CHALLENGES AND OPPORTUNITIES FOR ASSESSMENT AND ATTRIBUTION OF CLIMATE CHANGE IMPACTS ON NORTH PACIFIC SEABIRDS

William J. Sydeman, Sarah Ann Thompson, Julie A. Thayer, Mike Litzow, Marisol Garcia-Reyes, Jarrod A. Santora, Heather Renner, John F. Piatt, and Yutaka Watanuki

www.faralloninstitute.org; **FUTURE OSM, 13 April 2014**

Where are we and where do we need to go?

Talk Overview…

1. Background, Literature
2. Mechanism(s) and Forecasting
3. Large-Scale Data Availability
4. Modeling Approaches

Seabirds of the North Pacific


Photo by Yuri Artukhin


Photo by Glenn Bartley


Photo by Claude Nadeau

- **135+ species, 200,000,000 individuals (Hunt et al. 2000)**
- **"k"-selected: longevity = 10-80 yrs; but 1-3 offspring/yr**
- **foraging habitats: surface to ~200 m (murres)**
- **omnivorous (e.g., *Neocalanus* spp., euphausiids, cephalopods, *Ammodytes spp.*, age-0 gadids, salmonids, etc.)**


Neocalanus cristatus
Hopcroft/UAF/CoML


Hopcroft/UAF/CoML/NOAA

Prey consumed by seabirds in 6 regions of the North Pacific (Hunt et al. 2000)

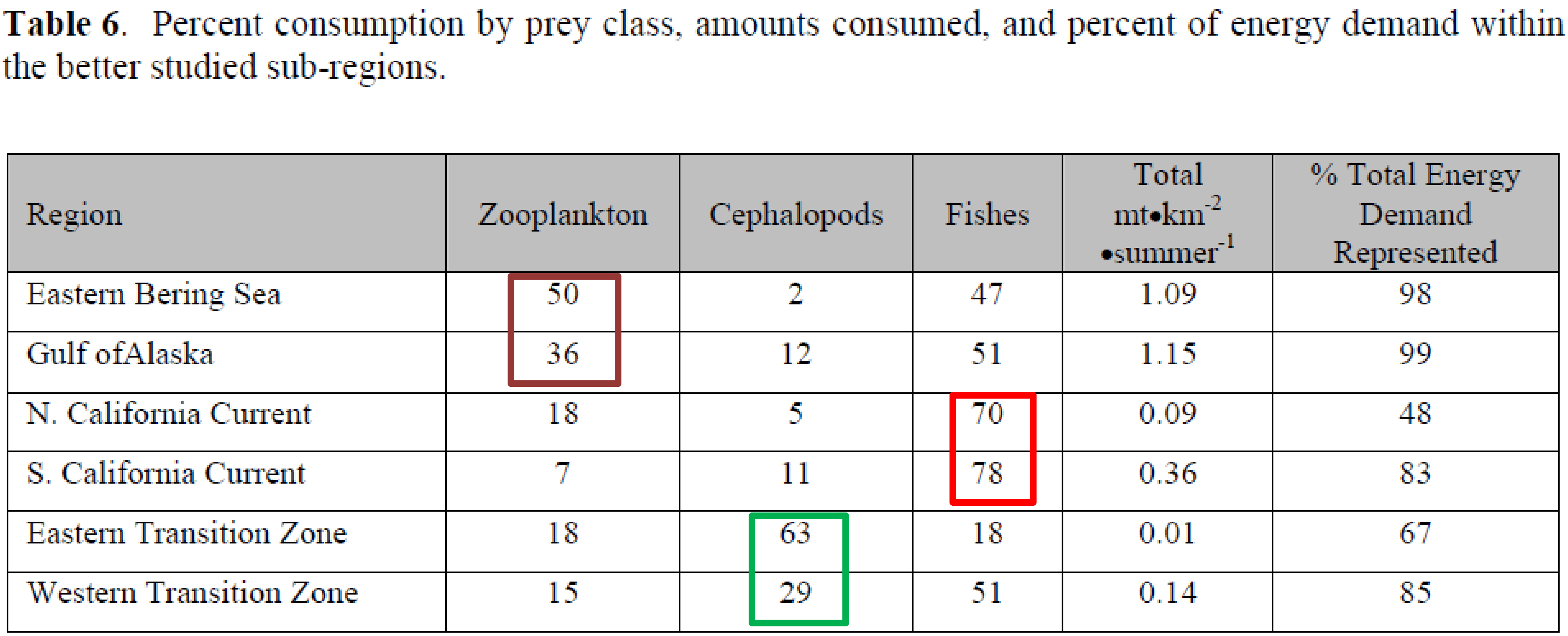


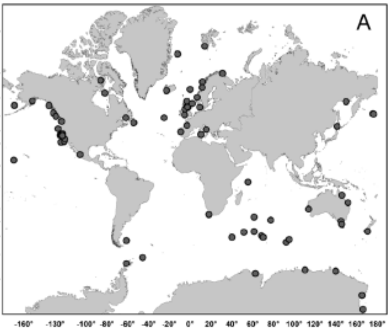
Table 6. Percent consumption by prey class, amounts consumed, and percent of energy demand within the better studied sub-regions.

Region	Zooplankton	Cephalopods	Fishes	Total $\mathrm{mt \bullet km^{-2} \bullet summer^{-1}}$	% Total Energy Demand Represented
Eastern Bering Sea	50	2	47	1.09	98
Gulf ofAlaska	36	12	51	1.15	99
N. California Current	18	5	70	0.09	48
S. California Current	7	11	78	0.36	83
Eastern Transition Zone	18	63	18	0.01	67
Western Transition Zone	15	29	51	0.14	85

Background: Meta-Analysis of Seabird-Climate Literature

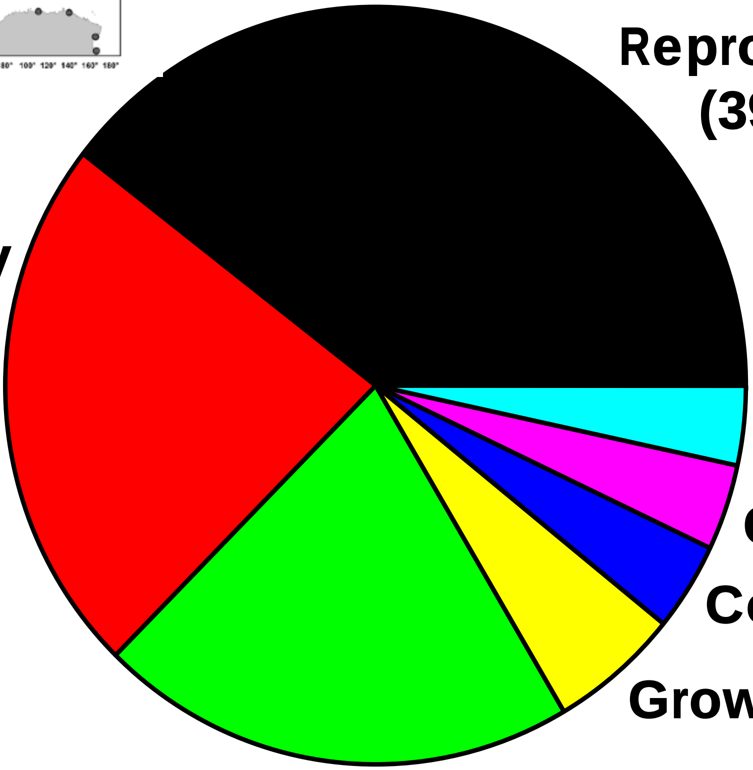
Global Seabird-Climate Meta-Database

Global studies: n=108 peer-reviewed papers, ~3200 “obs.” (thru 2011)

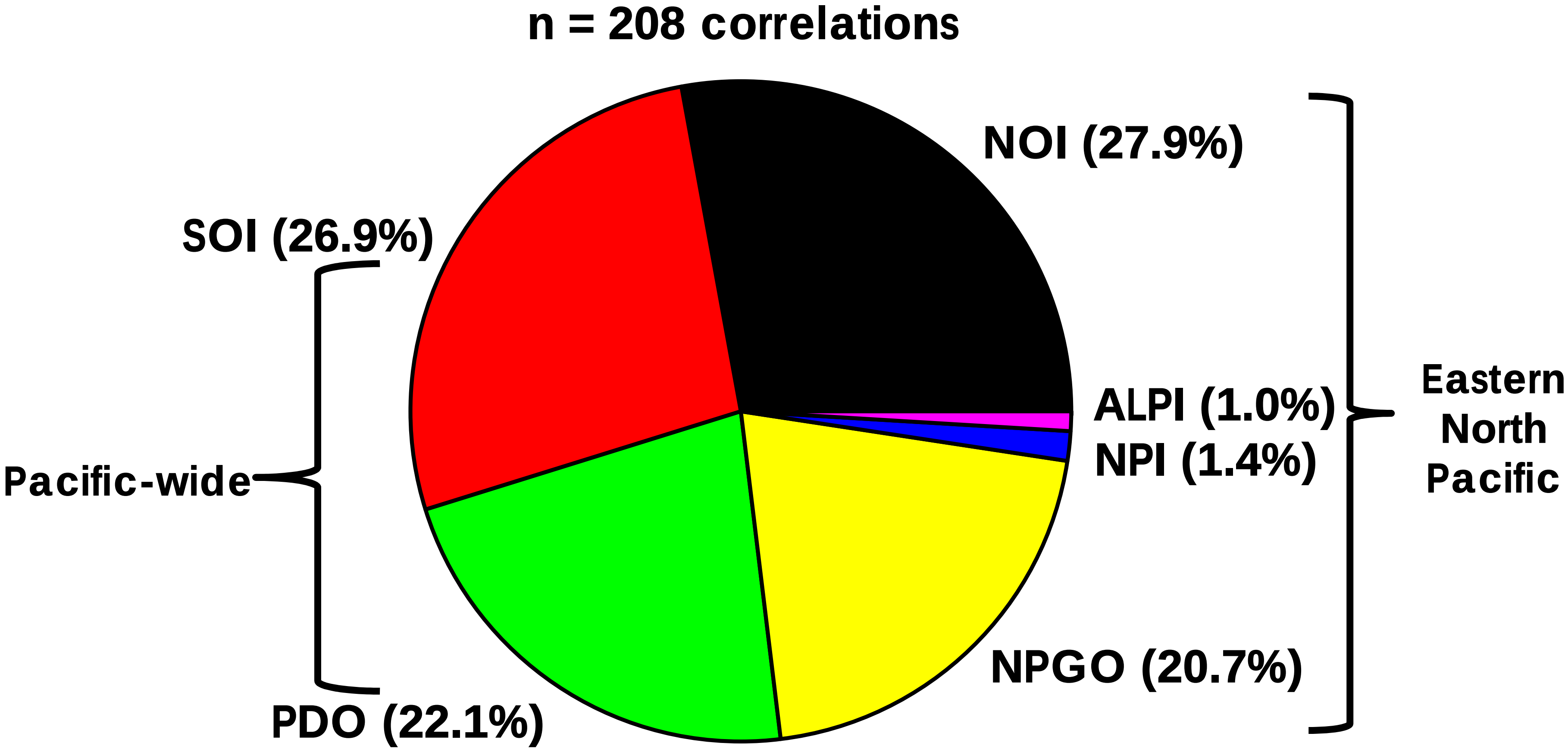


North Pacific: n = 38 papers
Observations: n = 1091 (correlations)
Species: n = 51 (+ 5 “assemblages”)

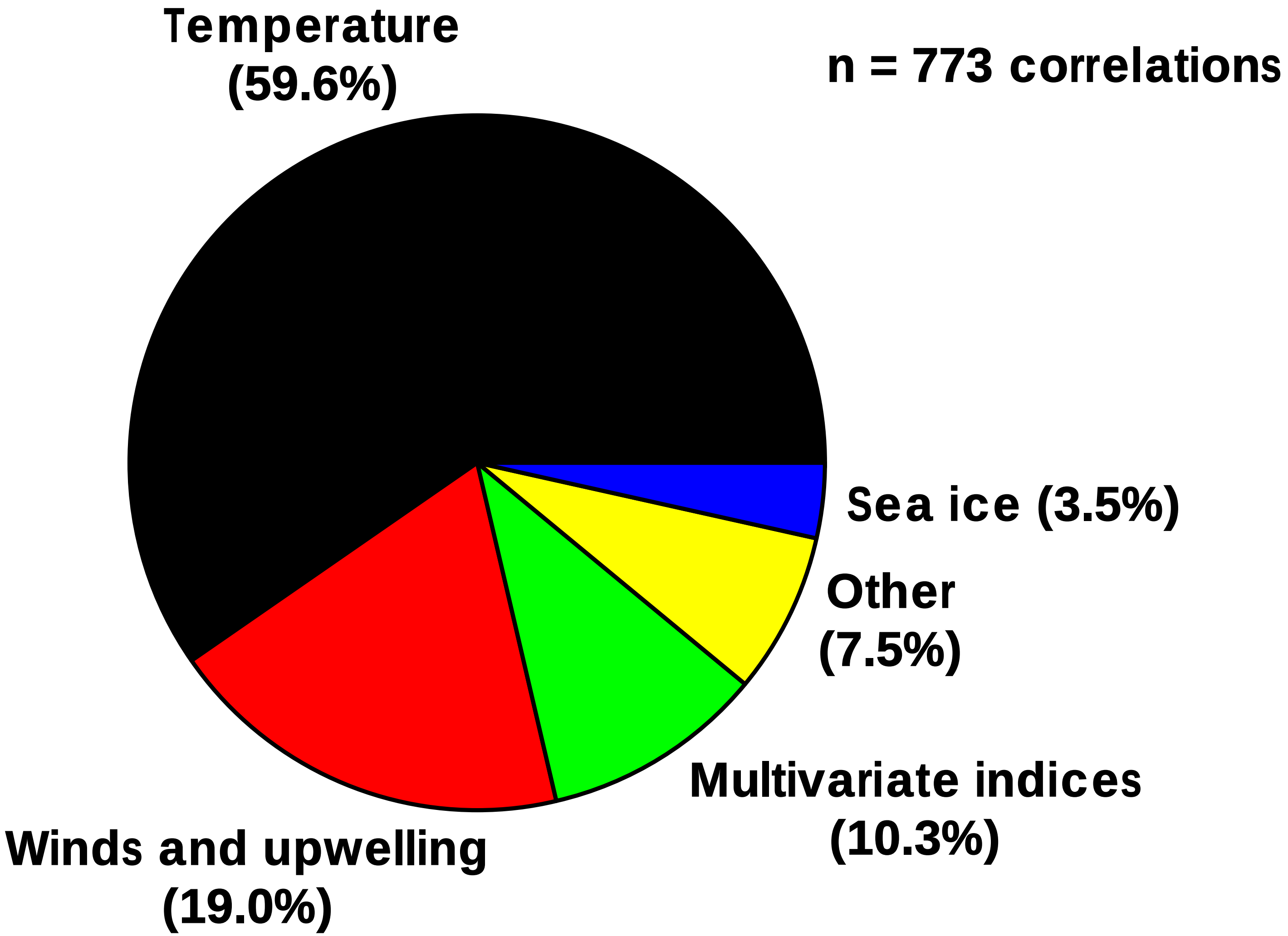
Parameters Examined



Large-scale ocean-climate Indices examined

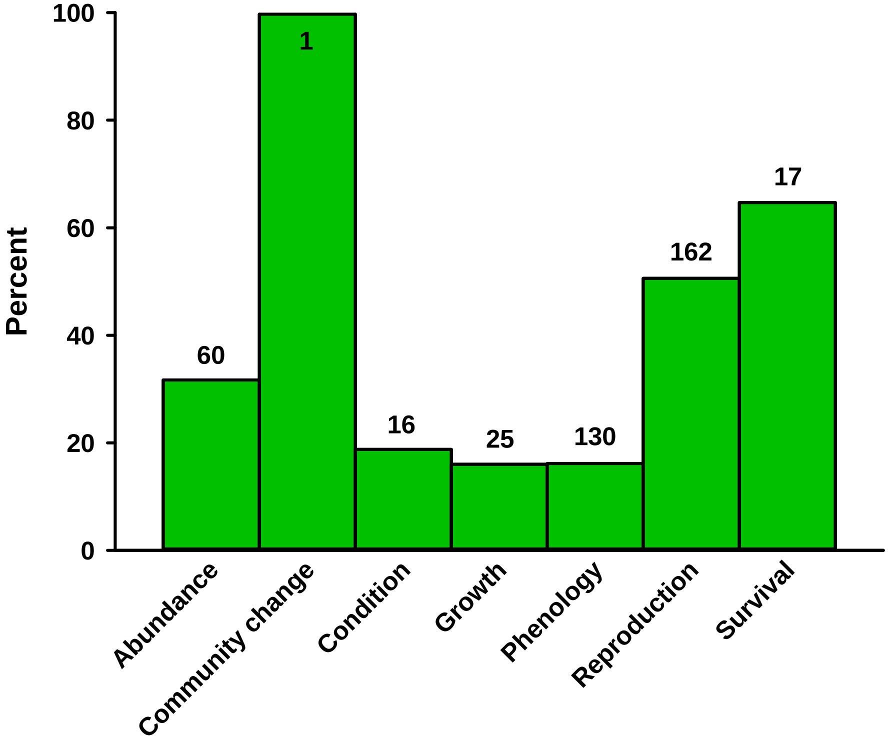


Regional/local environmental Parameters examined

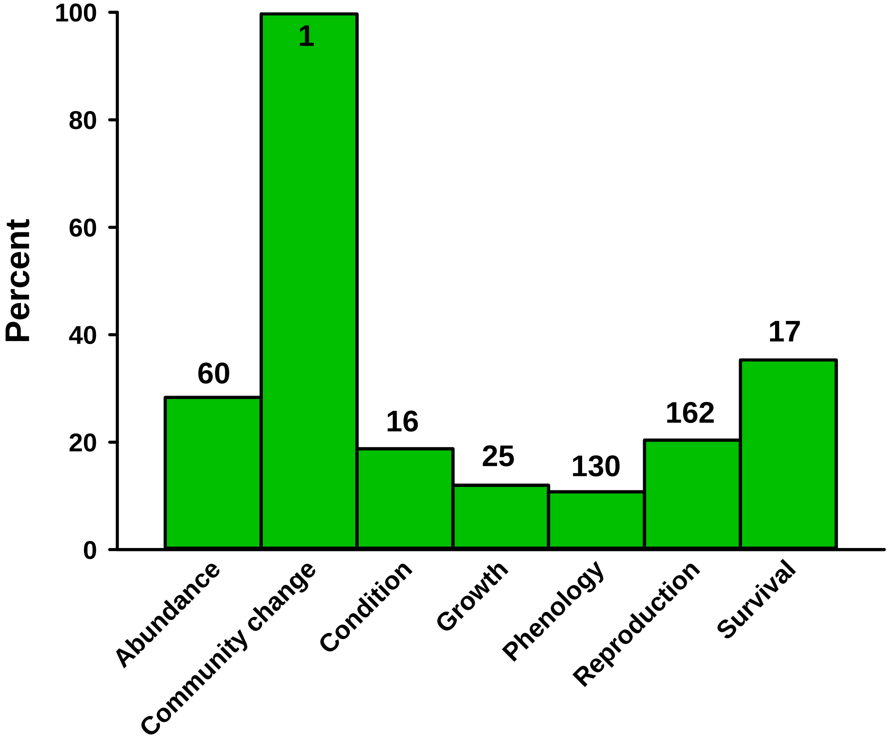


Re. Ocean warming: Have North Pacific seabirds *generally* responded negatively to temperature? (n = 411)

Percent of repsonses with a negative relationship with temperature



Percent of responses with a significant negative relationship with temperature



- ➢ Seabirds will not always respond negatively to ocean warming
- ➢ But, “point-studies”; need ecosystem-scale analyses and synthesis

FUTURE will make advances by:

- Investigating the mechanisms underlying ecosystem responses to natural and anthropogenic forcings;

- Improving forecasting capabilities and providing estimates of the uncertainty associated with these forecasts; and

- Developing more effective ways to convey knowledge and predictions to society.

Mechanism and Forecasting

H_o: Climate change will disrupt food web structure, predator-prey functional and numerical responses, and thereby affect North Pacific seabird populations

- ➢ **Models of climatic and anthropogenic impacts on marine ecosystems should focus on understanding spatial and temporal variation TL 2-3 organisms (zooplankton, squids, and forage fishes)**

Pelagic food web (mid to upper levels) "forage nekton interaction nodes"

- "Meso-Predators", such as Seabirds are closest to mid trophic level micronekton communities

North Pacific seabirds: Data available for large-scale climate change impacts studies (*risk assessment*)

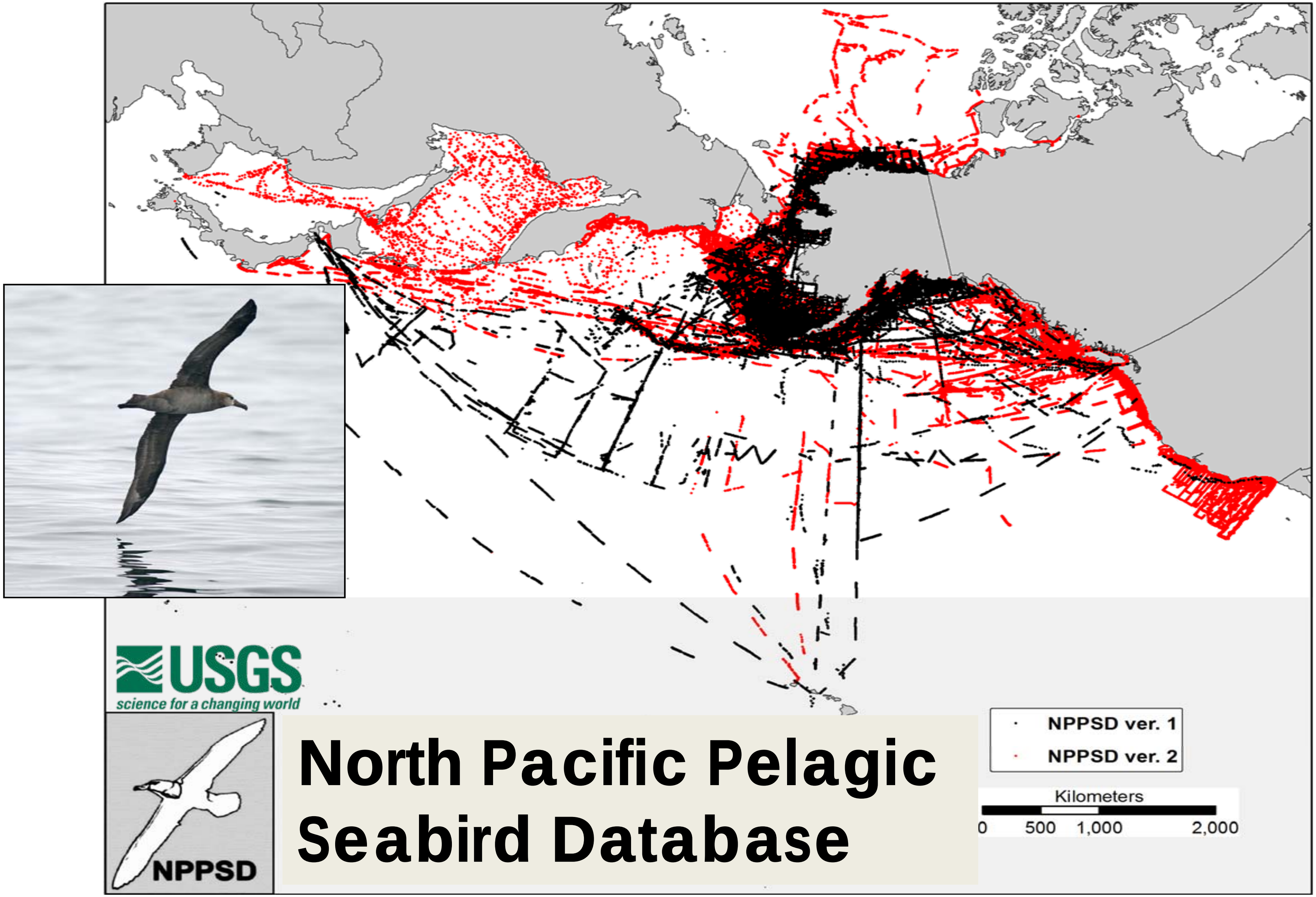
Changes in:

i. distribution/range/foraging ecology
ii. phenology (timing) and other life history traits

iii. vital rates (fecundity/survival)
iv. populations

- ➢ **Trend analyses do not provide mechanistic understanding needed for forecasting and risk-resilience analyses**

Extensive data on seabird distributions at sea

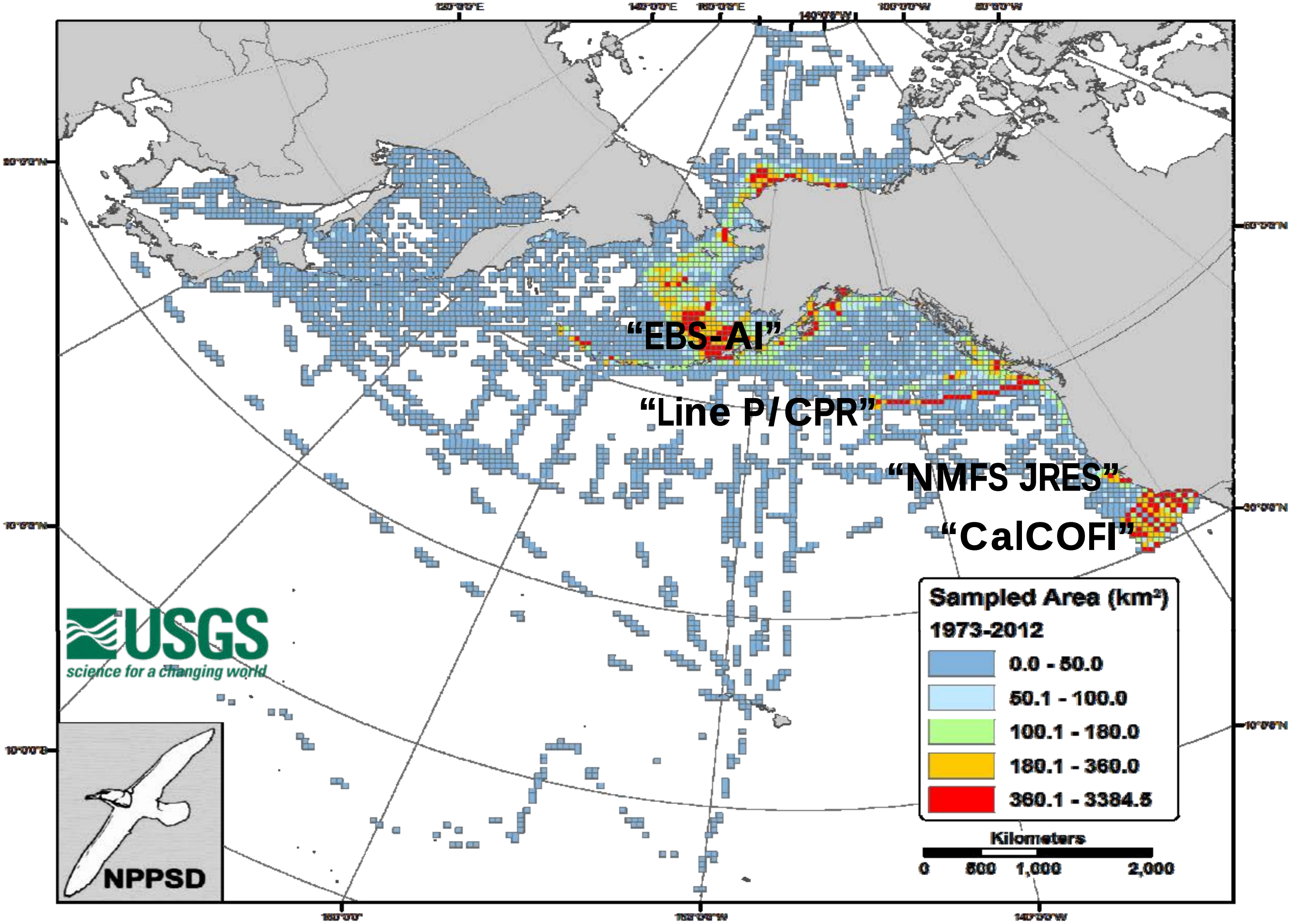


North Pacific Pelagic Seabird Database

http://alaska.usgs.gov/science/biology/nppsd/index.php

Sampling effort, NPPSD, 1973-2012

(250 km^2 grid cells)

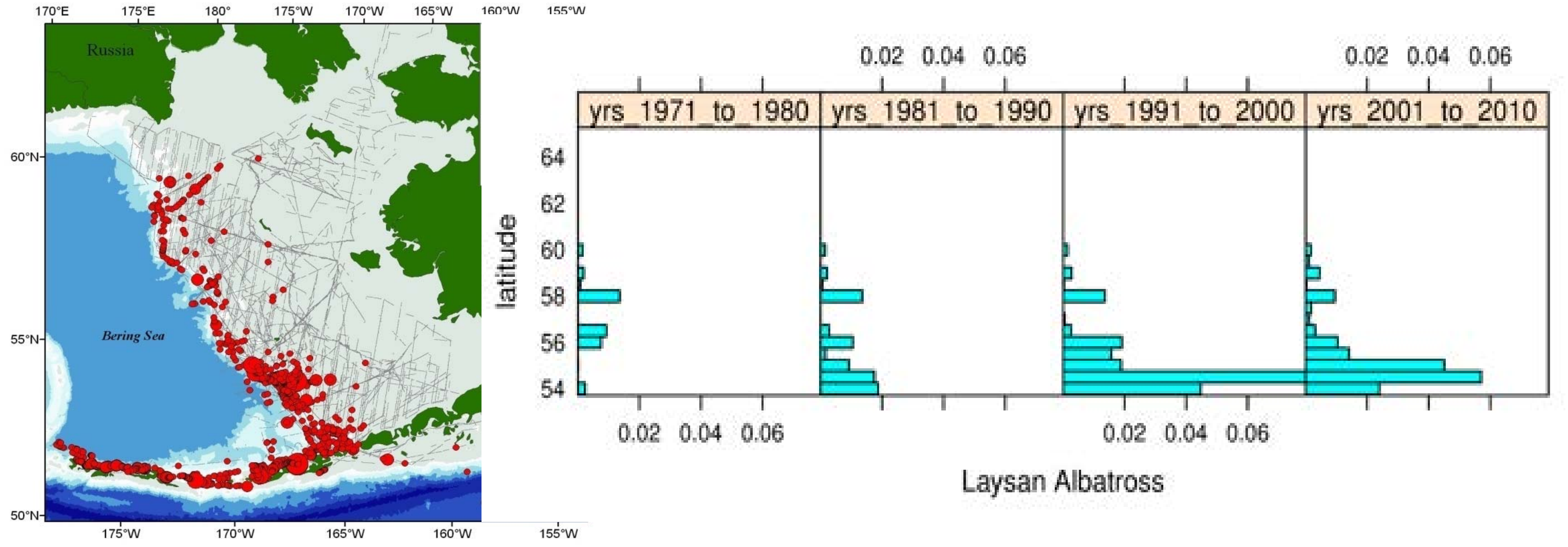


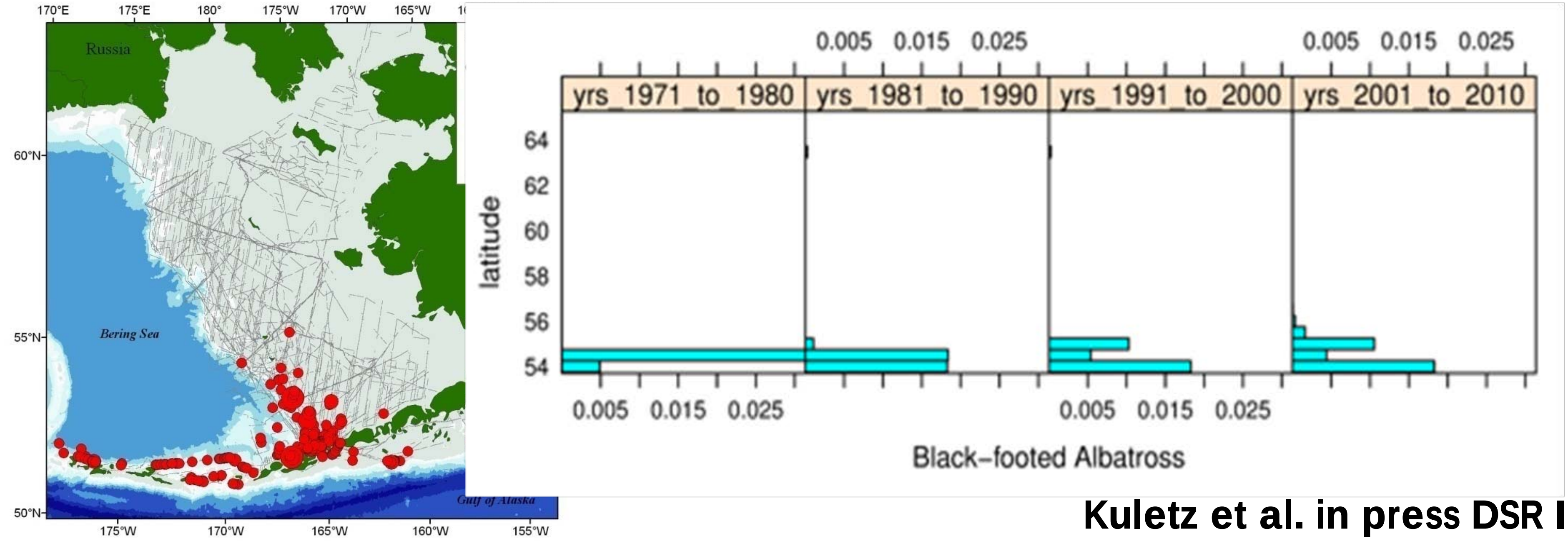
“EBS-AI”

“Line P/CPR”

“NMFS JRES”

“CalCOFI”

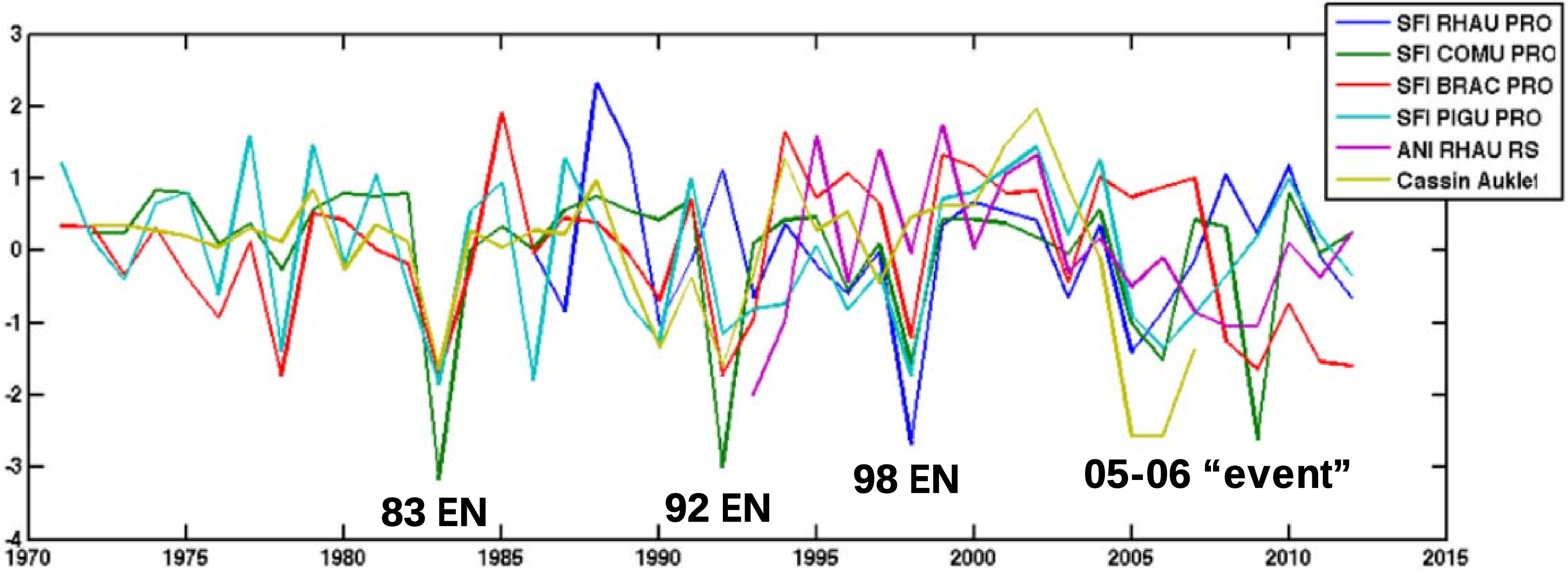




Kuletz et al. in press DSR II

Extensive Seabird Demographic Data

Standardized breeding success: California Current



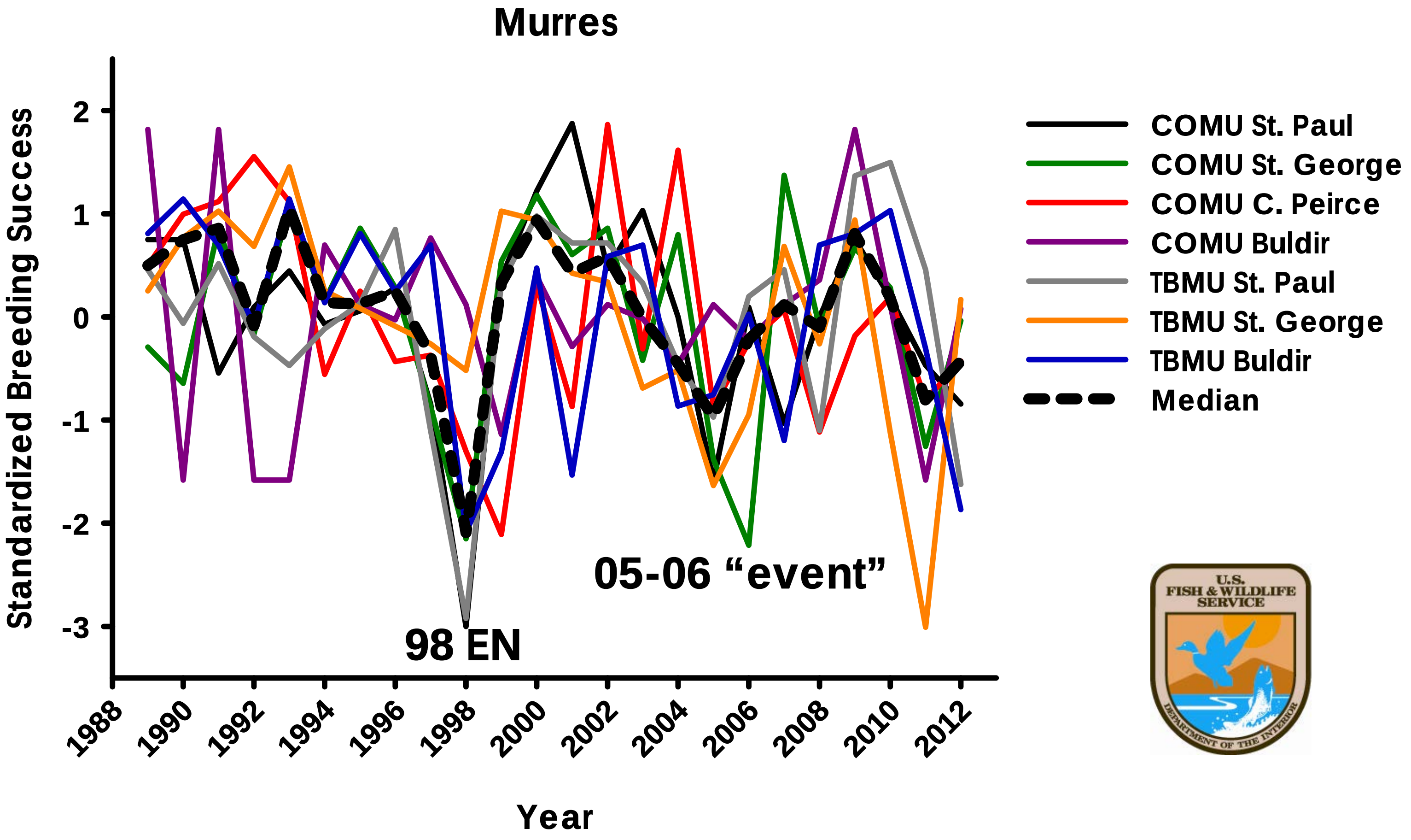
83 EN

92 EN

98 EN

05-06 “event”

Standardized breeding success: Eastern Bering Sea



98 EN

05-06 “event”

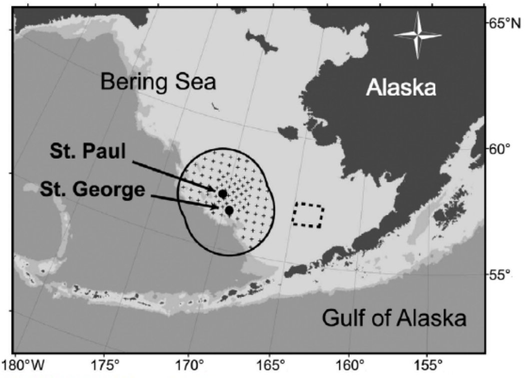
Vol. 485: 245–258, 2013
doi: 10.3354/meps10336

MARINE ECOLOGY PROGRESS SERIES
Mar Ecol Prog Ser

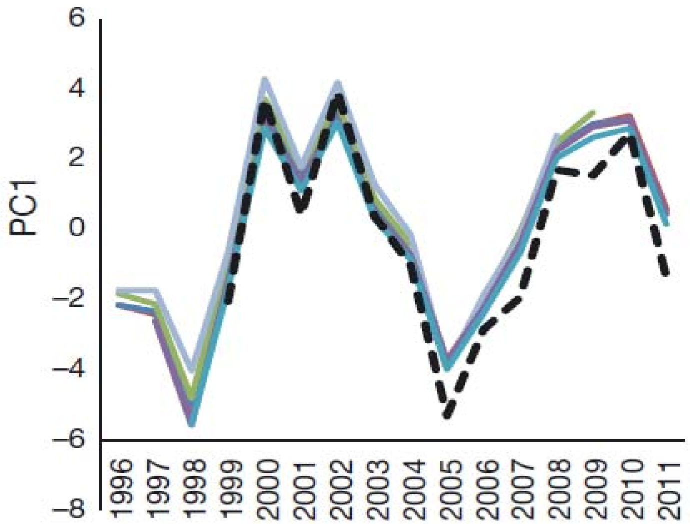
Published June 27

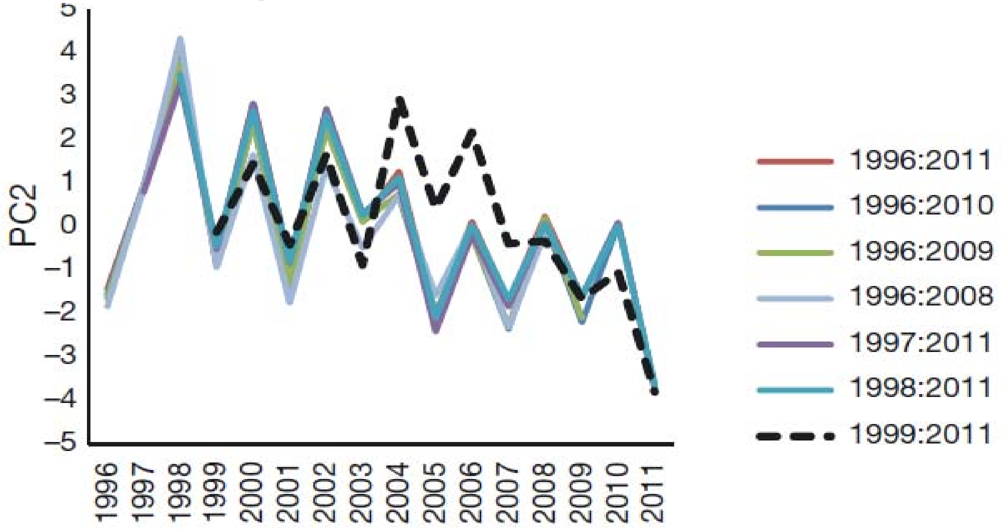
Combined seabird indices show lagged relationships between environmental conditions and breeding activity

Stephani Zador[1],*, George L. Hunt Jr.[2], Todd TenBrink[1], Kerim Aydin[1]



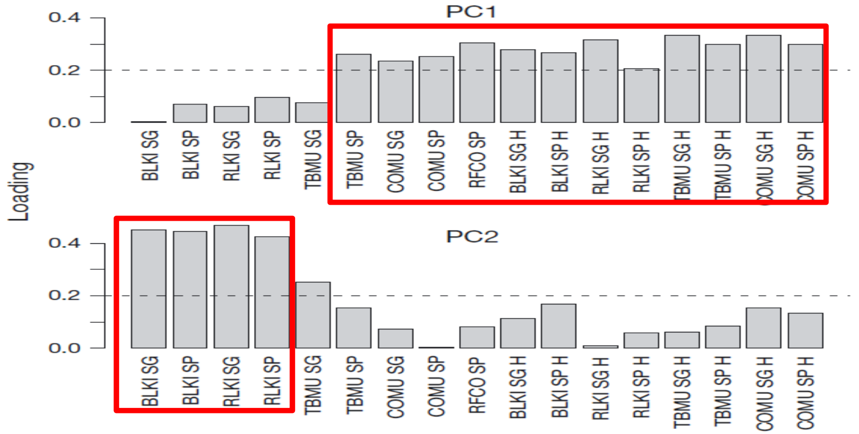
the i

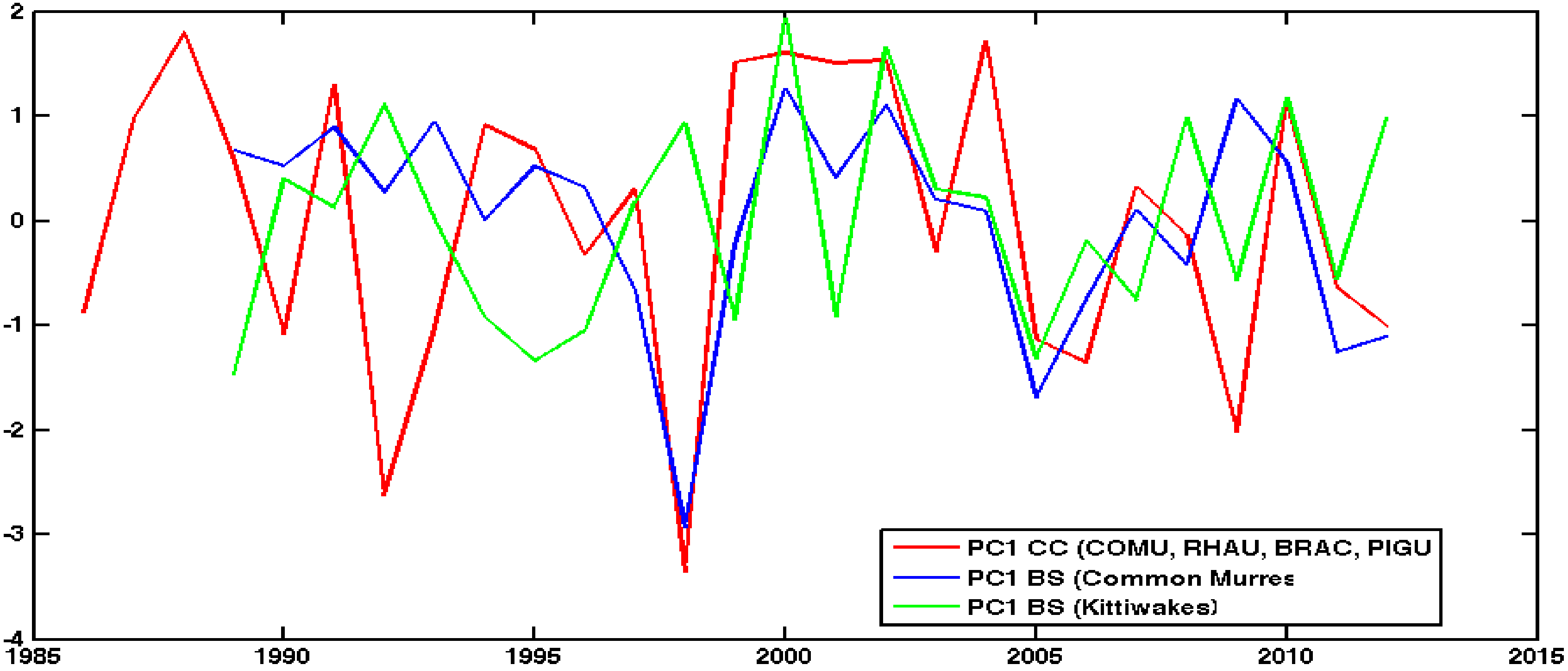




- ➢**PC1: “Productivity” (earlier hatching, higher breeding success); <u>1998, 2005 anomalies</u>**

PC2: “Kittiwake breeding success”; *sawtooth* <u>pattern and decline</u>

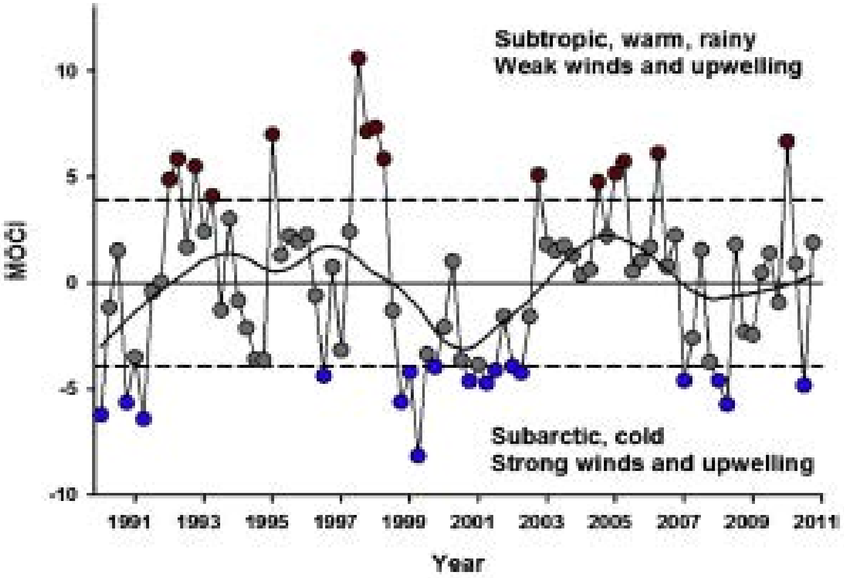


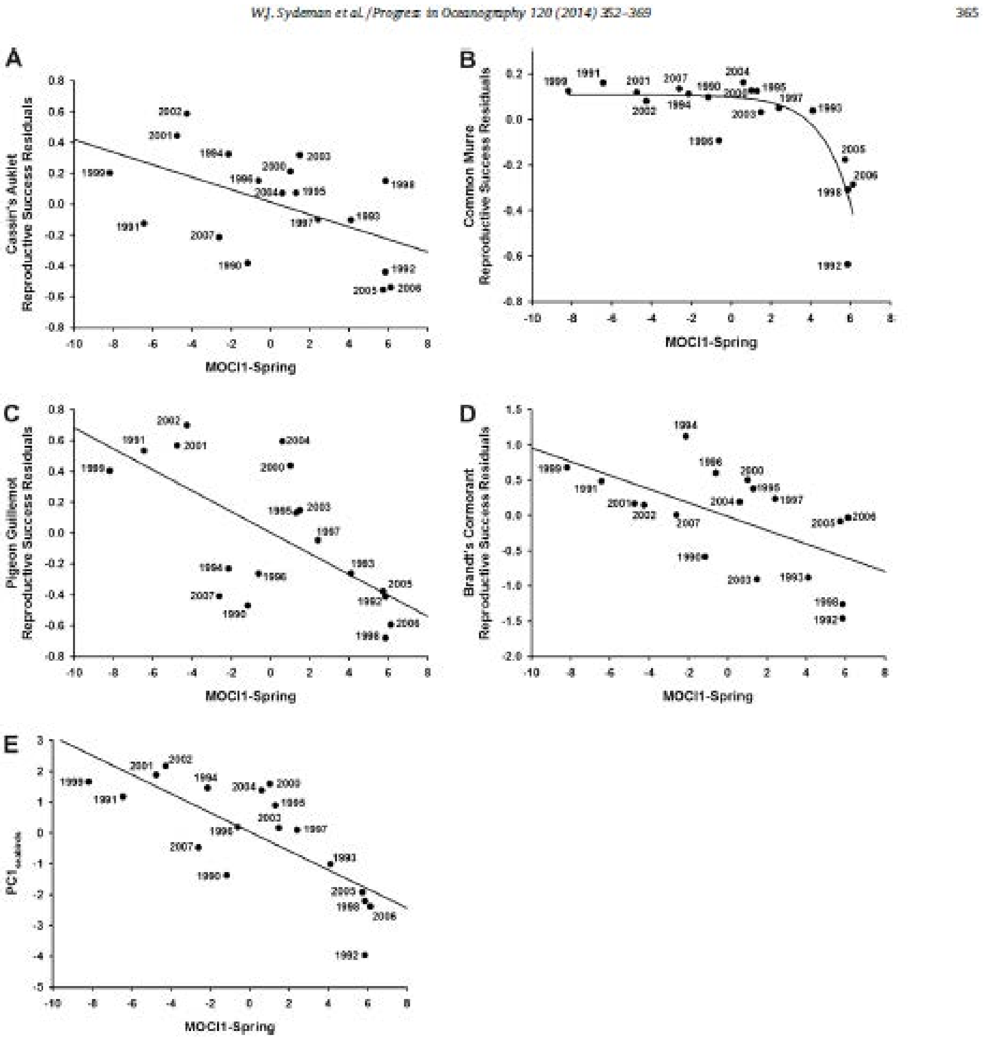

2
1
0
-1
-2
-3
-4
1985
1990
1995
2000
2005
2010
2015
PC1 CC (COMU, RHAU, BRAC, PIGU
PC1 BS (Common Murres
PC1 BS (Kittiwakes)


© STEVEN METILDI
WWW.STEVEMETILDI.COM

Connecting Seabirds to the Environment and Micronekton Communities

Multivariate indicator and breeding success

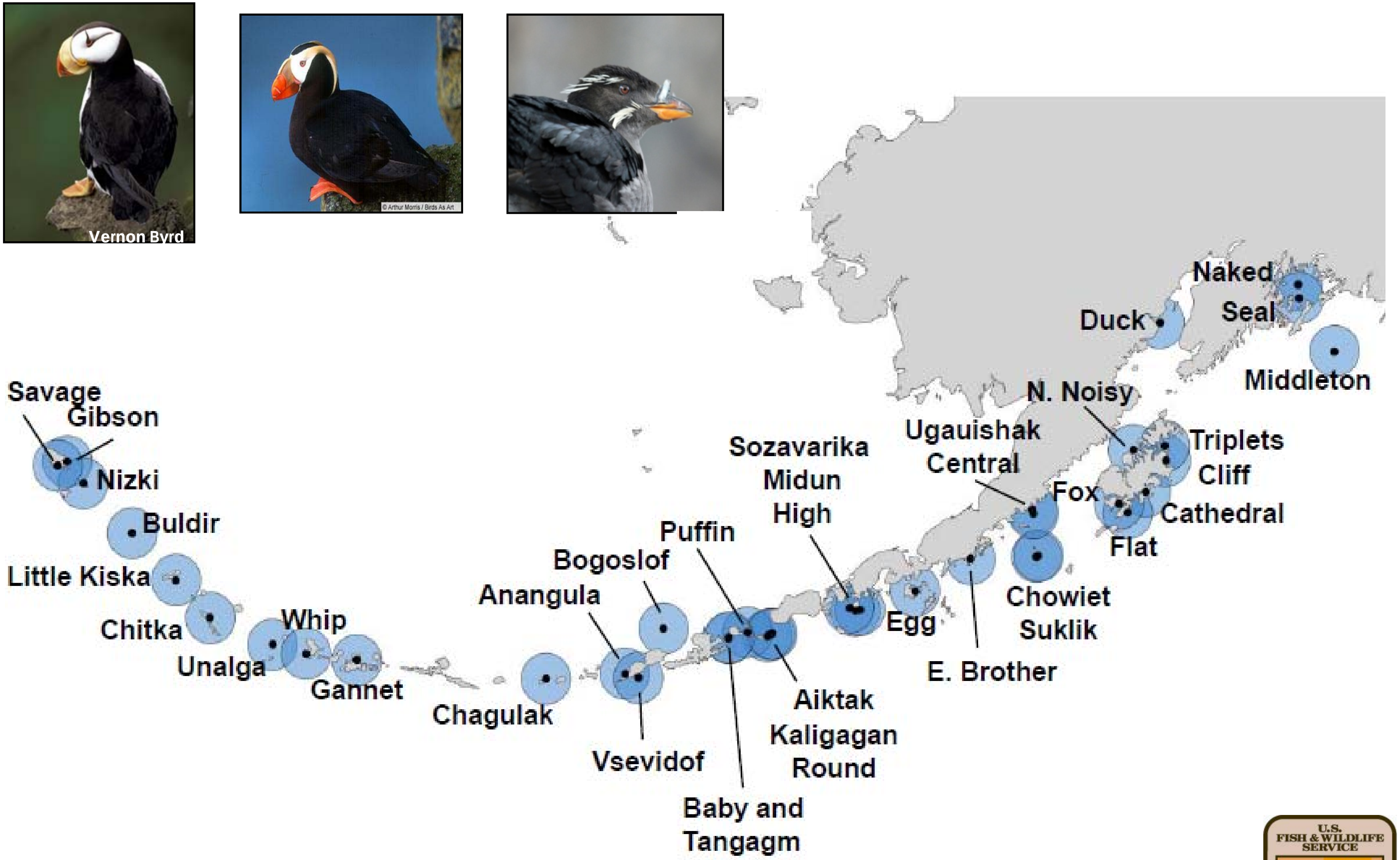



W.J. Sydeman et al. / Progress in Oceanography 120 (2014) 352–369 365

Sydeman et al. 2014 Prog Oceanogr

Extensive Seabird Food Habits Data

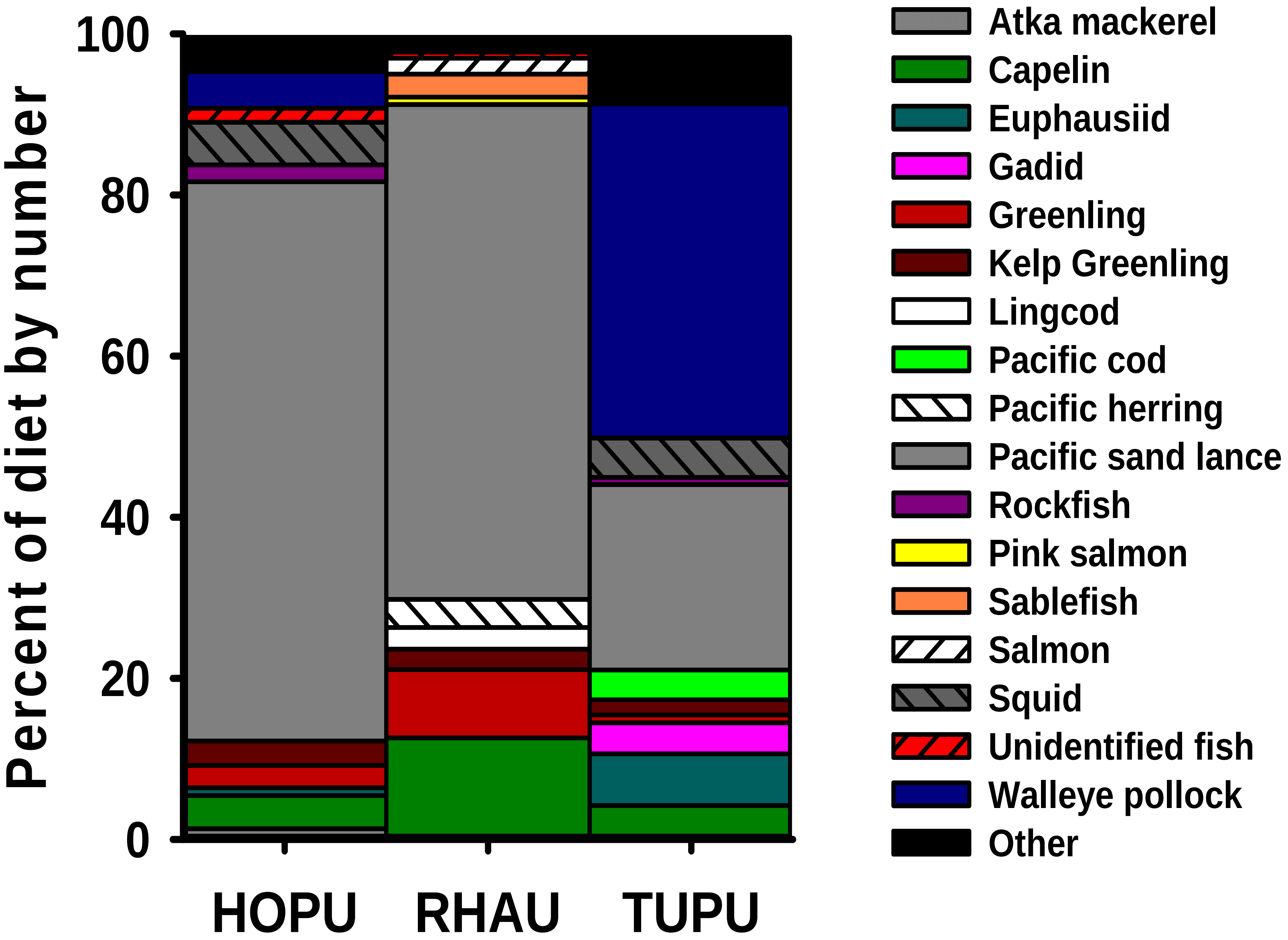
Puffin food habits sampling sites



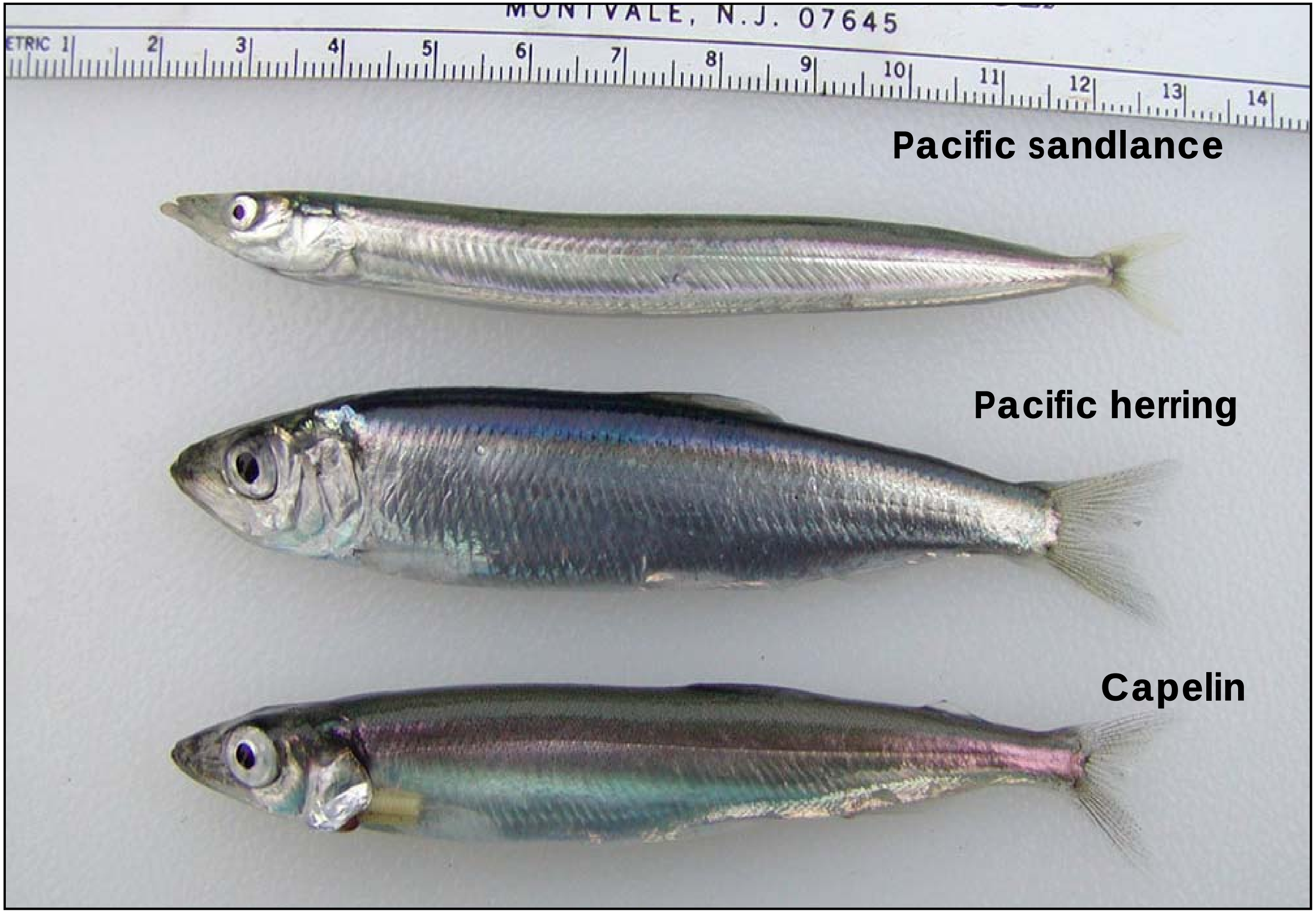
USGS
science for a changing world

U.S. Fish & Wildlife Service
Department of the Interior

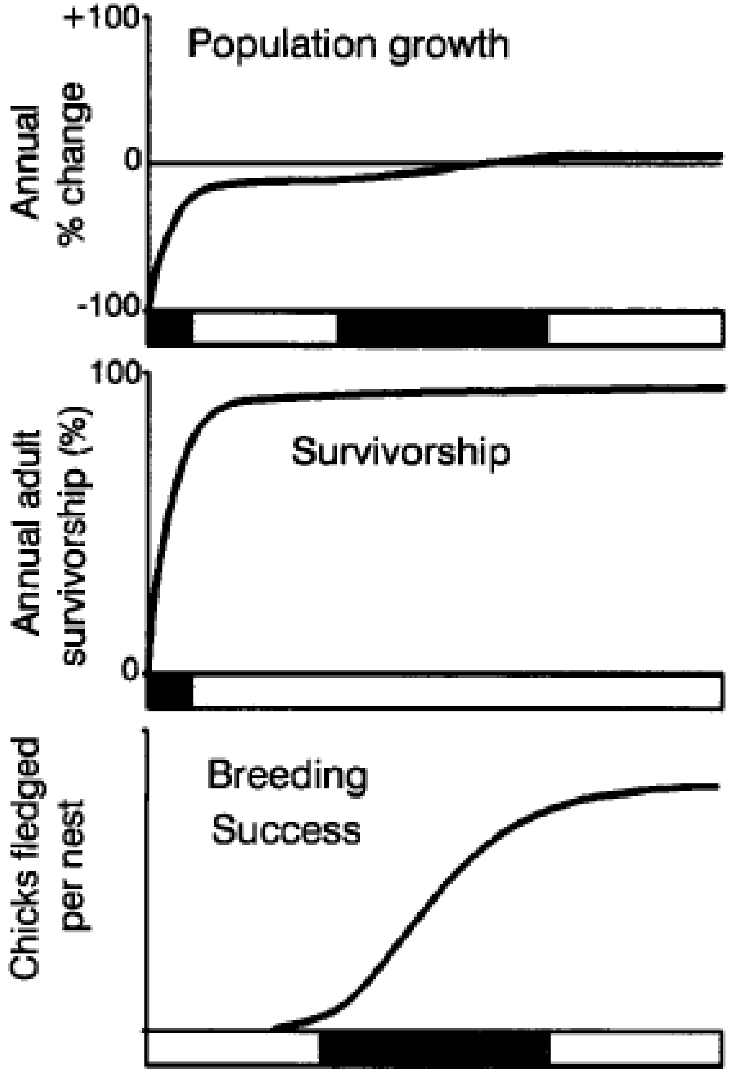
Diet composition of 3 species, all sites, all years



Connecting Seabird Demography to Prey



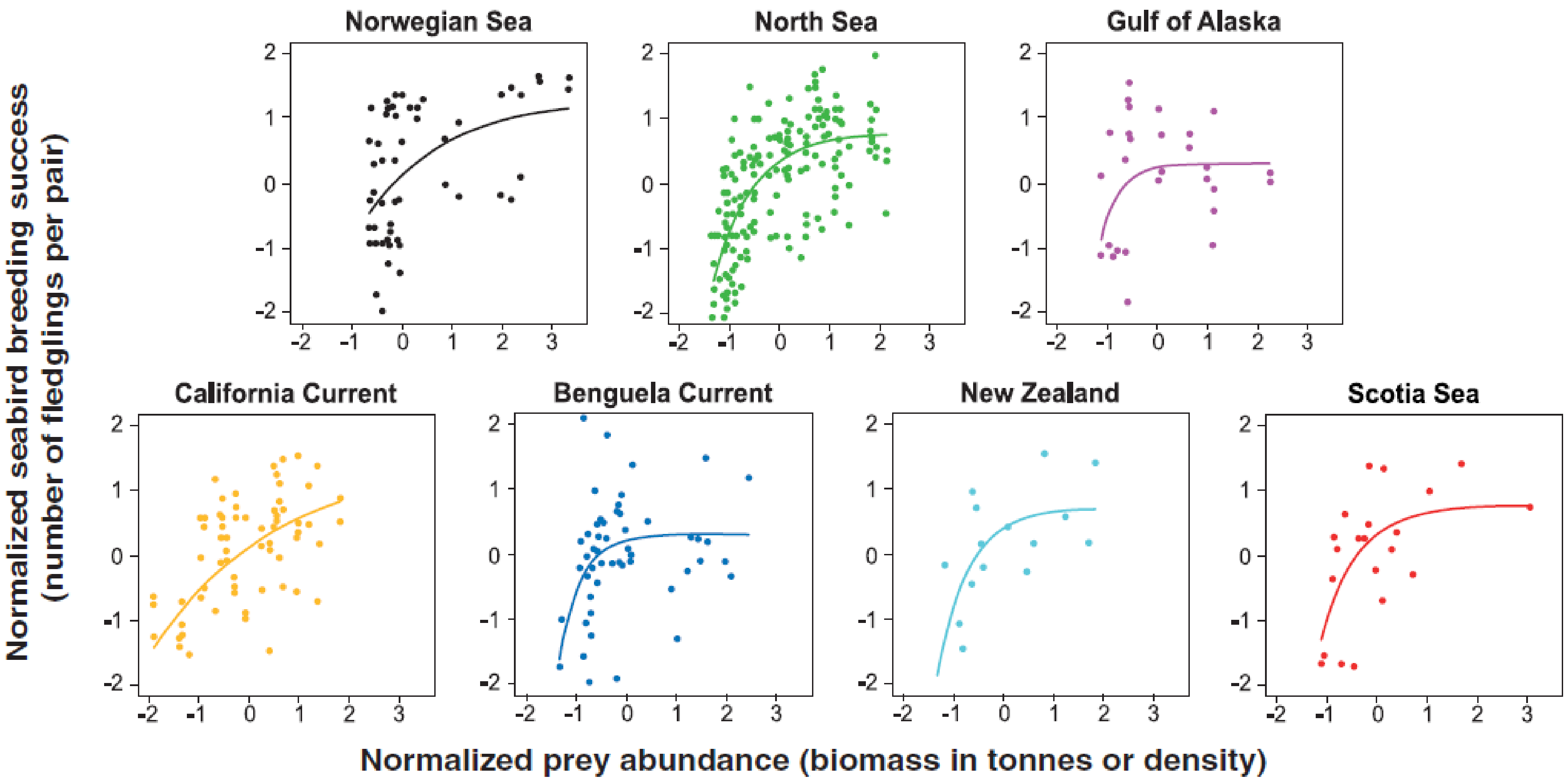
Non-linear numerical response modeling (Cairns 1987; updated by Piatt et al. 2007)



- Population growth & survival rates change rapidly, but over a narrow window of prey abundance, and only when prey abundance is very low.

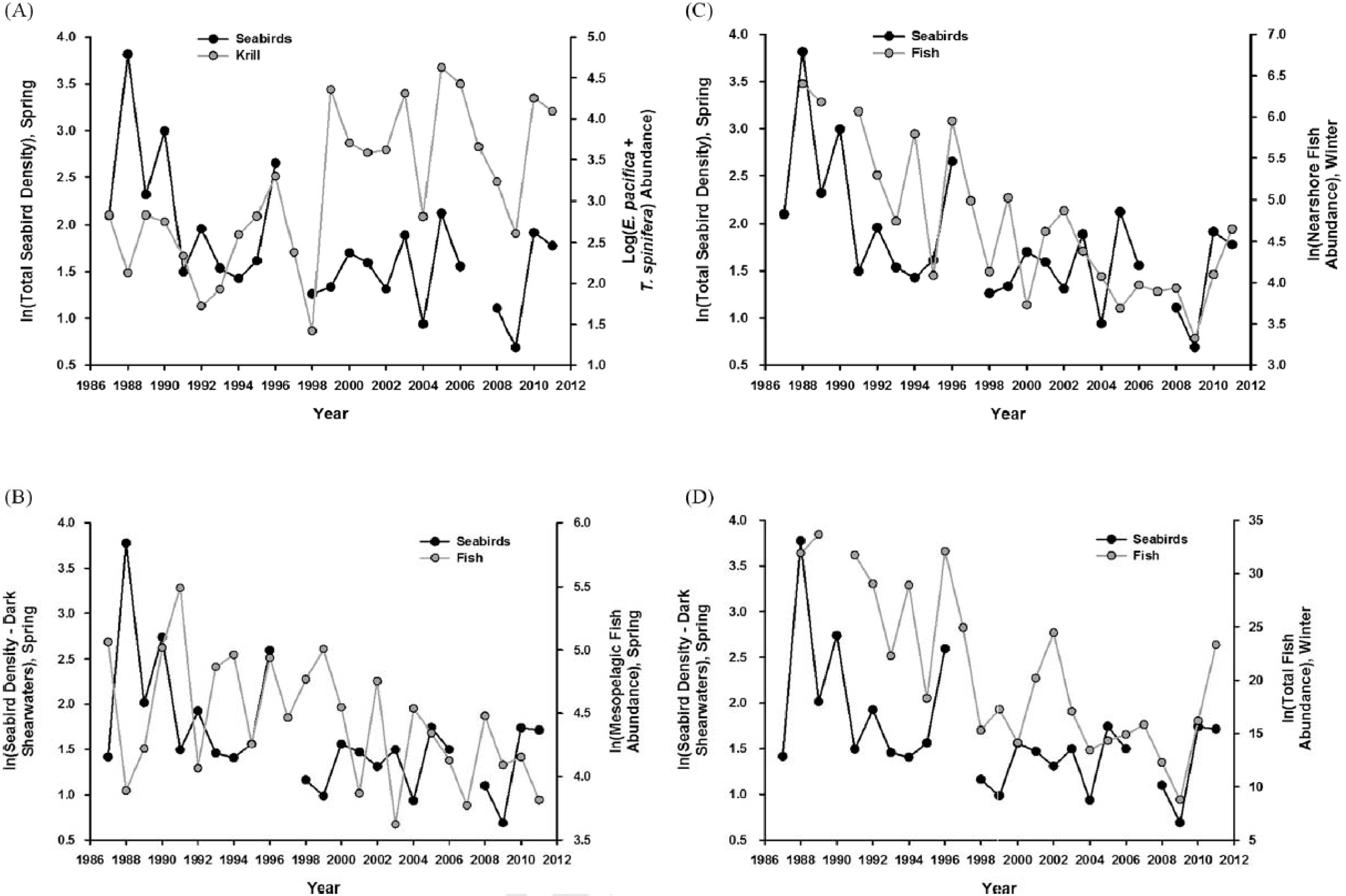
- Breeding success responds over a broader range of prey abundance variability; most responsive when prey abundance is at moderate levels. Breeding success – food relationships well-studied, globally.

Global analysis of numerical response: Breeding success and prey abundance



Cury et al. 2011 *Science*

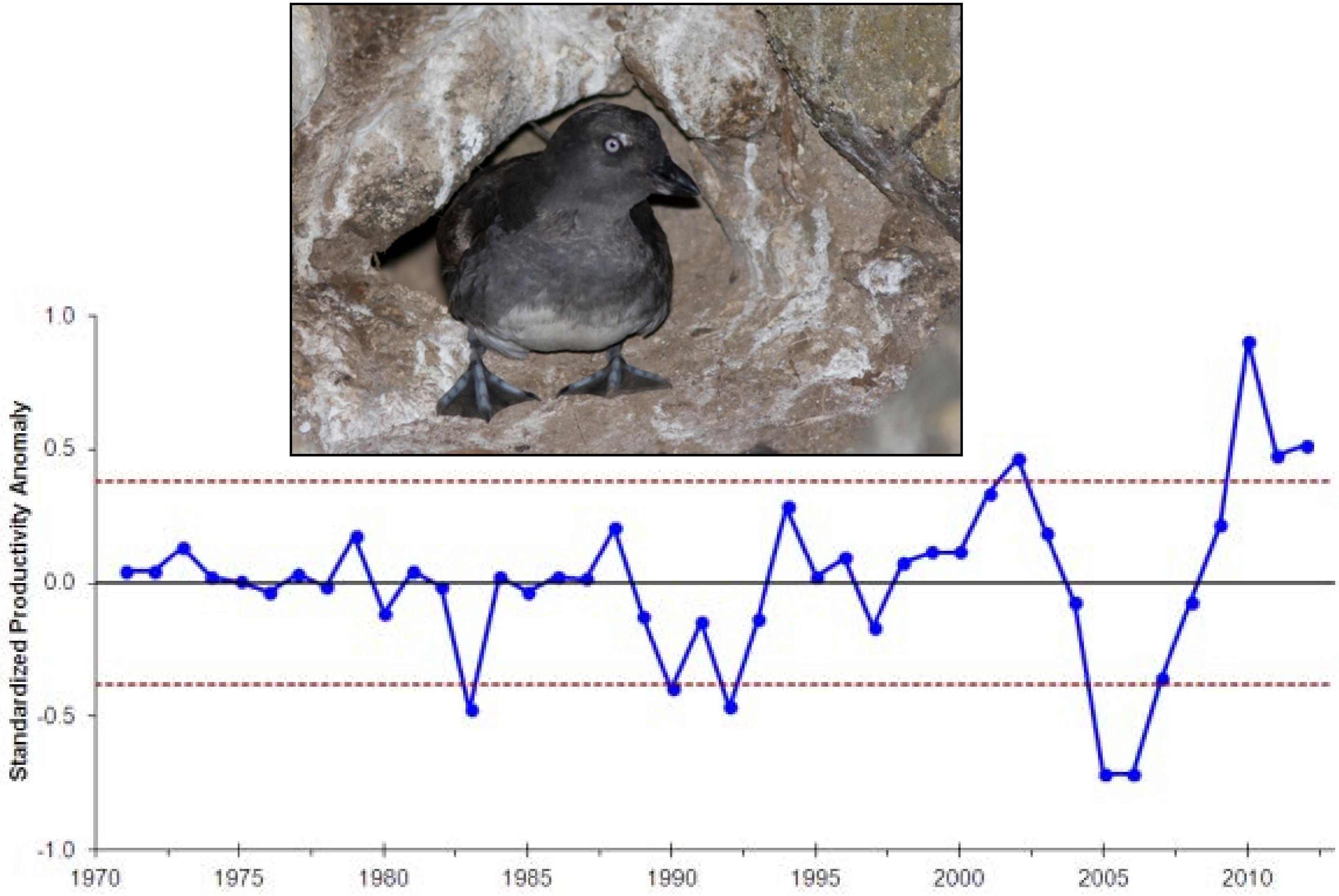
Seabird density and prey abundance (CalCOFI)



Sydeman et al. 2014 DSR II

End to End Modeling of Climate Impacts

The case of the Cassin’s auklet



(figure from Point Blue/ACCESS website)

http://accessoceans.org/index.php?page=research-monitoring-and-management

Forecasting

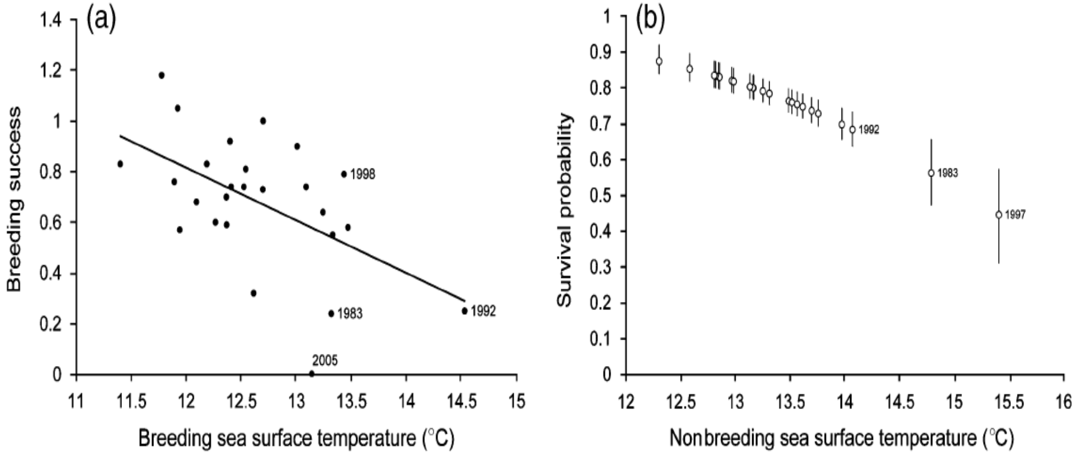
“Population Viability Assessment (PVA)”

dN/dt = BIDE
([births + immigration] – [deaths + emigration])

How do environmental conditions impact demographic traits (production, survival, recruitment)?

Can be synthesize demographic relationships using Leslie population matrices…but few have.

Population risk assessment: Couple RCM with seabird population data to forecast



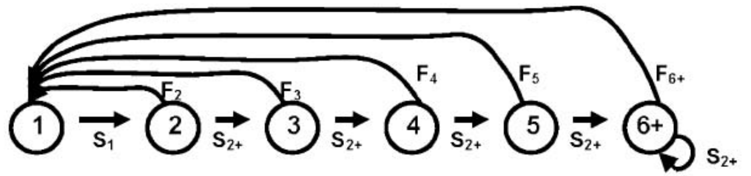
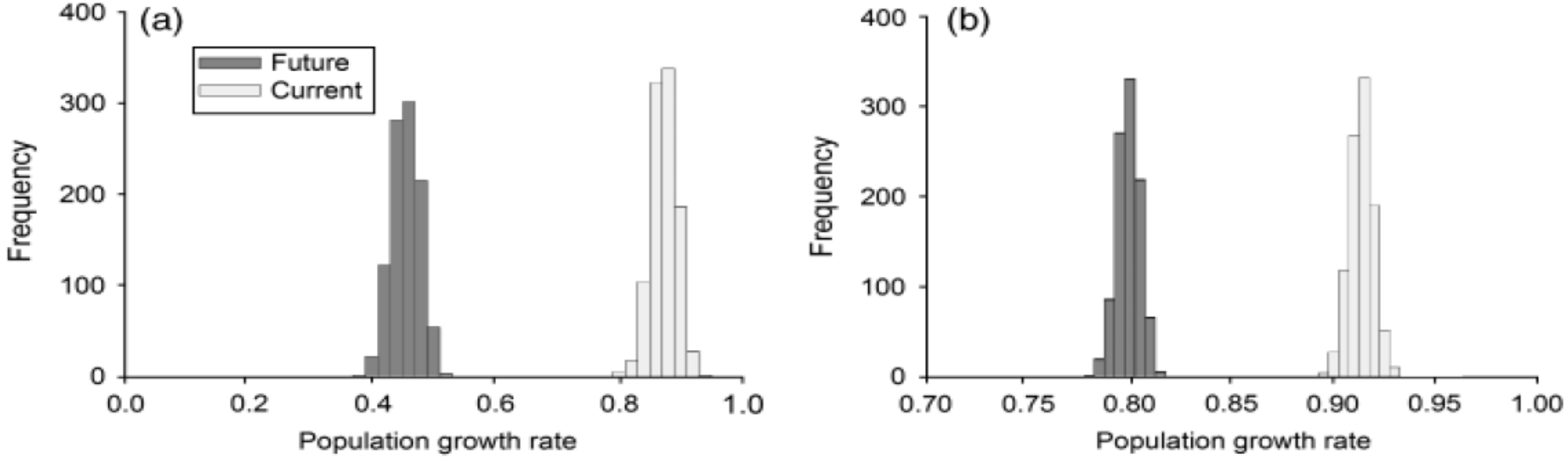


Fig. 2 Diagram of the age-based model developed for Cassin's auklets. Circles indicate age classes (1–6 +). Symbols associated with transition arrows indicate the types of transitions: *S*, the probability of surviving; *F*, fecundity, meaning the probability of producing a viable 1-year-old in the next generation.



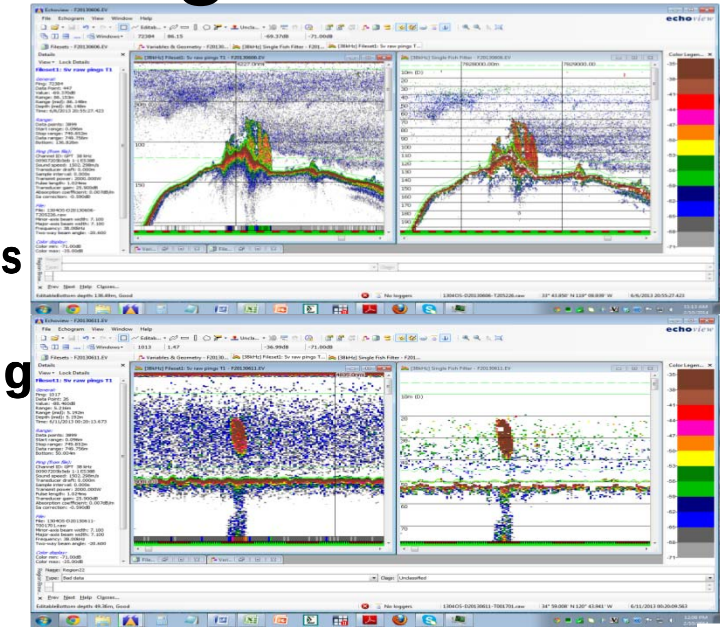
Wolf et al. 2010 GCB

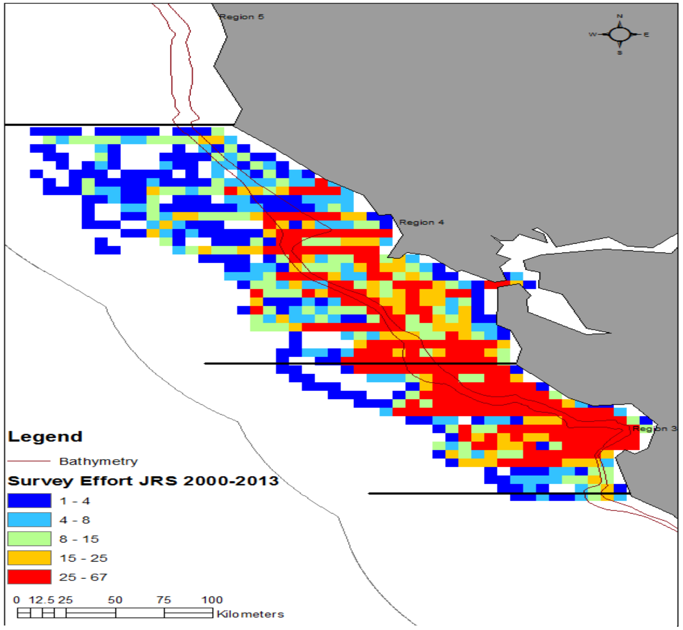
Climate, auklets and krill

40+ species in the CCS, but 2 are dominant in the coastal environment:
Euphausia pacifica **(shelf-break and slope habitats primarily)**
and *Thysanoessa spinifera* (neritic shelf habitats)

Modeling krill habitat utilization distributions

Acoustics Signal Processing

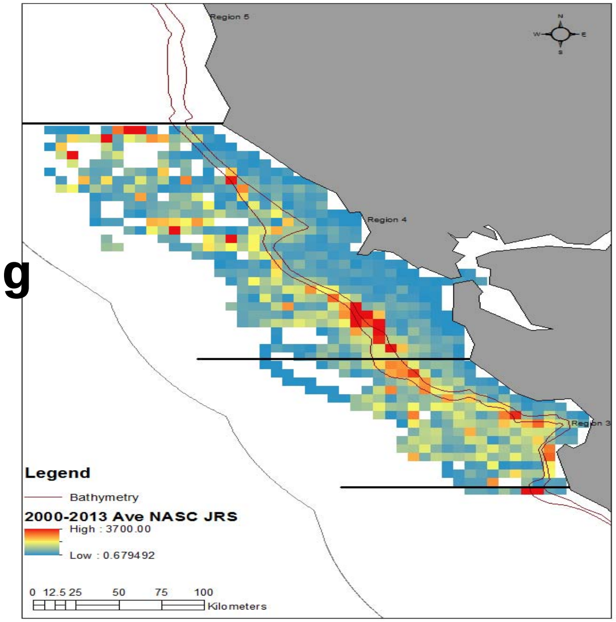




Effort

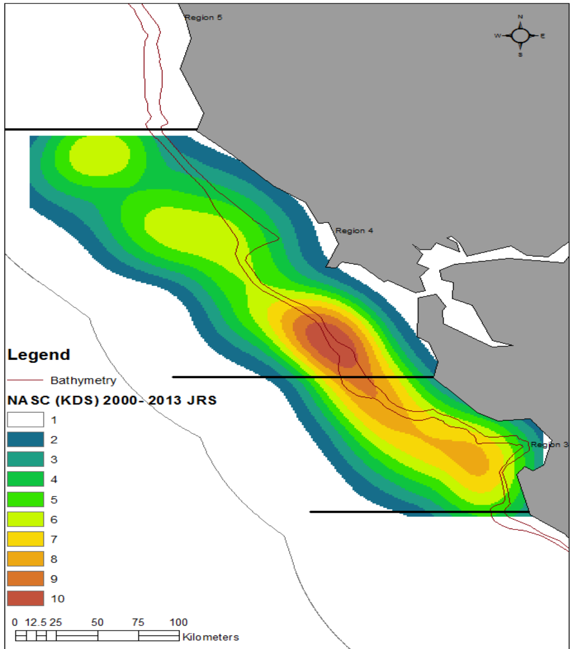
NMFS Juvenile Rockfish Survey (J. Field. PI)

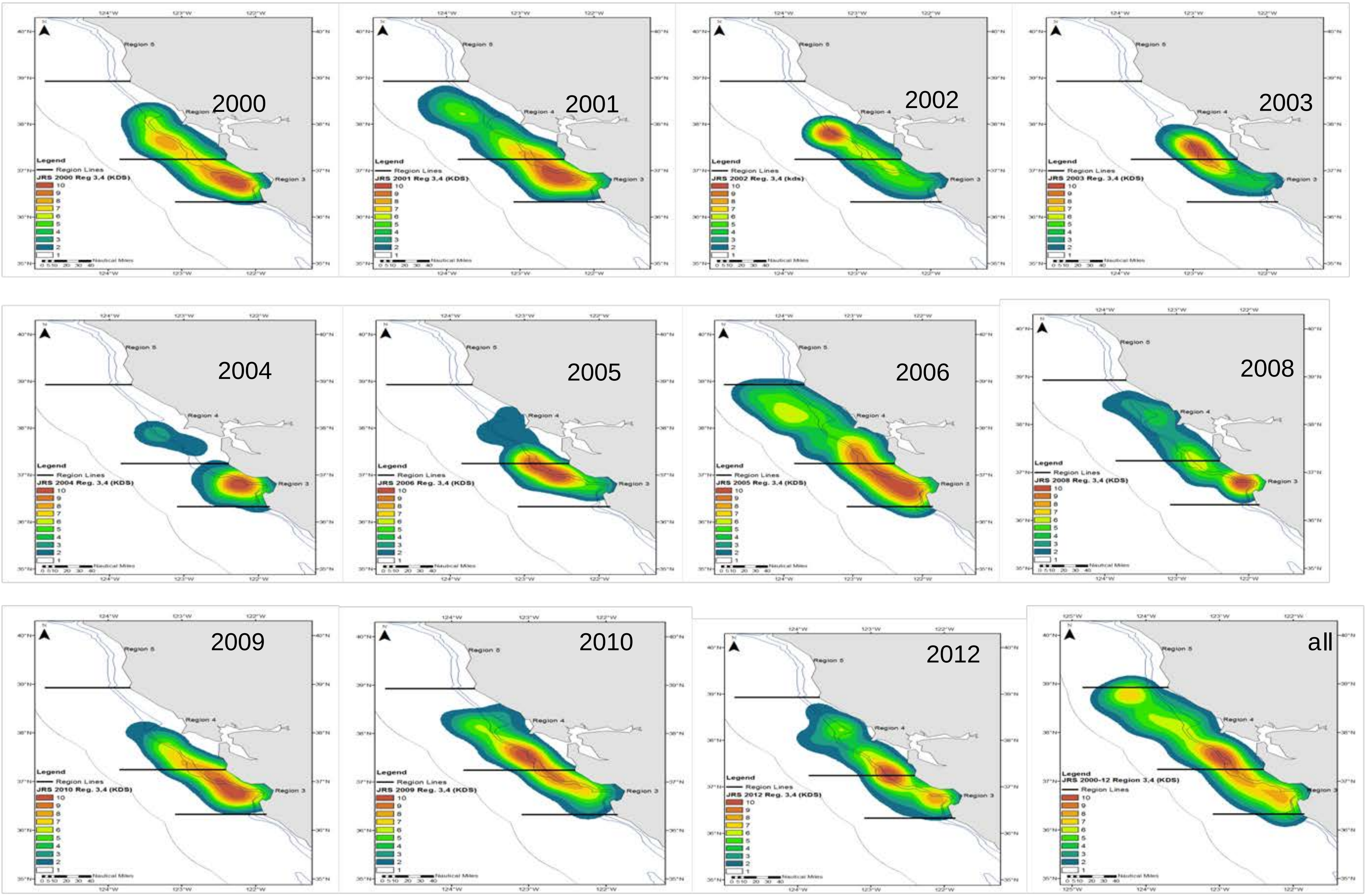
Grid Averaging



Spatial Contouring

"GISing"





Integrating time and space. Kernel density smoothing (KDS) of krill 'hotspots' by year, Juvenile Rockfish Survey, core region, May-June, 2000-2012. Warmer colors = higher abundance (Sydeman et al. in prep).

Individual-Based Model of Krill

- ➢ Advection and mortality help explain poor breeding success and recruitment (2005-2006 [birds] to 2007-2009 [salmon])

- ➢ modeling krill prey fields (could be done with other miconekton)

L04605 DORMAN ET AL.: KRILL DECREASES IN 2005 OFF CALIFORNIA L04605

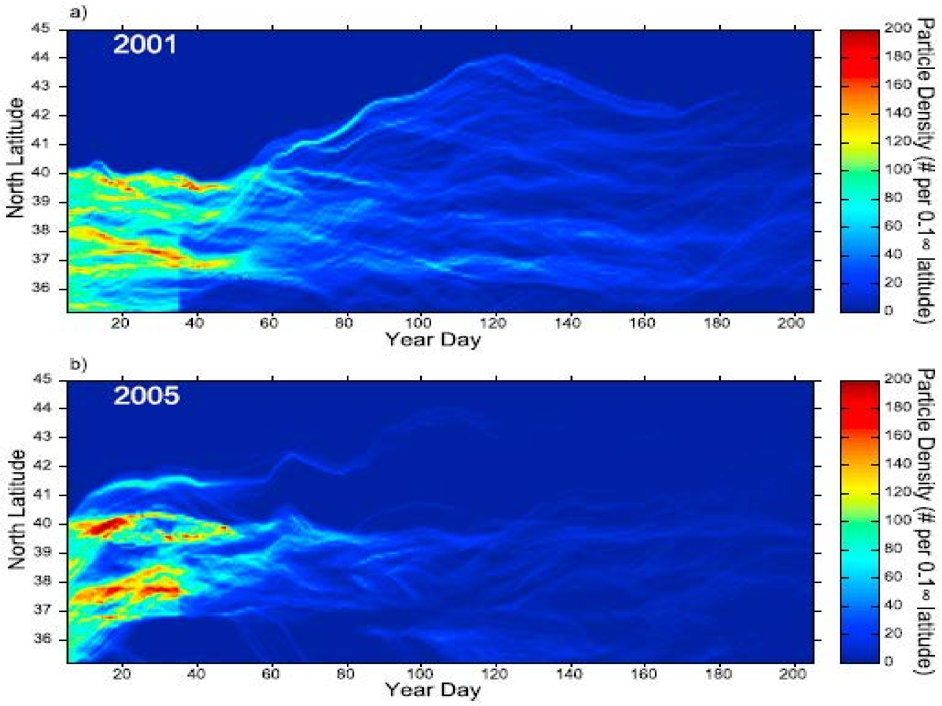


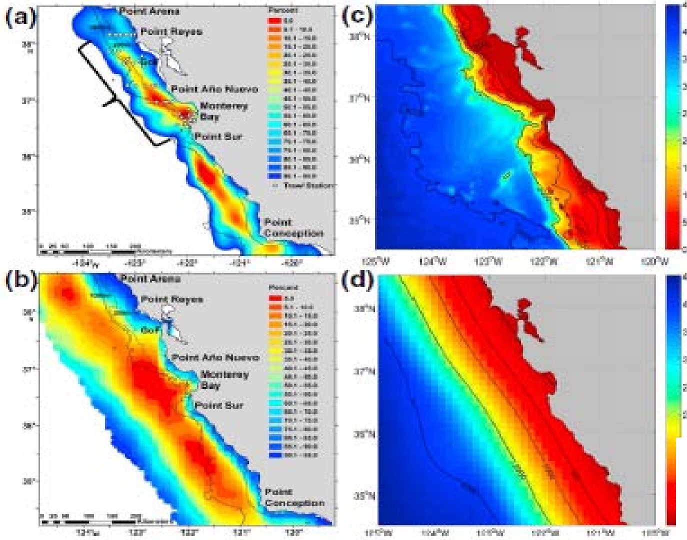
Figure 2. Particle density (number per 0.1° latitude) within 100 km of the coastline during (a) 2001 and (b) 2005. Note the northward advection of particles in January 2005 and greater number of particles in 2001.

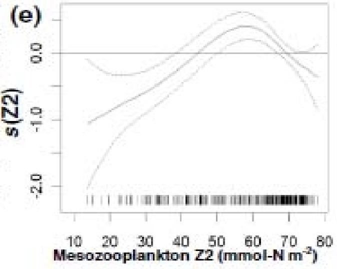
Dorman et al. 2011 GRL

ROMS-CoSINE (mesozoop)-krill-PC1seabirds

Observ.

Model





Santora et al. 2013 GRL

Modeled Krill, Observed Krill

Relationships to Seabirds

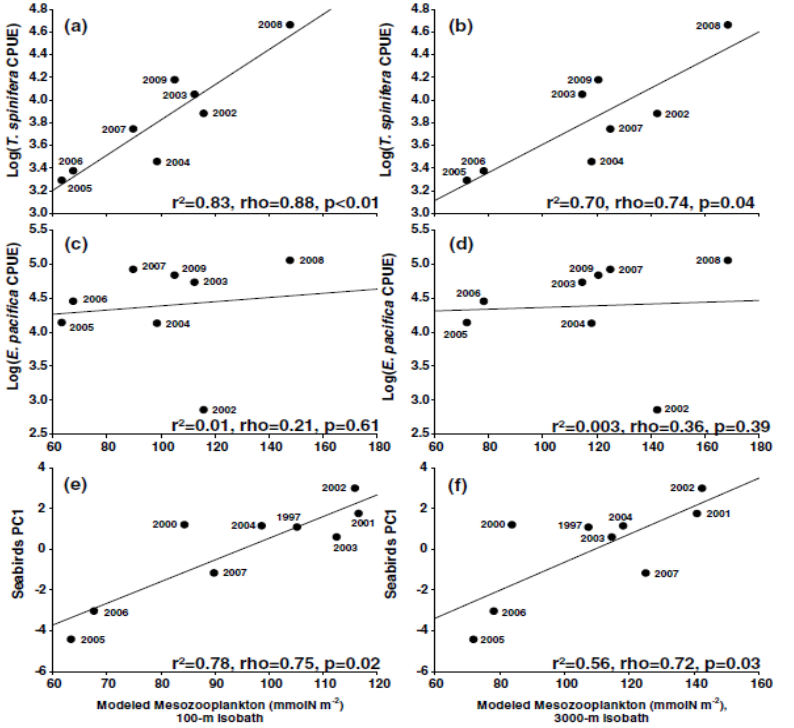


Figure 3. Temporal comparison of (a, b) mean CPUE of *T. spinifera* and modeled mesozooplankton (Z2), (c, d) mean CPUE of *E. pacifica* and Z2, and (e, f) seabird principal component 1 and Z2.

Seabirds and climate change in the North Pacific: Opportunities and challenges

- **Opportunities**: couple RCM with ROMS-NPZ, food web observations, numerical response models, and age-structured population models; model evaluations on “prey fields”, paying particular attention to spatial organization and shifts in prey patchiness

- Large (ecosystem)-scale comparative integrations of seabird datasets are needed; data intensive, but North Pacific seabird datasets are data-rich (moreso than fish or mammals w.r.t demography and diets)

- **Challenges**: data sharing and data organization; statistical considerations such as downscaling, prey-switching/multi-species numerical responses, separation of interdecadal from unidirectional anthropogenic change, non-stationary environmental and predator-prey relationships

- Other mechanistic hypotheses: top-down (recovery of marine mammals), interactions with fisheries and other anthropogenic impacts on food webs and ecosystems