WINGS AND FINS: ECOSYSTEM-BASED FISHERIES MANAGEMENT USING SEABIRDS

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and

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FARALLON NATIONAL WILDLIFE REFUGE

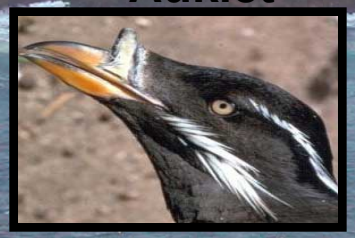
(USFWS & PRBO)

…a living laboratory: 30+ years

Common Murre

Uria aalge

Rhinoceros Auklet



Cerorhinca monocerata

Brandt's Cormorant

Phalacrocorax penicillatus

Pelagic Cormorant

Phalacrocorax pelagicus

Pigeon Guillemot

Cepphus columba

Cassin's Auklet

Ptychoramphus aleuticus

Western Gull

Larus occidentalis

Overview of Presentation

- How seabirds can be used as ecosystem indicators
- Case studies illustrating use of seabirds in ecosystem-based fisheries management
  - Pacific Herring (*Clupea pallasi)*
  - Rockfish (*Sebastes* spp.)
  - Chinook Salmon (*Oncorhynchus tshawytscha*)
- How seabirds and other top predators can be used in fish stock assessments and fisheries management plans

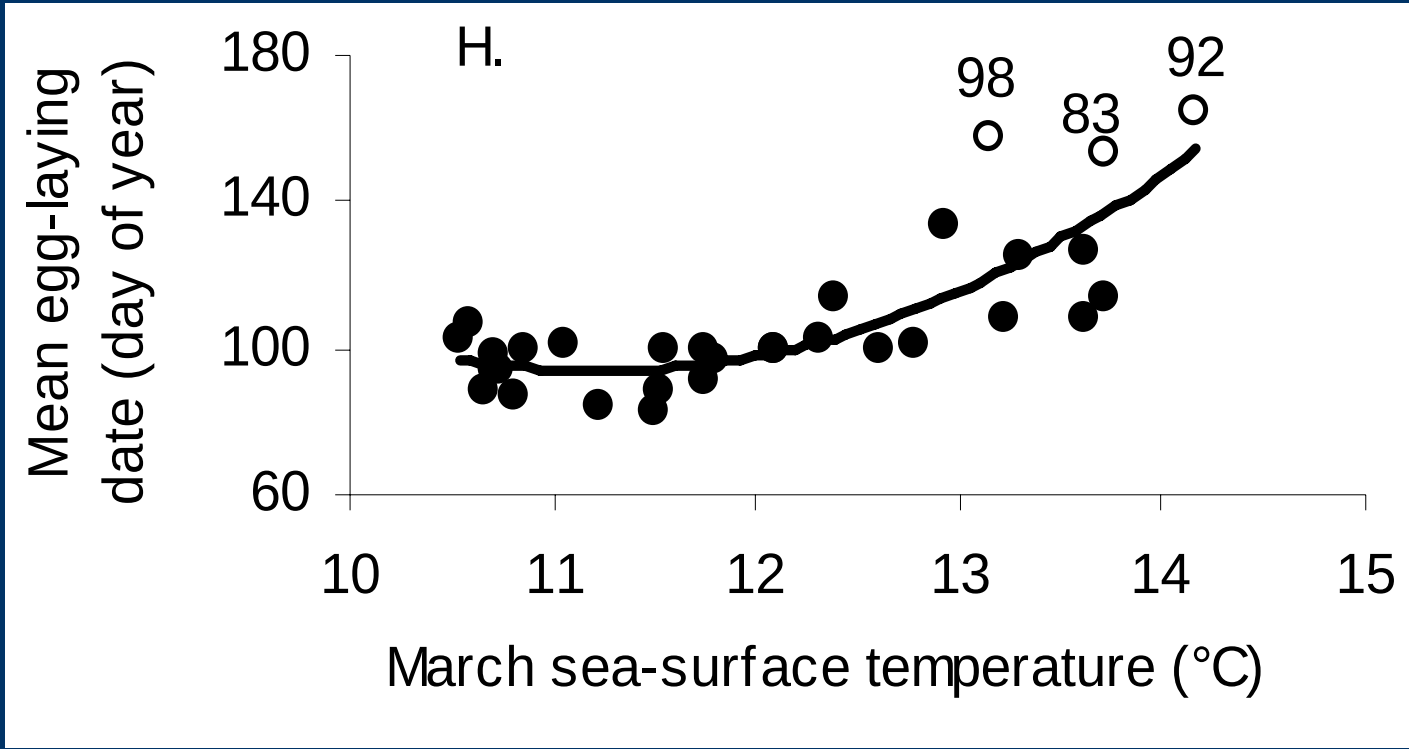
What makes seabirds good indicators?

- Depend on ocean for survival
- Depend on the ocean for producing young
- Long-lived

Seabird Variables that Reflect Ocean Conditions

- Adult survival (population counts)
- Breeding propensity
- Timing of breeding, date of egg-laying, chick-hatching
- Breeding success; double-brooding (e.g. CAAU)
- Nestling growth rates
- Length of foraging trips
- Diet composition (adult and chick)

Seabirds as Ecosystem Indicators

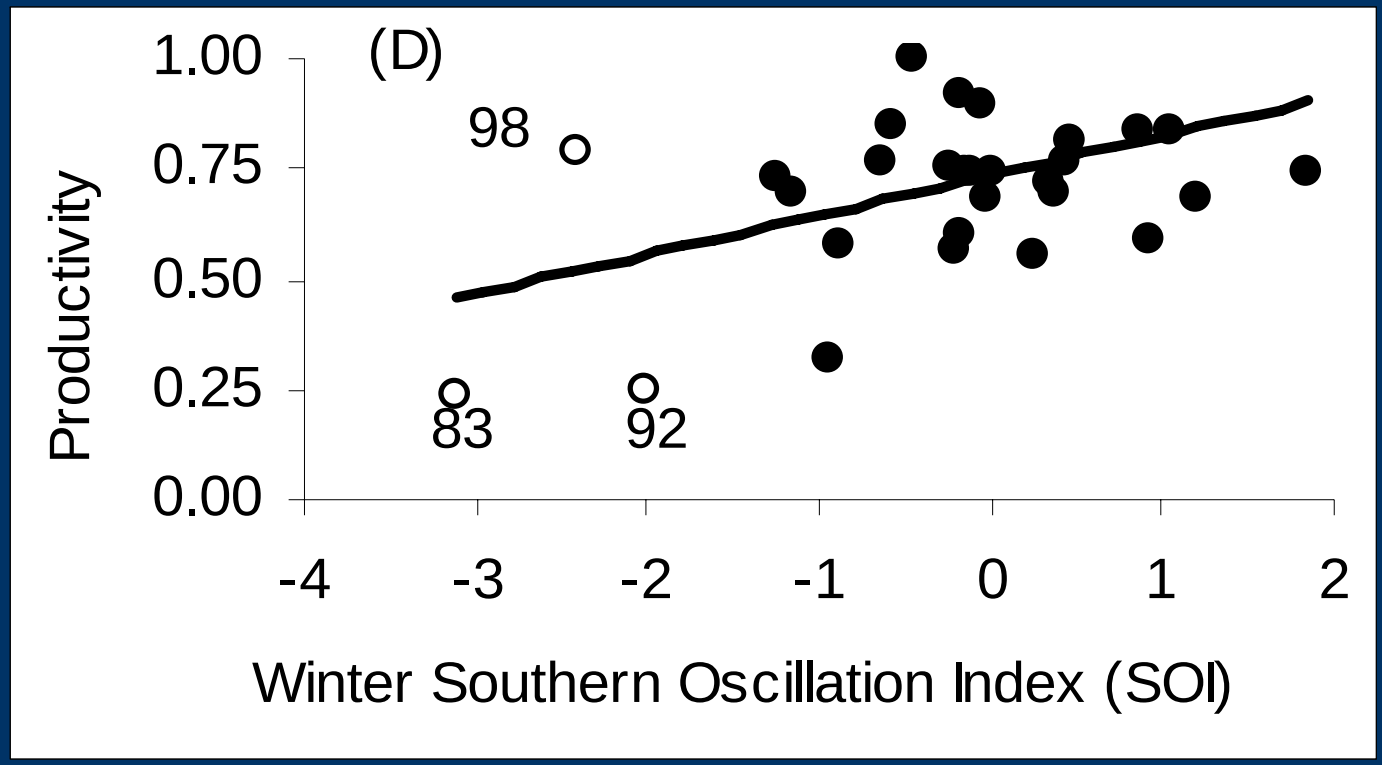


March SST indicates upwelling strength.

Warm-water years (1983, 1992, 1998) are indicative of little or no upwelling, and low prey availability.

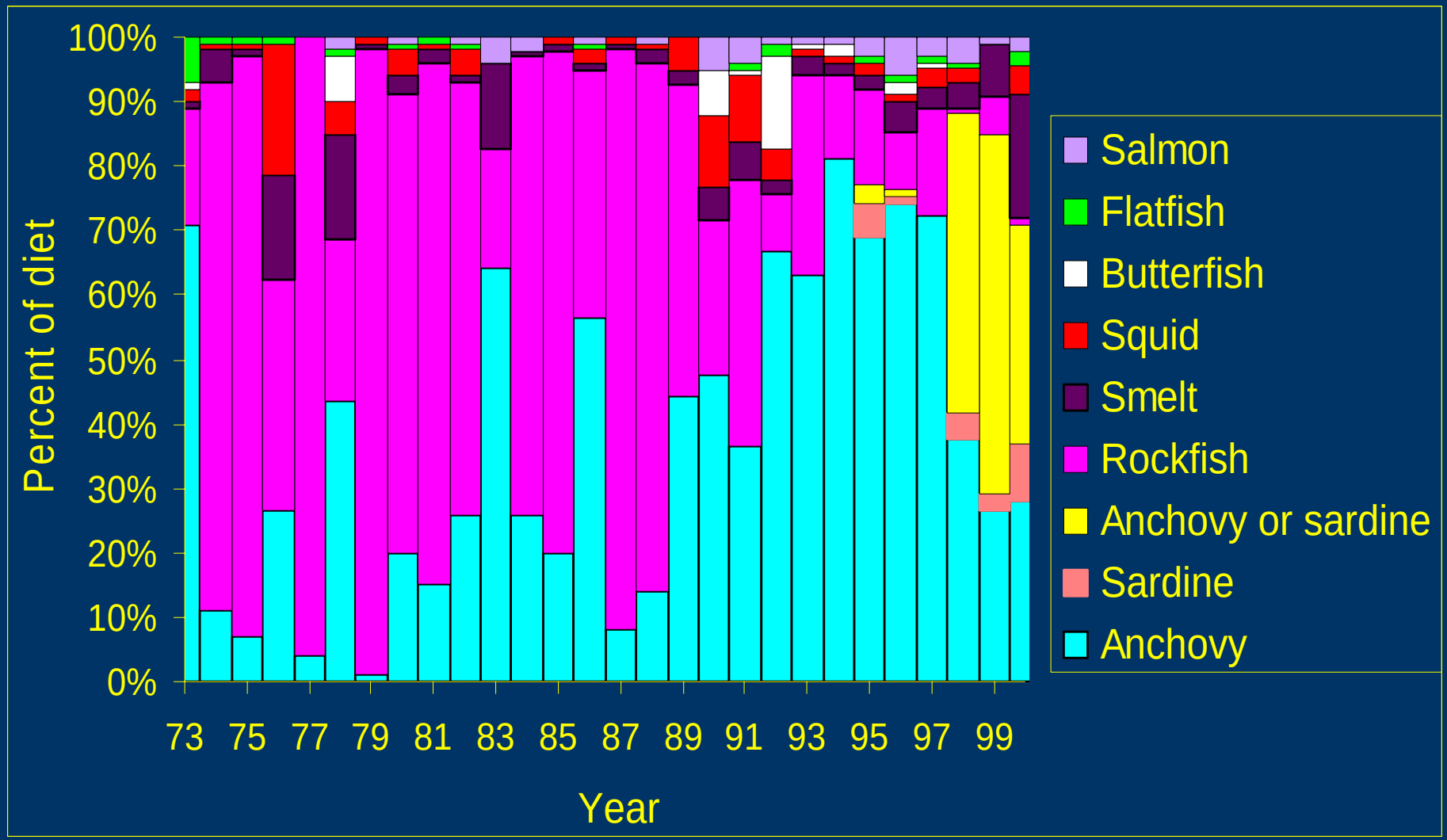
Seabirds as Ecosystem Indicators

SOI = Southern Oscillation Index (measurement of basin scale atmospheric pressure difference)



<u>Negative SOI</u> = warmer, less productive waters (reflective of lower food availability)

Seabirds as Ecosystem Indicators



- **Annual proportion of diet for each prey species for Murre chicks**
- **Diet reflects relative abundance and availability of prey in ocean**

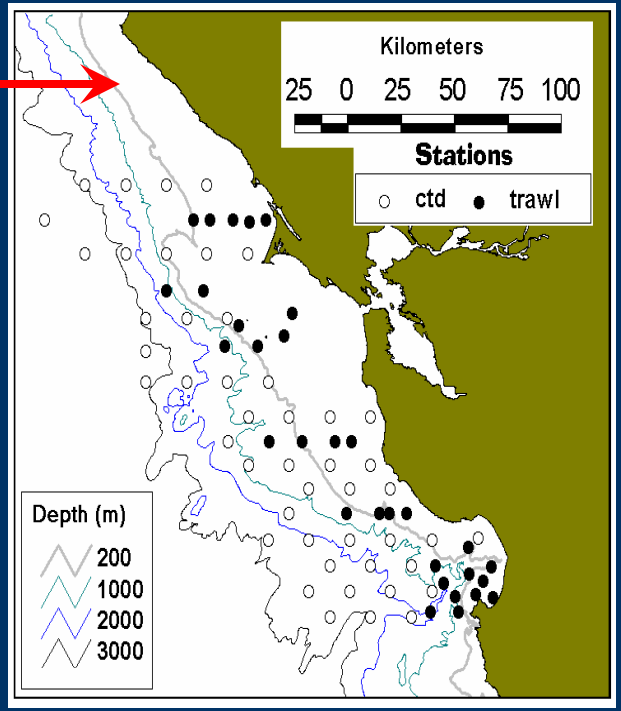
Long-Term Data Sets

1. Herring: spawning biomass, 1979-2004 and body condition, 1983-2002.

2. Rockfish: abundance from mid-water trawl surveys, 1983-2002.

3. Salmon: (a) gut contents, 1980-1999. (b) estimates of the Central Valley Index (CVI) and jack (2-yr-old males) returns to hatchery, 1976-2004.

4. Seabirds: chick diet and breeding success, 1972-2002 on Southeast Farallon Island.



Case Study 1: Herring

Seabird breeding success can be used to understand (and possibly predict) variation in herring spawning biomass and body condition.

SPRING SUMMER FALL WINTER

Herring Feed at Sea

Seabirds Breed on Farallones

Herring Enter Bay and Spawn

Seabird Breeding Success on SE Farallon Island

Diet of Herring and Seabirds in the Gulf of the Farallones

Pacific Herring

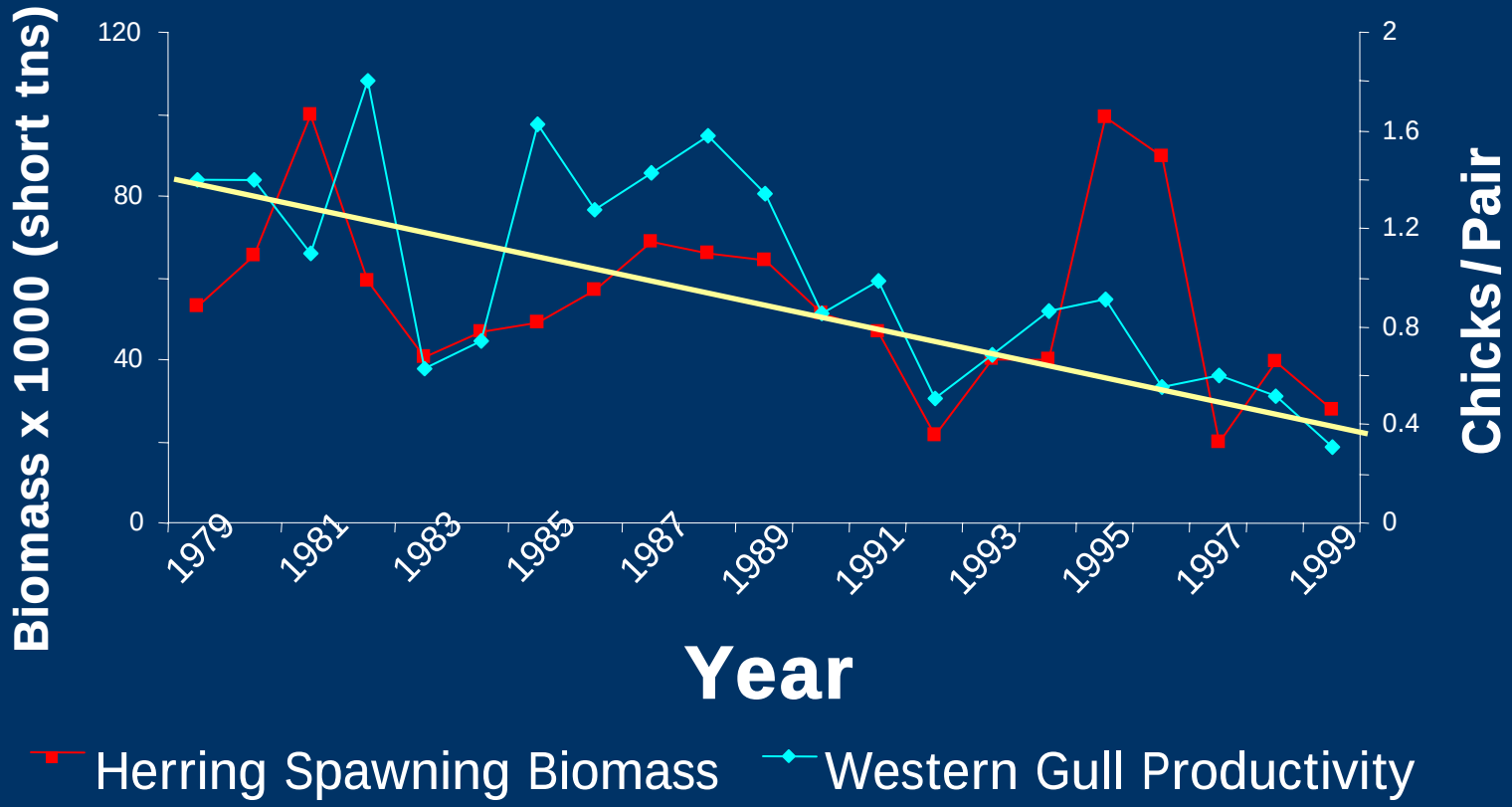
Common Murre

Cassin's Auklet
obligate planktivore

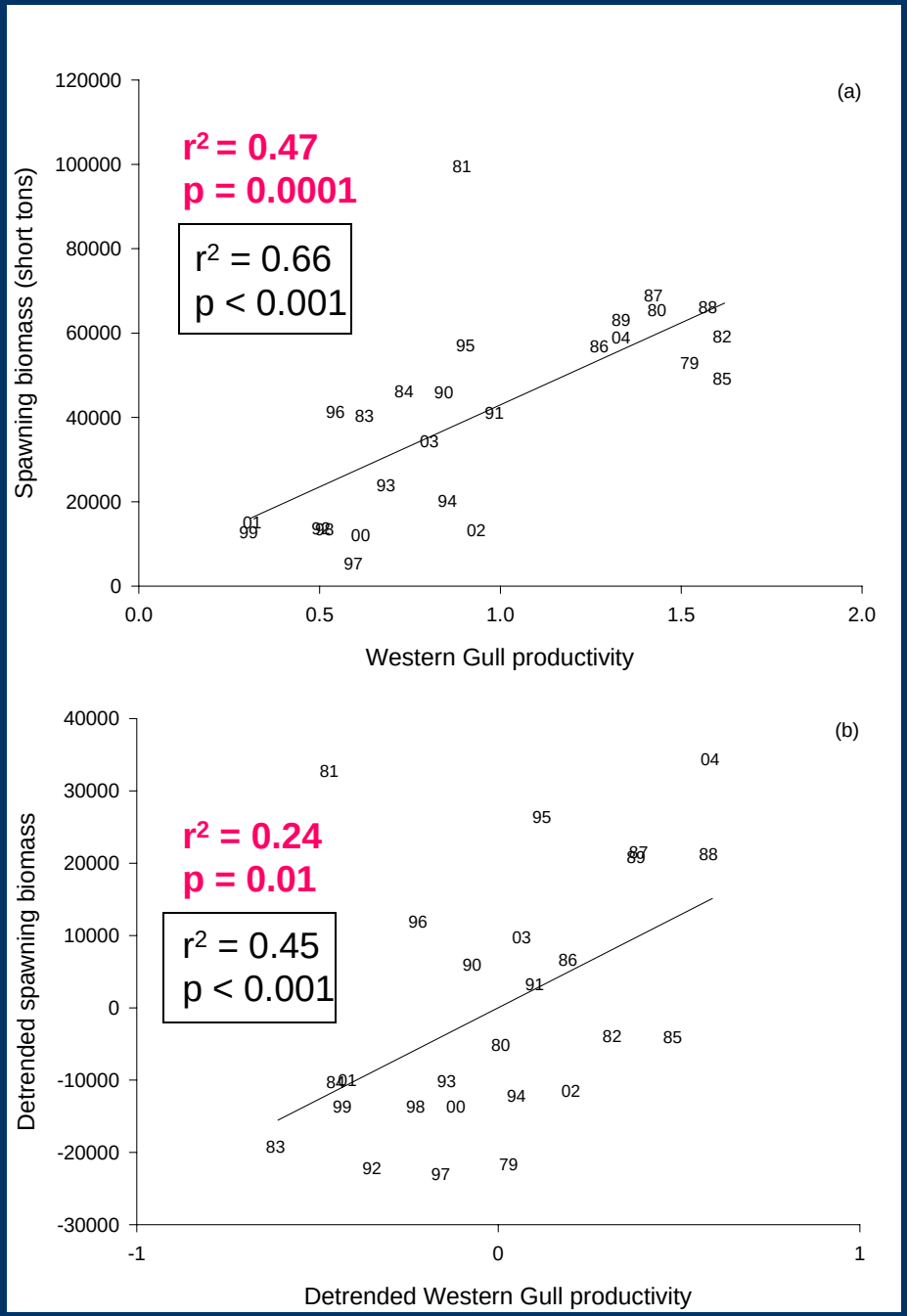
Western Gull

MACROZOOPLANKTON (euphausiid crustaceans: *E. pacifica, T. spinifera; larval fish*)

Western Gull Breeding Success and Herring Spawning Biomass



Herring Spawning Biomass and Western Gull Breeding Success



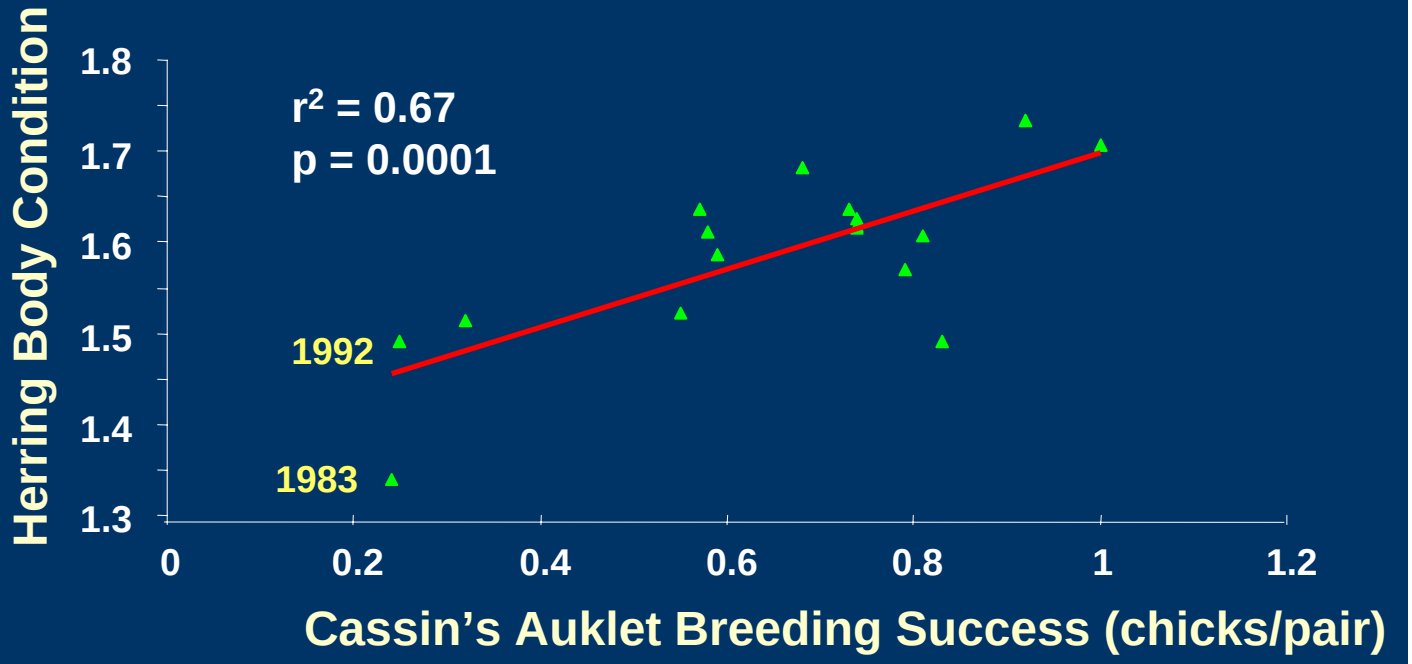
Seabird – Herring Body Condition (M/L^3) Co-Variation

Herring Age (yrs)

	1	2	3	4	5	6	7
Western Gull					*	*	*
Common Murre		*	*	*			
Cassin's Auklet					*	*	*

*** = significant at the 0.05 level**

Cassin's Auklet
Herring, Age 6



Forecasting Potential for Pacific Herring

Year	Spawning Biomass	Predicted Spawning Biomass	% Deviation
1979	52869	64980	23
1997	5248	29023	453
2004	58934	55998	-5
Ave. % Deviation (1979-2004)			37
Ave. underestimate			-22
Ave. overestimate			88
Cross-validation r^2 value			0.41

Case Study 2: Rockfish

Top predator diet can be used to assess pelagic juvenile Rockfish abundance.

Chinook Salmon *(adult)*

Common Murres

Pigeon Guillemots

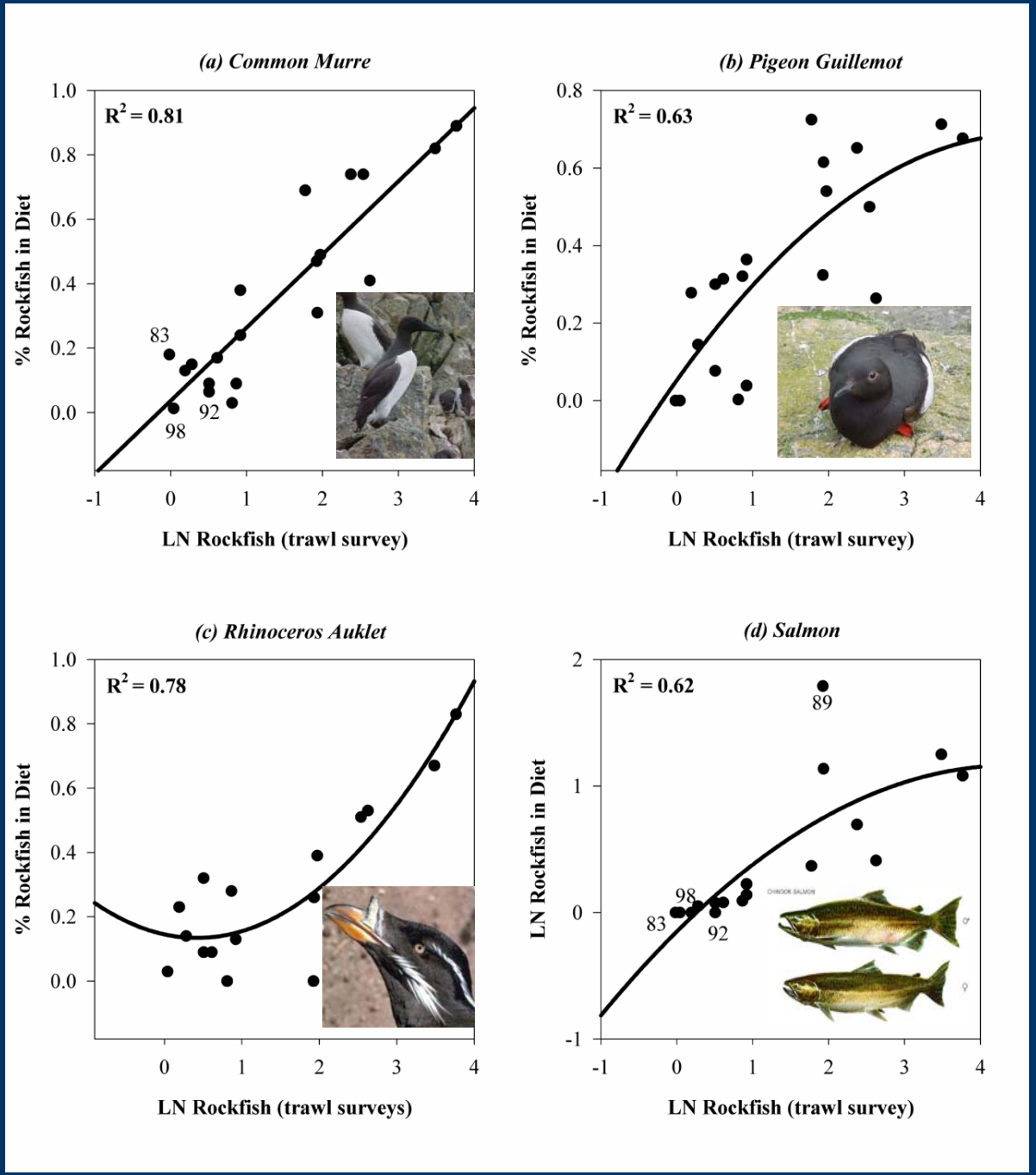
Rhinoceros Auklets

Pelagic Juvenile Rockfish

Trawl Surveys

- **Annual indices of juv. rockfish relative abundance:**
  - ***Proportion in seabird chick diet (3 spp)***
  - ***No. in salmon stomachs***
  - ***Abundance in mid-water trawl surveys***

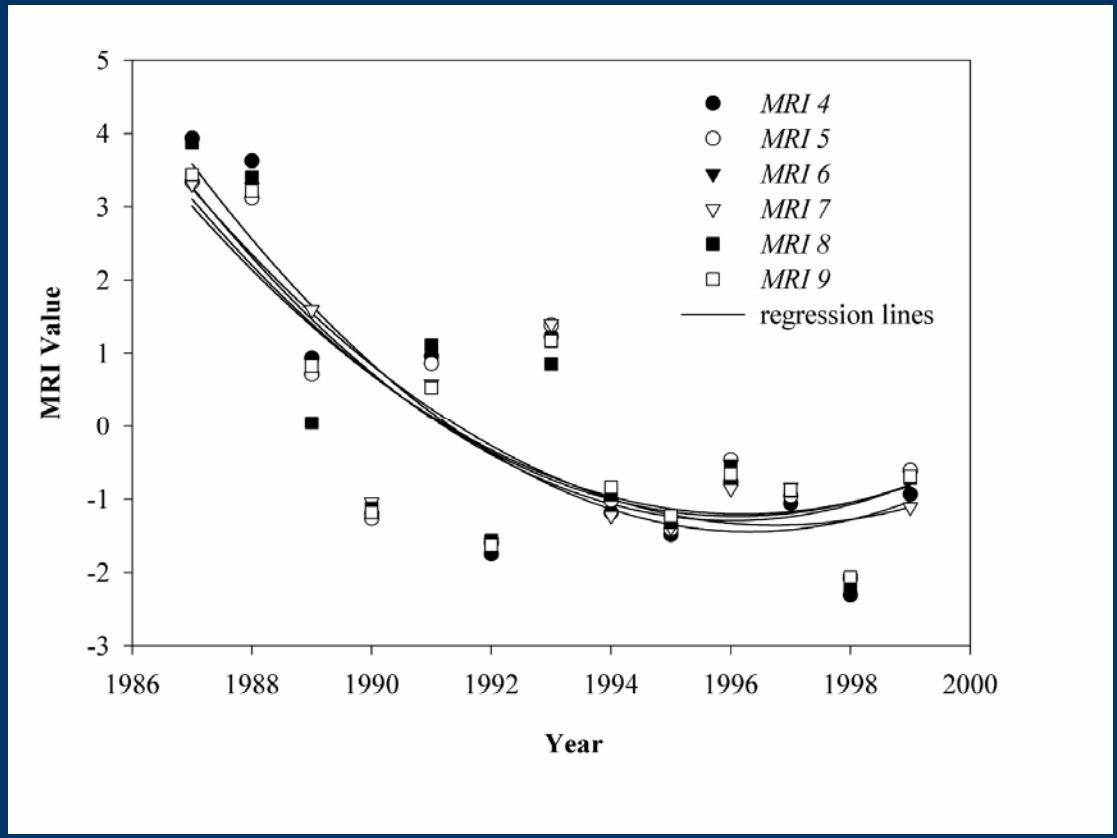
Trawls and Rockfish in Predator Diet



From: Mills et al. 2007
(Fisheries Oceanography 16:3)

Multivariate Rockfish Index (MRI)

- Derived using PCA to combine the different indices.
- Provides synoptic perspective on abundance.
- Reveals interannual variability.



MRI 4 = all indices
MRI 5 = excludes COMU
MRI 6 = excludes PIGU
MRI 7 = excludes CAAU
MRI 8 = excludes salmon
MRI 9 = excludes trawls

From: Mills et al. 2007 (Fisheries Oceanography 16:3)

Case Study 3: Salmon

Seabird breeding success can be used to help predict Central Valley (CA) Chinook Salmon returns (hatchery fish).

Chinook Salmon *(adult)*

Brandt's Cormorants

Pelagic Cormorants

Common Murres

Cassin's Auklets

Pigeon Guillemots

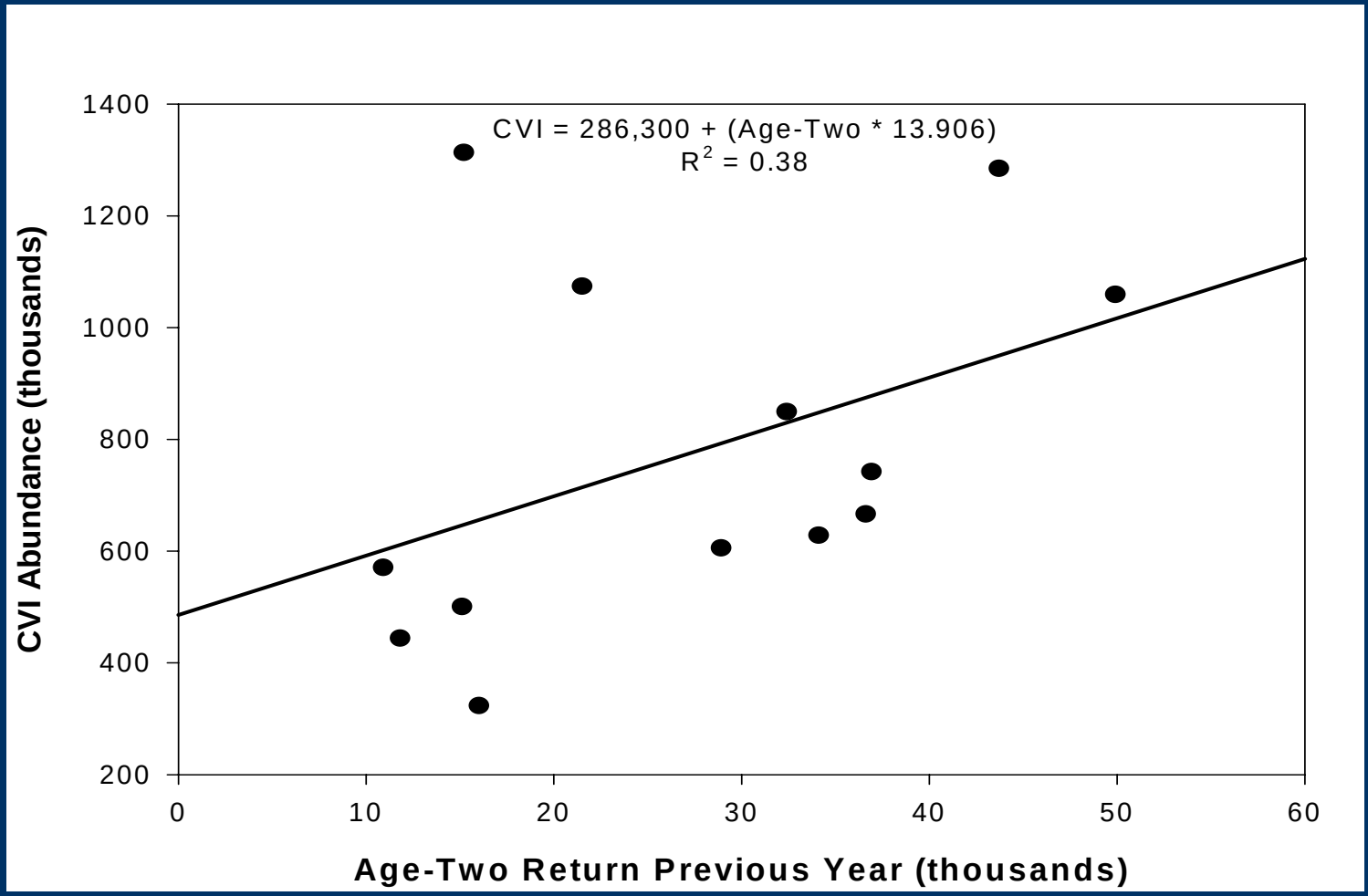
Marine invertebrates and fish

Salmon and Seabirds = "Trophic Equivalents"

Study Methods

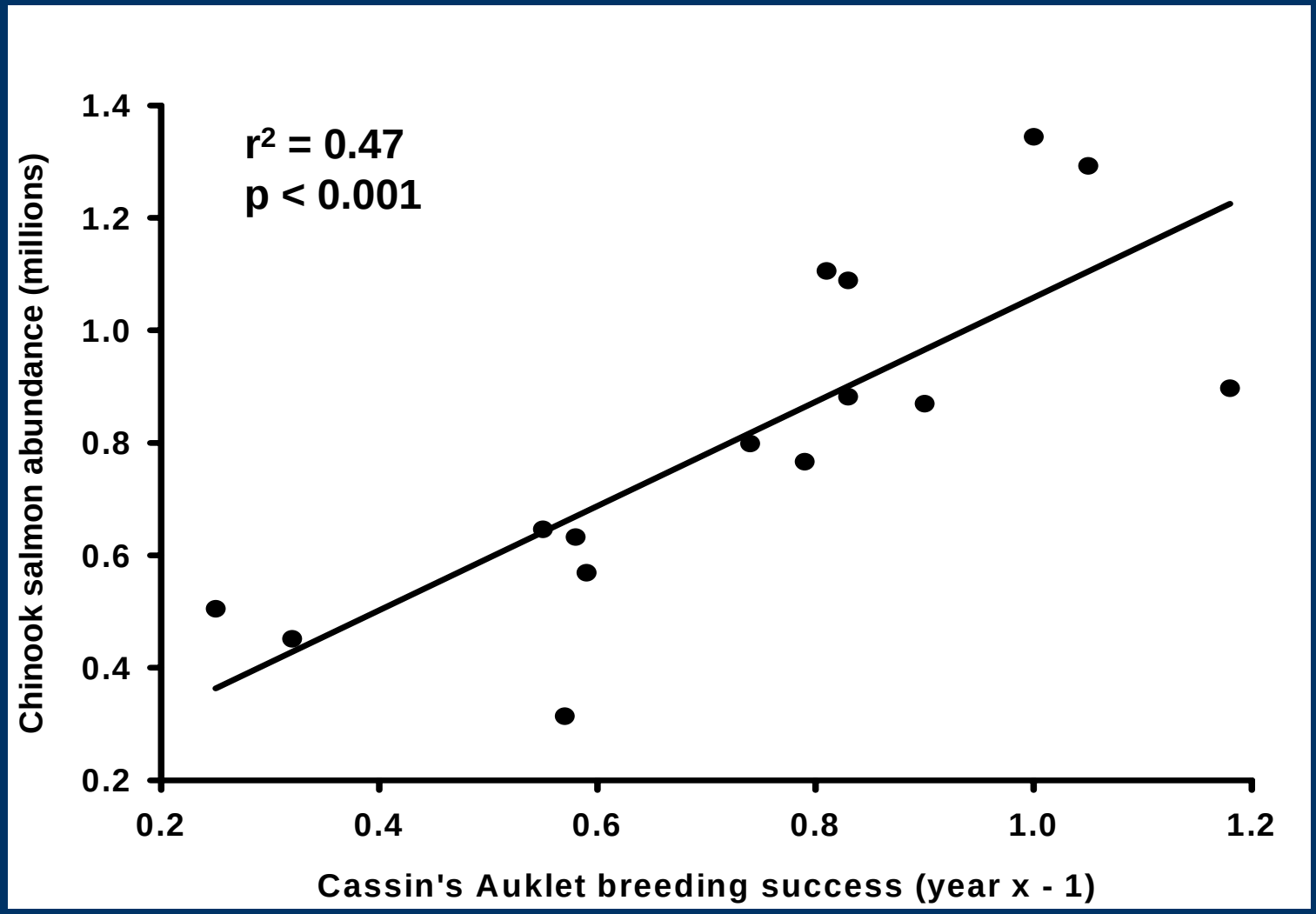
- **Breeding success of CAAU, COMU, BRAC, PECO, PIGU on Farallon Islands vs. salmon abundance (CVI).**
- **Running averages of breeding success (up to 3 previous years).**
- **Two time periods: 1990-2004 (shorter) and 1976-2004 (longer).**

Current Method of Forecasting Salmon



CVI = Central Valley Index

Cassin's Auklets Predict Salmon



From: Roth, Mills, Sydeman 2007 (Can. J. Fisheries Aqua. Sci. 64)

Forecasting Potential - Comparison of Models

Central Valley Index

	1990-2004	1976-2004	1990-2004 *2-yr ave.*	1976-2004 *2-yr ave.*
Jack Models				
Adjusted r^2	**0.61**	**0.16**		
***p*-value**	**<0.001**	**<0.05**		
Seabird Models				
Adjusted r^2	**0.60**	**0.33**	**0.60**	**0.64**
***p*-value**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
Combined Models				
Adjusted r^2	**0.61**	**0.60**	**0.80**	**0.70**
***p*-value**	**<0.001**	**<0.01**	**<0.001**	**<0.001**

From: Roth, Mills, Sydeman 2007 (Can. J. Fisheries Aqua. Sci. 64)

Conclusions

- **Co-variation in seabirds, herring, rockfish, and salmon time series evident; likely related to ocean climate variability**
- **Using seabirds to predict herring looks promising, but more calibration is needed.**
- **MRI may be useful for understanding rockfish abundance.**
- **Seabird data may be useful in a salmon forecasting context when combined with jack models.**

Why Use Seabirds?

- Predator-based sampling is a cost-effective enhancement of net sampling.
- Seabird studies are relatively inexpensive.
- Predators sample spatially and patchy prey; predators can provide information that enhances that obtained from net surveys.
- Seabirds and salmon sample fish species not caught in nets.
- Seabird breeding success integrates variation in the marine environment from egg-laying through chick-rearing each year.

Potential Applications

Fish Life History Information

Landings by Gear Type

Age/Length Compositions

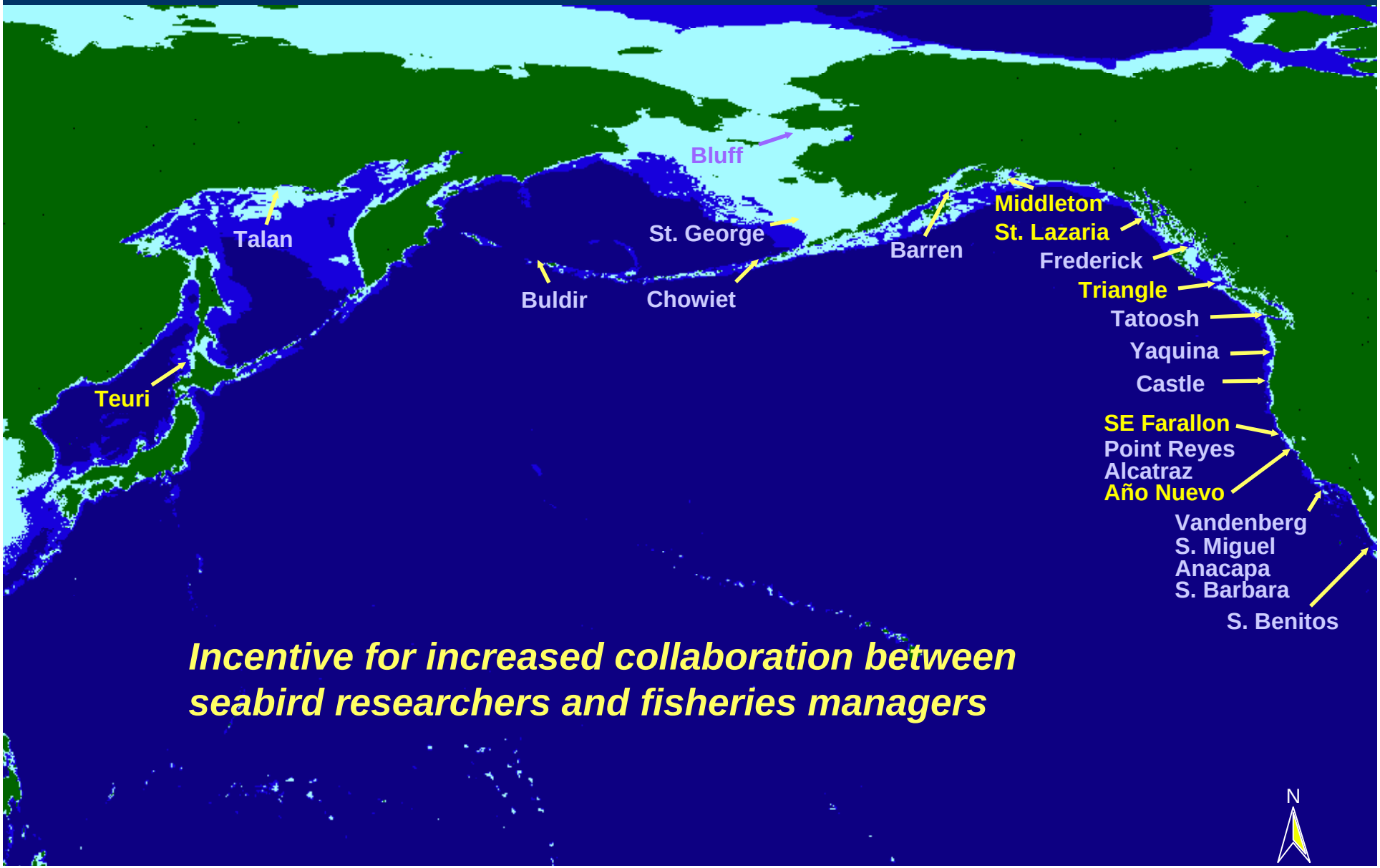
Stock Assessment

Fishery Dependent Data
(logbook data, etc.)

Fishery Independent Data
ROV
Trawl Surveys
Seabird Diet
Salmon Diet
Seabird breeding success

- California's Marine Life Management Act and federal law (Magnuson Act). Using seabirds may provide adaptive management of herring, salmon and rockfish.
- An ecosystem approach is important to improving forecasts of fish abundance and maintaining sustainable fisheries.

North Pacific Seabird Colonies with "Sufficient" Data to be Useful in Fisheries Management



Incentive for increased collaboration between seabird researchers and fisheries managers

ACKNOWLEDGEMENTS

People:

Diana Watters (CDFG)
Tom Laidig (NMFS)
Steve Ralston (NMFS)
Joelle Buffa (USFWS)
Nathan Mantua (JISAO)
Jen Roth (PRBO)
Julie Thayer (PRBO)
Christine Abraham (PRBO)

Agencies and Foundations:

U.S. Fish and Wildlife Service
California Dept. of Fish and Game
National Marine Fisheries Service
Pacific Fisheries Management Council
PRBO Conservation Science
Packard Foundation
National Fish and Wildlife Foundation
Moore Family Foundation
Bradford Foundation