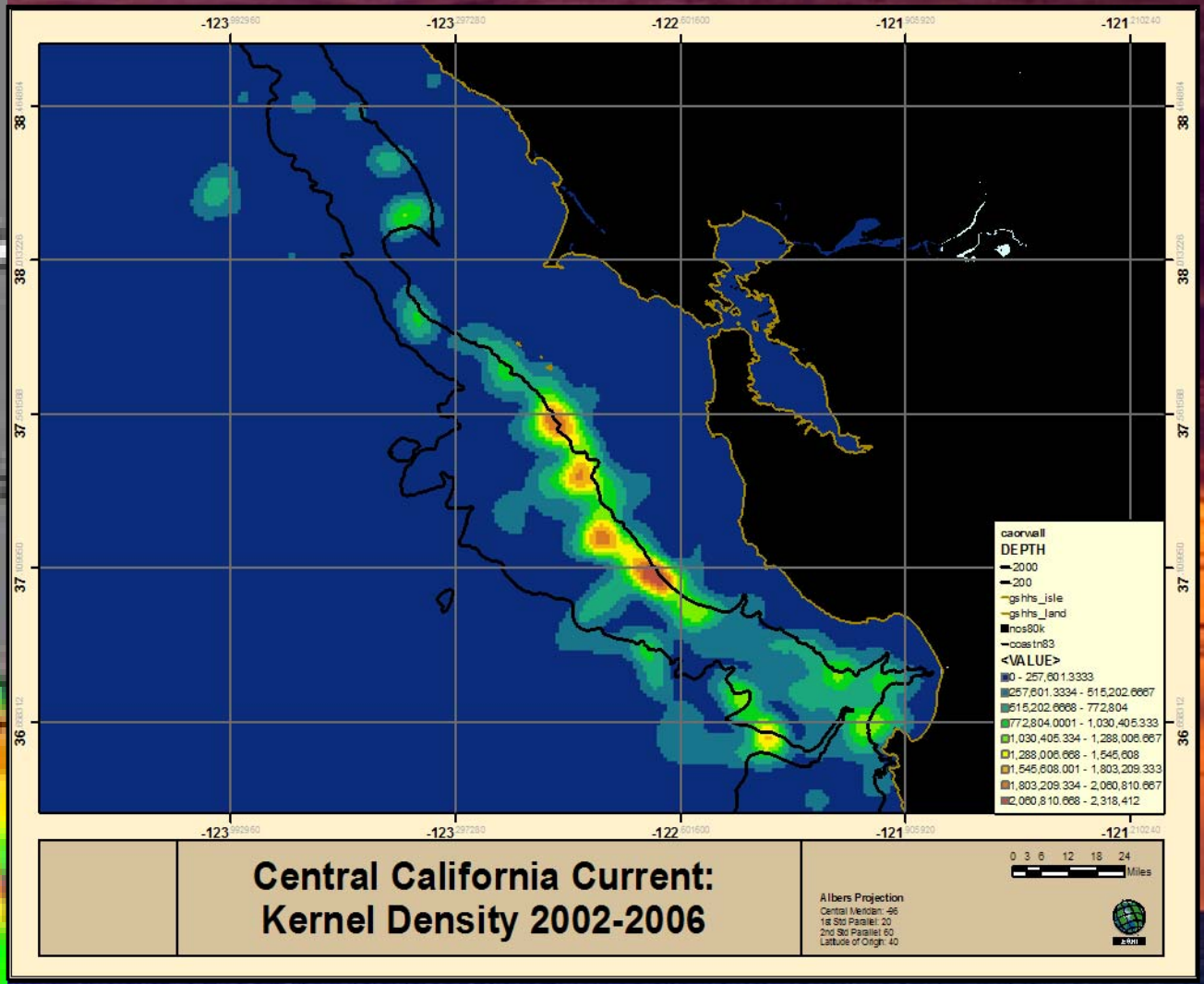


Gridded V winds (NOAA Blended), and AVHRR SST

Schroeder et al., unpubl.

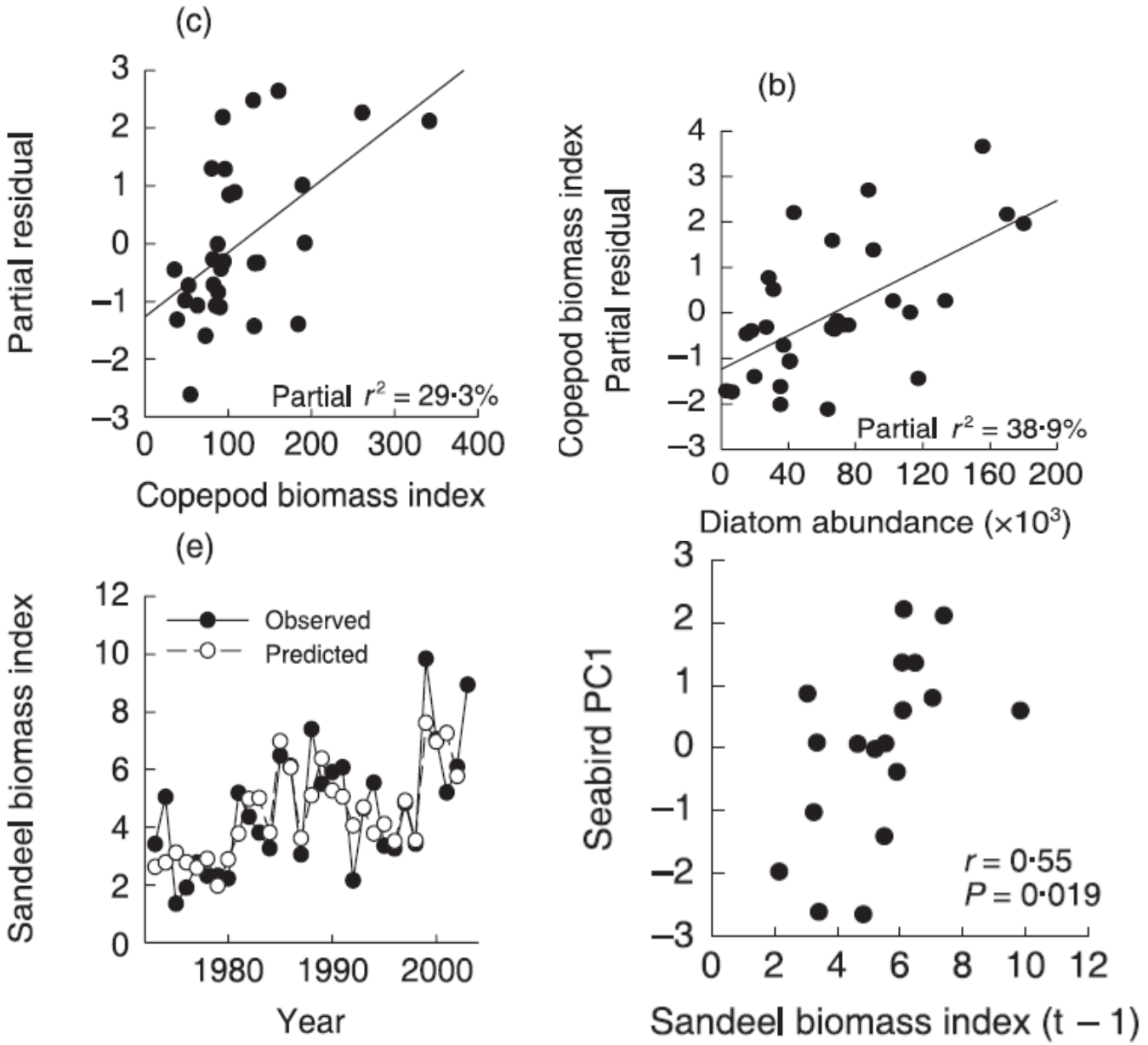
Meso-Scale Spatial Integrators?

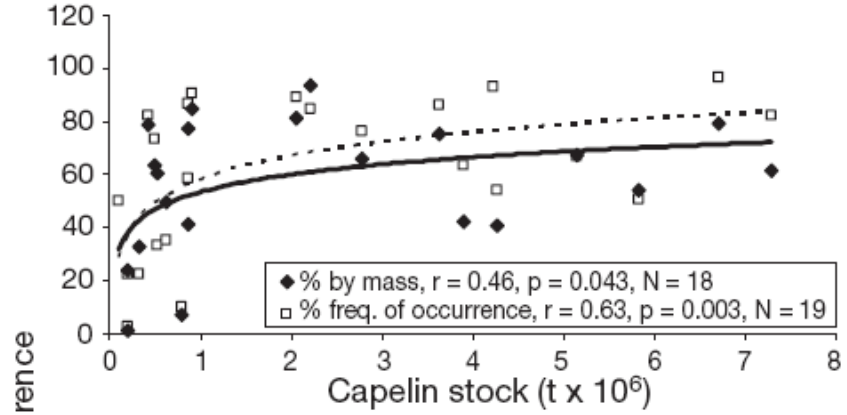


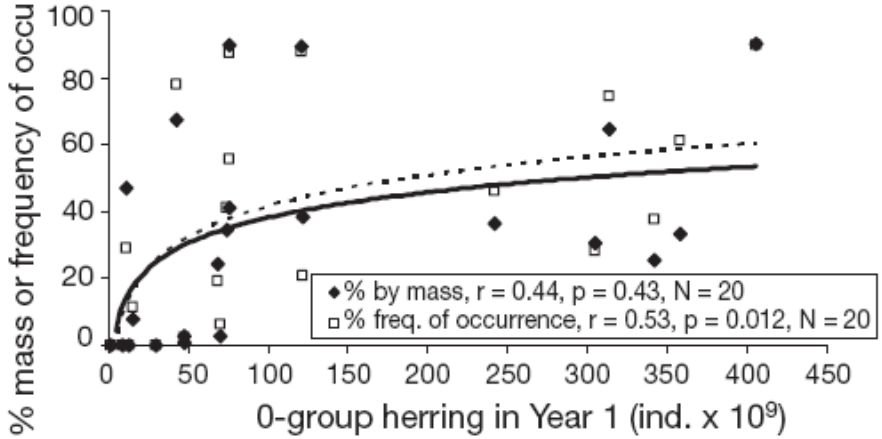


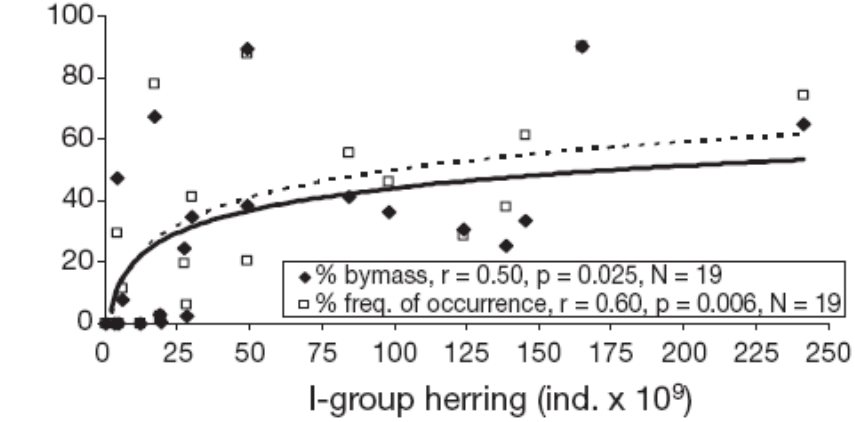
- Santora, Sydeman, Ralston talk @ 1450

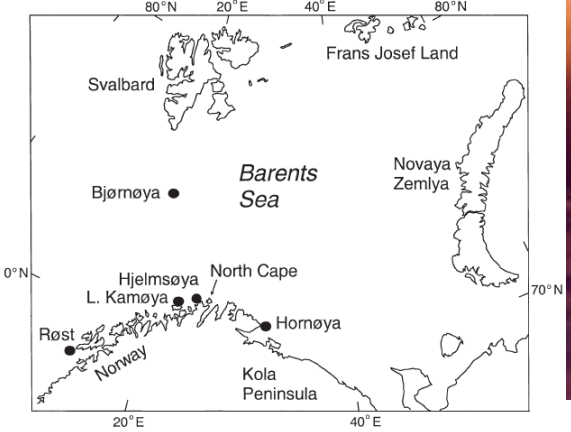
"Bottom-up" Temporal Integrators – North Sea (Fredericksen et al. 2006 JAE)

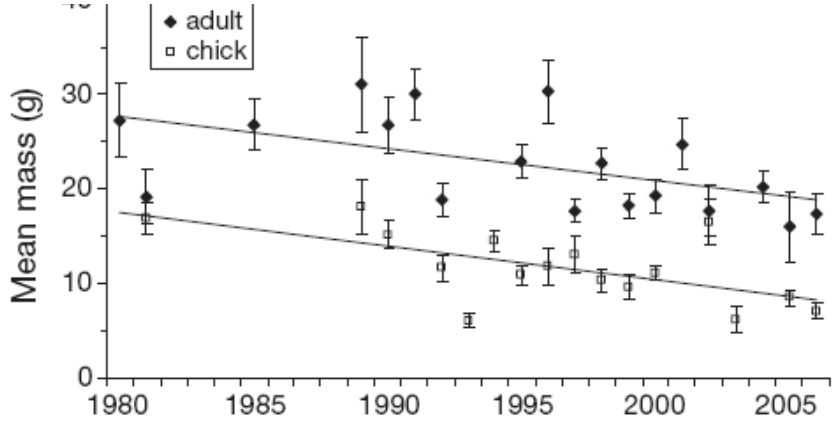


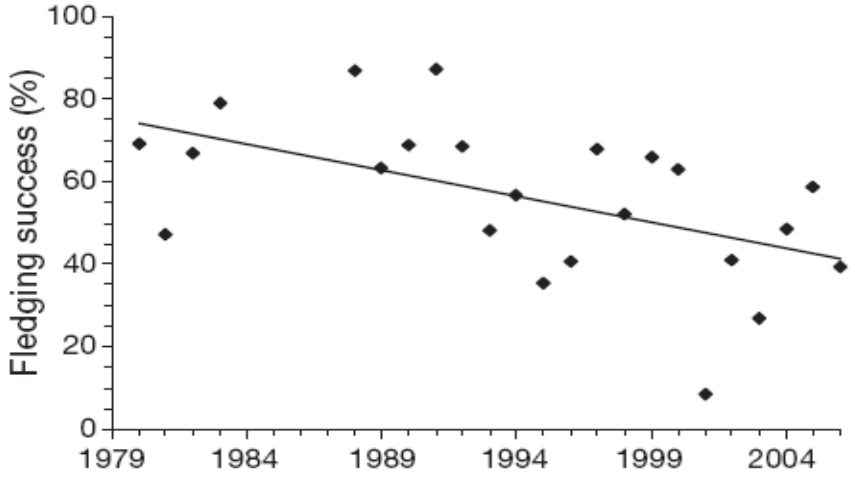






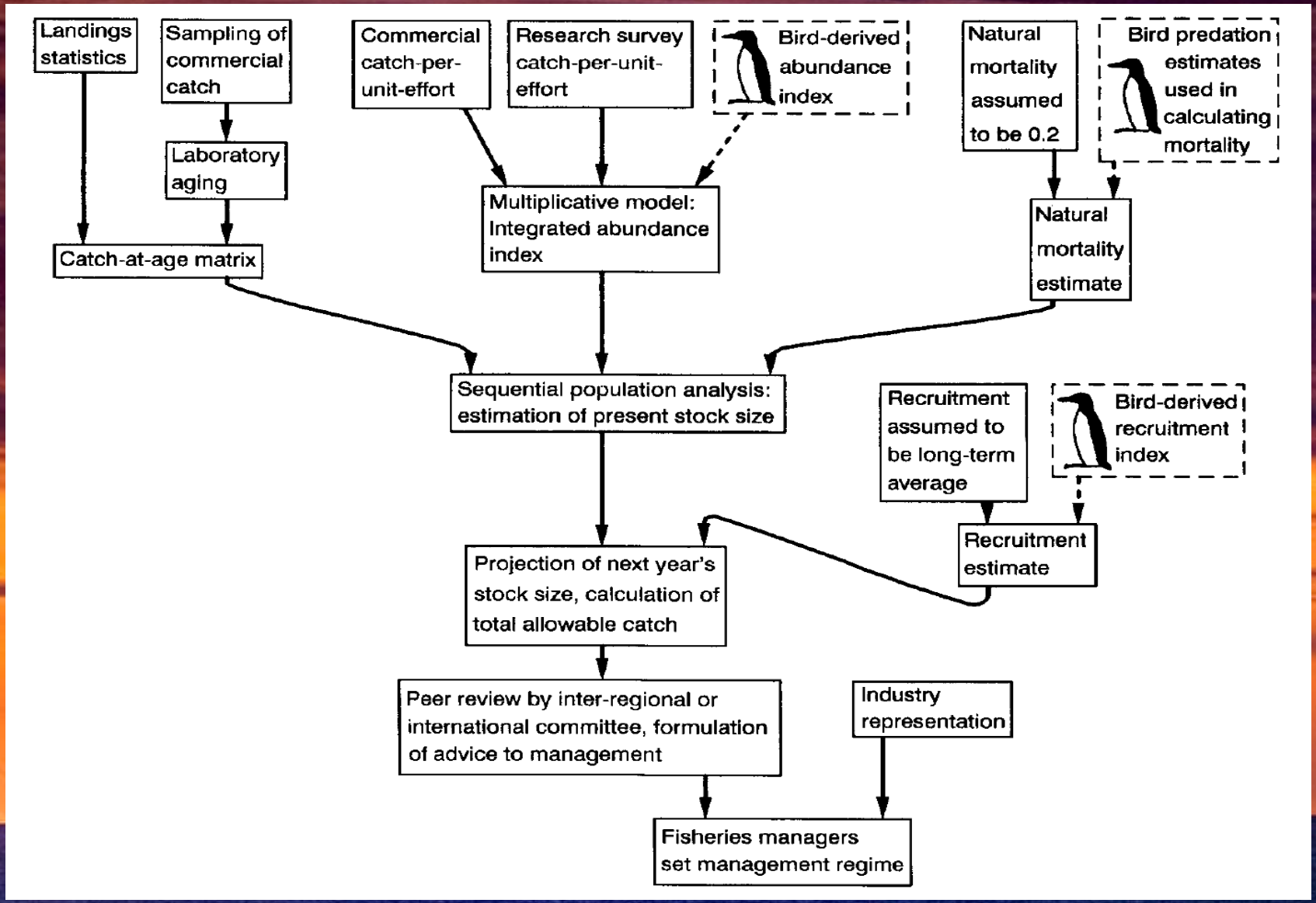






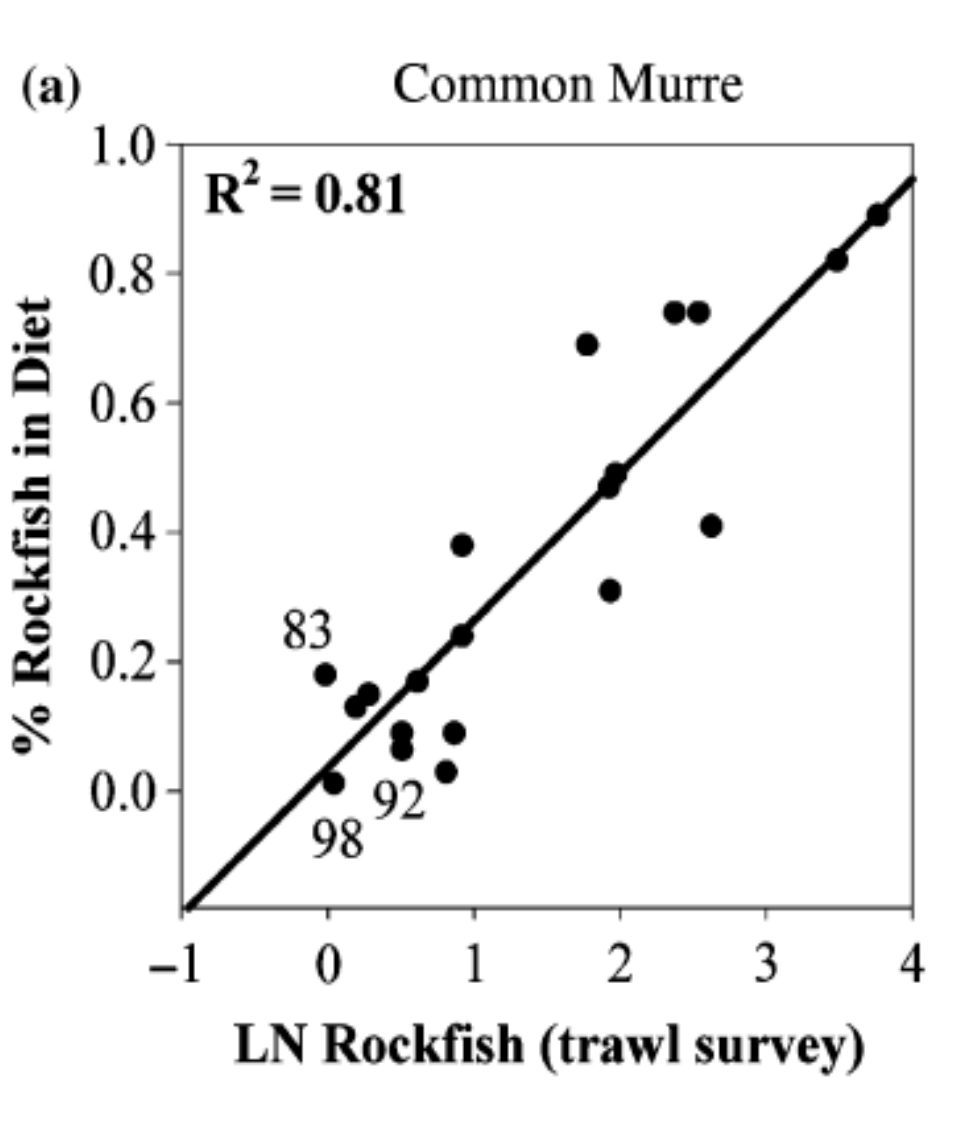
Barrett 2008 MEPS


Part C. Some Fisheries Applications (recruitment, catch, growth)


Landings statistics
Sampling of commercial catch
Laboratory aging
Catch-at-age matrix
Commercial catch-per-unit-effort
Research survey catch-per-unit-effort
Bird-derived abundance index
Multiplicative model: Integrated abundance index
Natural mortality assumed to be 0.2
Bird predation estimates used in calculating mortality
Natural mortality estimate
Sequential population analysis: estimation of present stock size
Recruitment assumed to be long-term average
Bird-derived recruitment index
Recruitment estimate
Projection of next year's stock size, calculation of total allowable catch
Peer review by inter-regional or international committee, formulation of advice to management
Industry representation
Fisheries managers set management regime

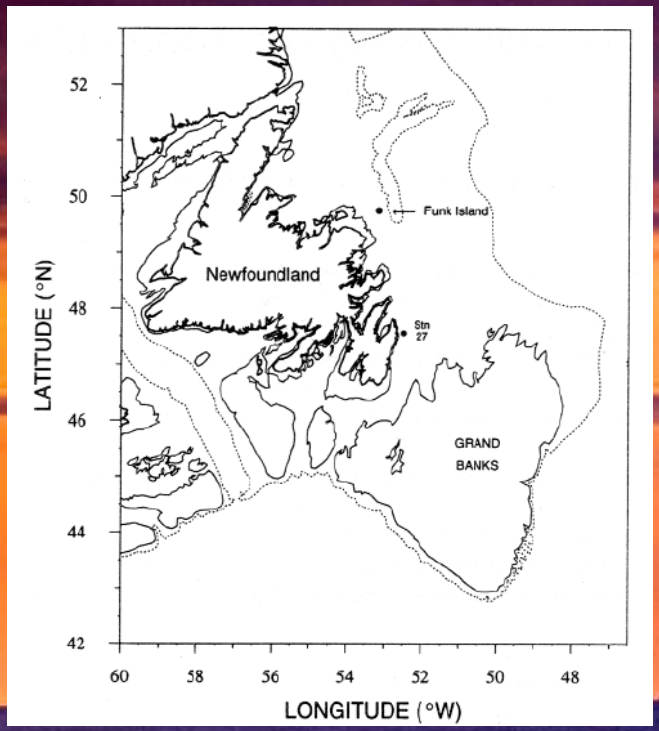
Cairns 1992

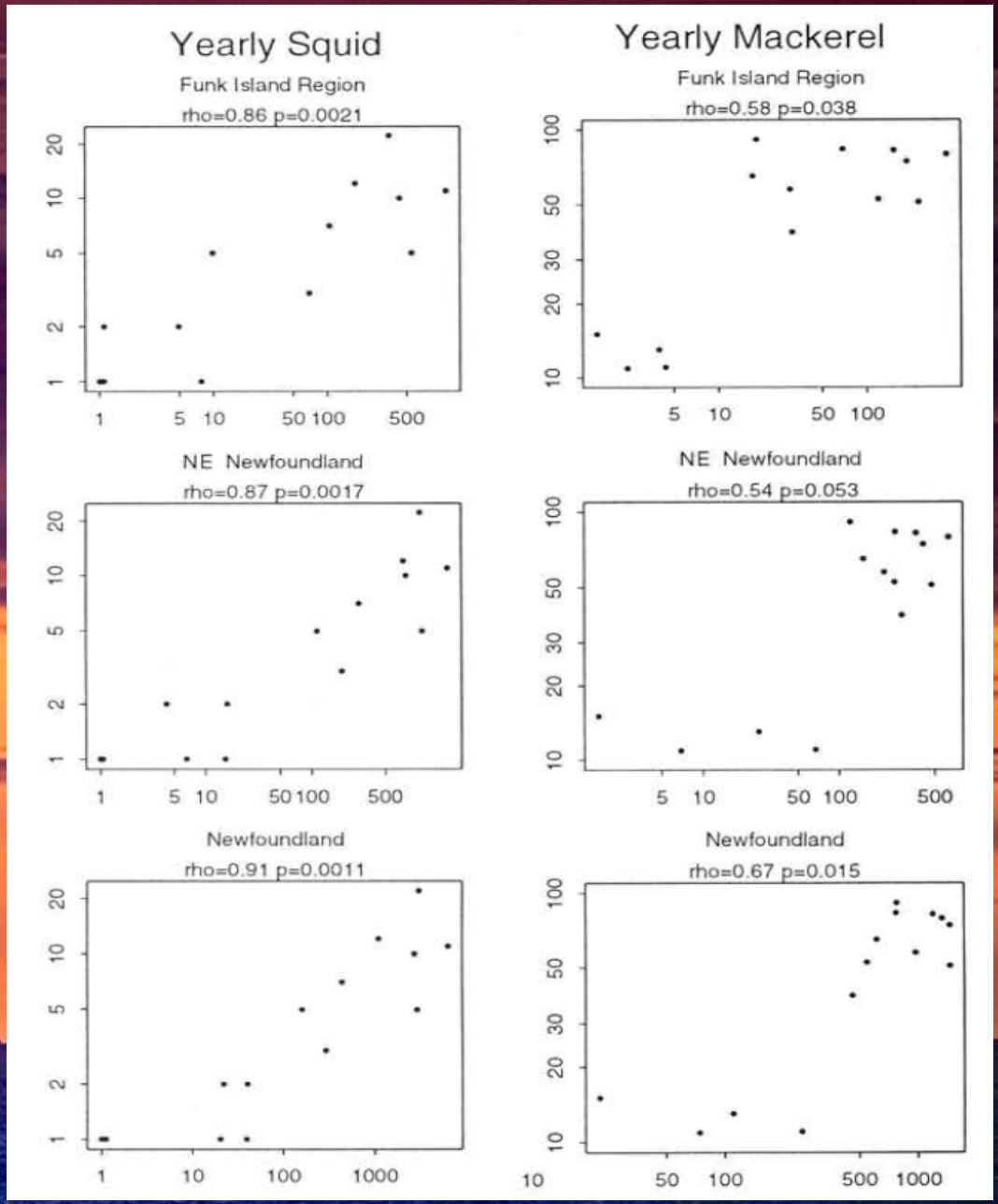
e.g., a bird-derived recruitment index



Mills et al. 2007 FOG

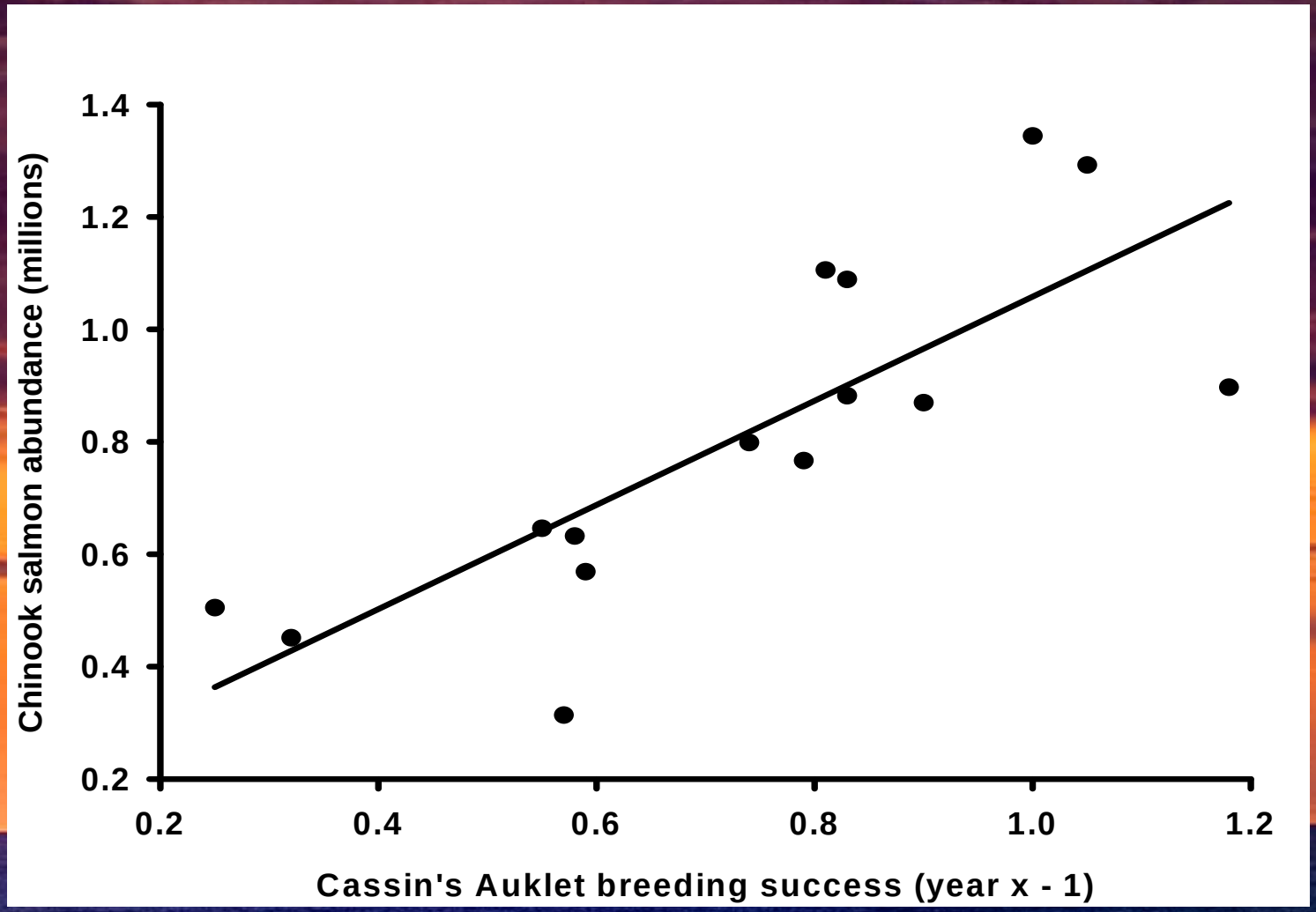
Seabird Diet Predicts Catch



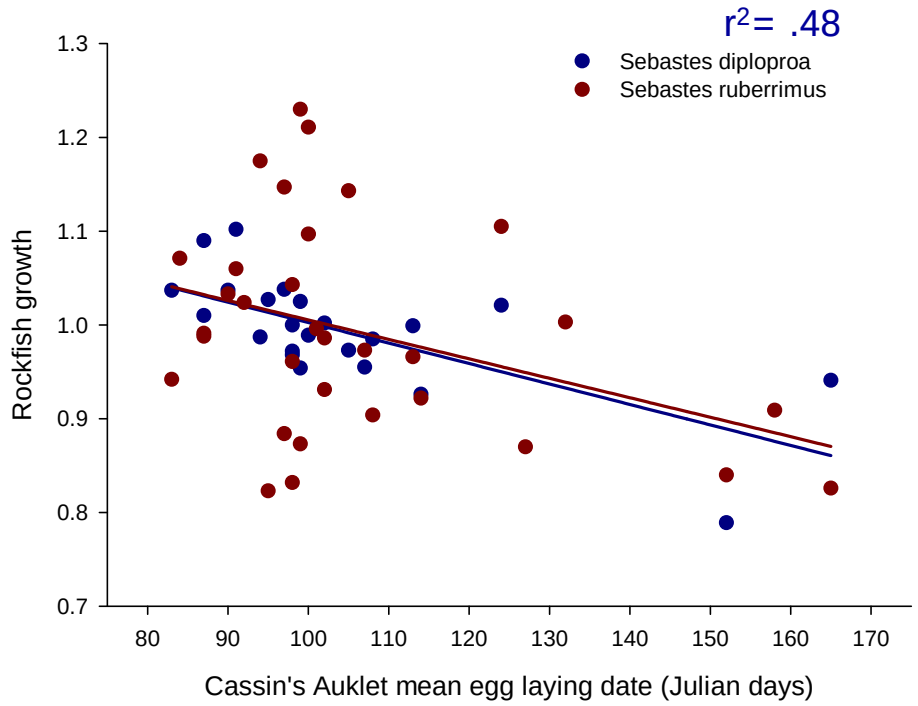


Montevecchi and Myers 2006 MEPS

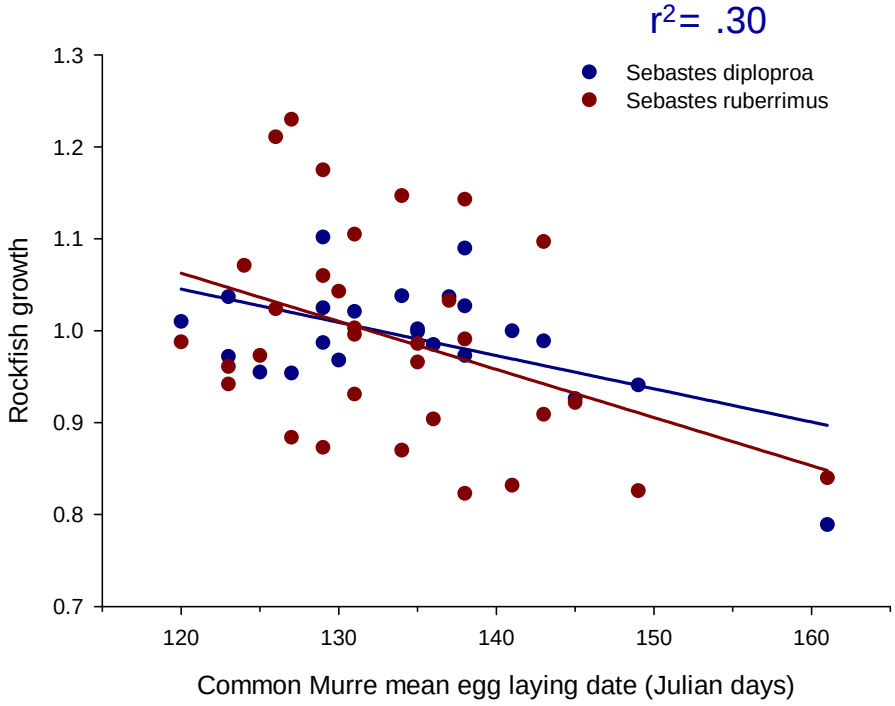
Seabirds and Salmon Catch/Escapement



Roth et al. 2007 CJFAS



Seabird Timing of Breeding Predicts Rockfish (Sebastes) Annual Growth



Summary and Conclusions

- Seabirds can help…
  - most conspicuous marine taxa
  - easily observed on ocean, at "hotspots", on colonies
  - large numbers (aggregations) offer statistical advantages
  - amenable to multiple approaches
  - do apparently integrate bio-physical and food web dynamics in space and time (across-ecosystem examples)

- Caveats…
  - sensitivity varies by species and parameter - calibration
  - population abundance data useful on interdecadal scale
  - aggregations cause statistical complexities
  - mostly qualitative information so far
  - different changes in food webs may result in similar signals from seabird indicators
  - to date, weak application in applied marine science
  - functional responses generally unknown
  - spatial variability often ignored
  - non-linear relationships limit interpretation and application (prediction)
  - limited data in fall, winter…when system dynamics set
  - limited role in ecosystem models (to date)

Thanks

- Critical thinking: John Piatt, George Hunt, Ian Jones, Bob Furness, Scott Hatch, David Hyrenbach – other seabird ecologists

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