Long-Term Observations of Seabird Density at Sea as Indicators to Shifts in Food Webs and Prey Resource Availability

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Outline of Talk

1. **Contrasting trends and variability in wintering seabird populations in the southern California Current Ecosystem (CalCOFI region)**

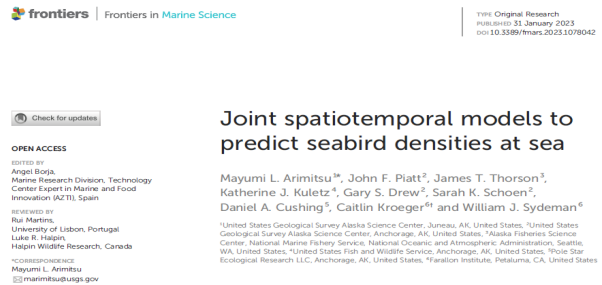
   - **comparison of piscivorous, omnivorous and planktivorous species**

2. **Recent changes in forage fish (anchovy/sardine) biomass in the domain**

3. **Relationships between seabird density at sea and prey availability, focusing on northern anchovy**

4. **Present hypothesis: recent shift to "wasp-waist" control (with coupled demise of sardine, and rapid, sustained population growth of anchovy)**

Vector Autoregressive Space Time (VAST) Models Based on on Long-Term CalCOFI Wintertime Seabird Observations ("reanalysis" product: density: birds/km^2)



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Joint spatiotemporal models to predict seabird densities at sea

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SEABIRD SIGNALS

Off the U.S. West Coast, several seabird species are suffering, and biologists suspect that global warming's impact on the Pacific is to blame

BY DOUGLAS CONE

Cassin's auklets may look nothing like canaries, but in a way that's what they are. These plump, dusky gray seabirds, like the prescribed birds in the coal mine, are telling scientists there is something wrong in the Pacific Ocean. In the 1970s, about 100,000 pairs of auklets nested on California's remote Farallon Islands. Today only 20,000 pairs remain. In 2005 and 2006, not one of the birds' eggs hatched, and only about a third of the pairs fledged young in 2007. "We see signals in birds," explains seabird biologist Bill Sydeman. "They're the best indicators of what's going on." As president of the

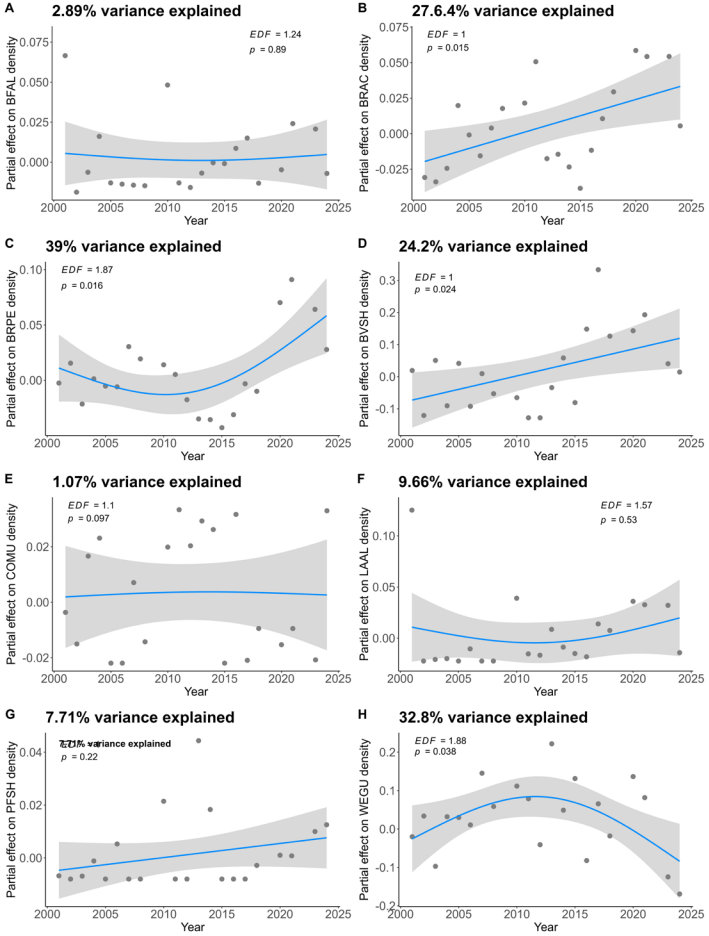
A TUFTED PUFFIN "FLIES" underwater as it pursues small fish. Like all members of the auk family, the bird is more at home in the ocean than it is on land or even in the air. Auks frequently dive as deep as 100 to 300 feet.

- Joint Dynamic Species Distribution Model (JDSDM)
  (uses species to covariance to predict other species)
- Covariates: latitude, longitude, water depth, distance from coast
  - Dependent variable: hurdle model
    (first P/A then density (*delta-gamma*)).
    - Deviance explained: ~35%

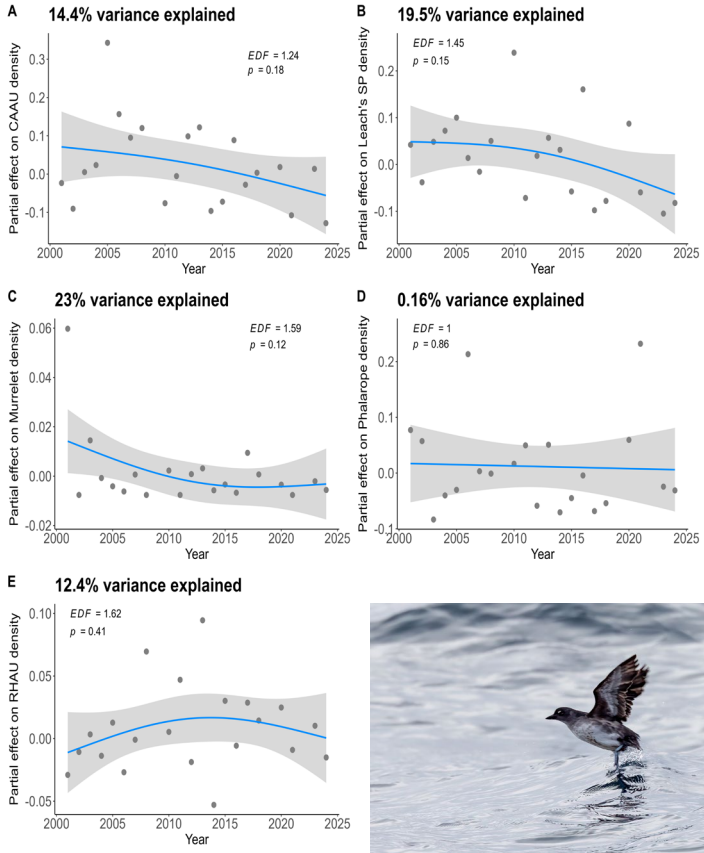
➢ **average spatially-explicit (gridded) estimates of seabird density to obtain annual density estimates**

➢ **Use GAMs to examine species to guild trends in population abundance**

GAM Trends: Piscivores (n=8 spp.)

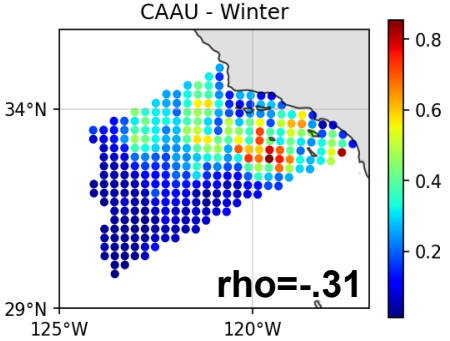


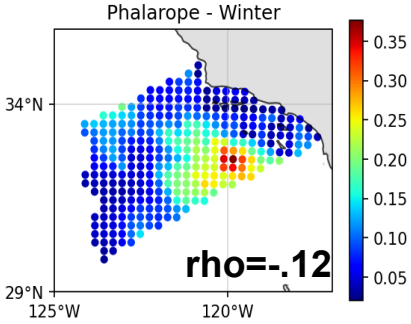
Planktivores (n=5 spp.)

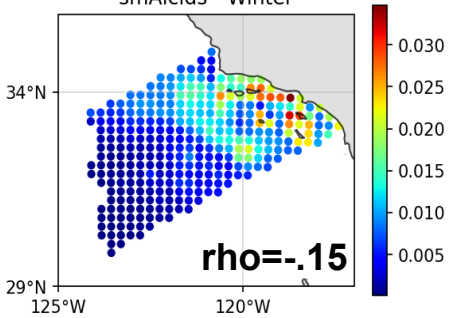


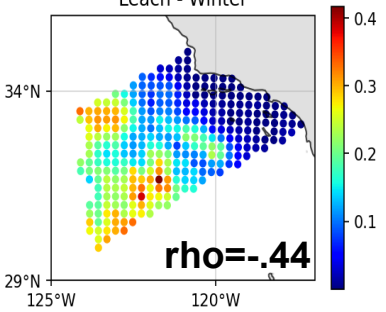
Planktivores (top row): Pelagic Distribution

(rho = rank correlation, thru 2026)

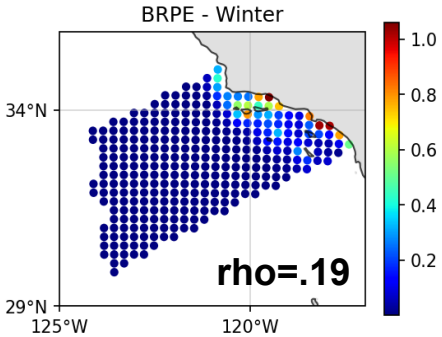


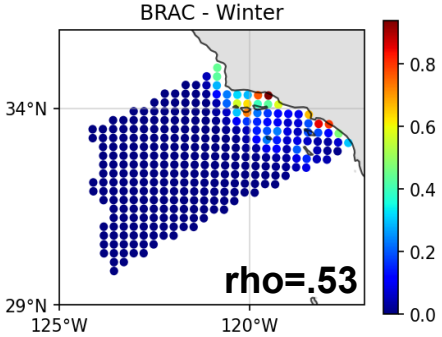


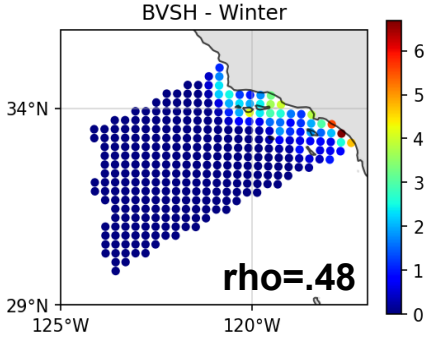




Piscivores (bottom row): Neritic Distribution







Forage Fish Biomass

Central Stock of Northern Anchovy (range along California)



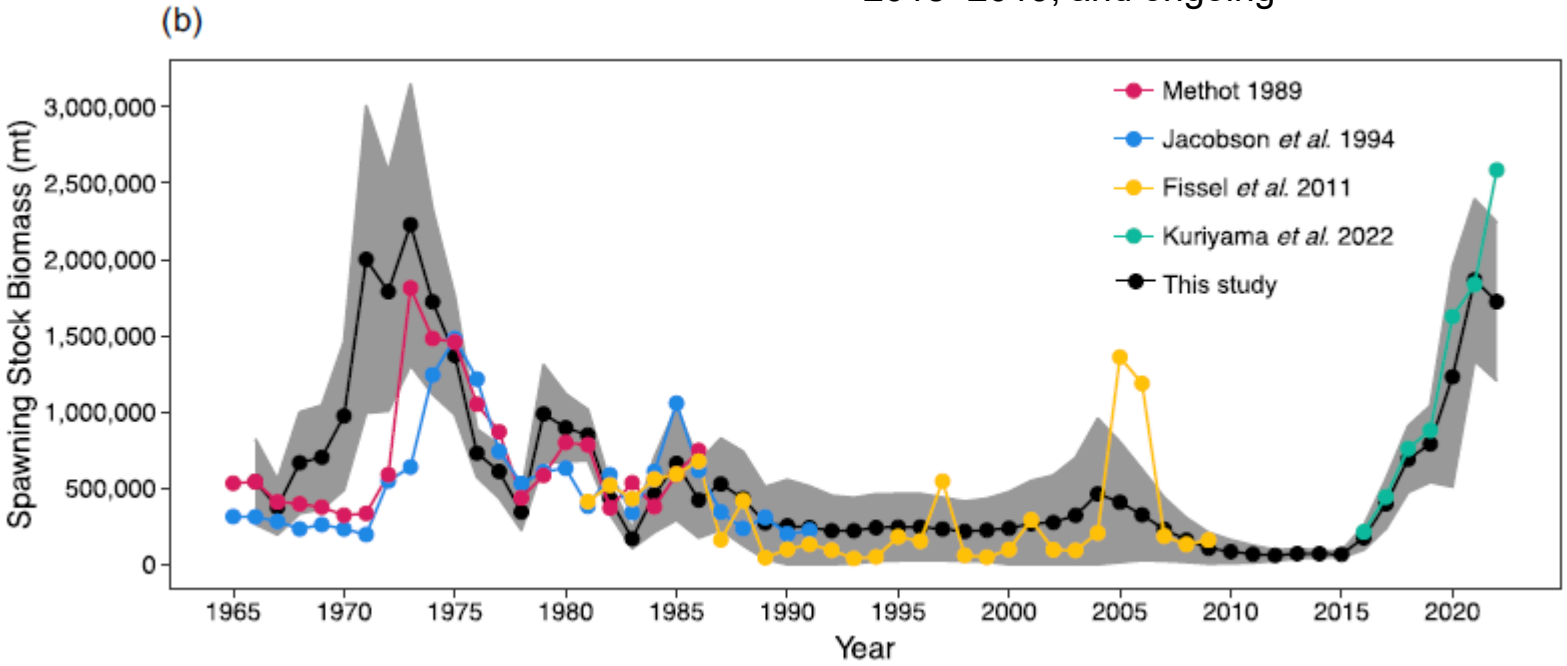




Arguably, the most important forage fish for seabirds and marine mammals of the California Current Ecosystem, particularly in the Southern CCE

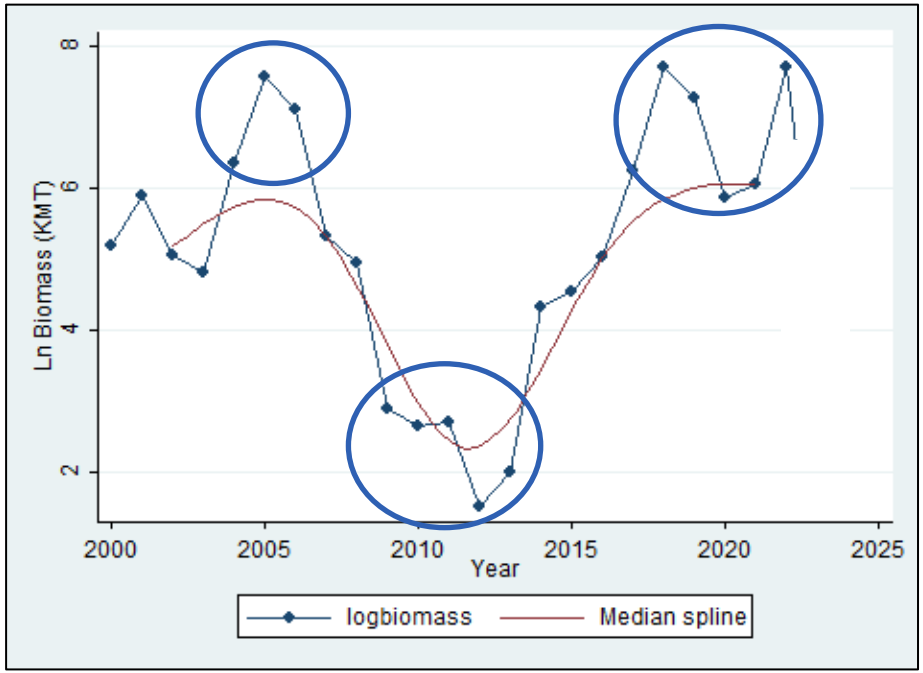
Anchovy Biomass (MMT)

unusually strong recruitment beginning in 2015, reinforced by very high recruitment in 2018–2019, and ongoing



Hinchcliffe et al. 2025 ICES JMS

Northern Anchovy Biomass (log scale, RELSSB), 2000-2023



Thayer, et al. 2017, unpublished. Biomass estimates based on approach of MacCall et al. 2010 (Fish. Res.)



Biomass peak in 2004-2006 (~2 MMT)
Biomass collapse in 2009-2013 (5 years)
Biomass recovery, peak in 2018-2023 (~2-3 MMT), ongoing,

Record high egg and larval counts in 2024-2026 (CalCOFI surveys, NOAA/SIO)

2009-2015 Anchovy Collapse Was Not Due to Fishery

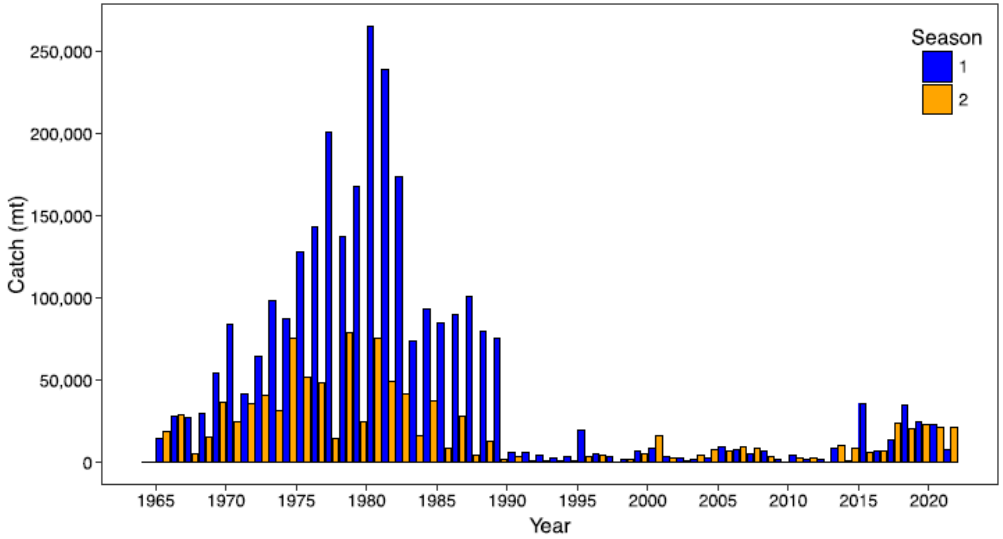


Figure 2. Catch (mt) of northern anchovy by season for combined port landings from central and southern California, USA, and Ensenada, Mexico.

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Sardine Biomass (ATM survey, 2025 stock assessment)

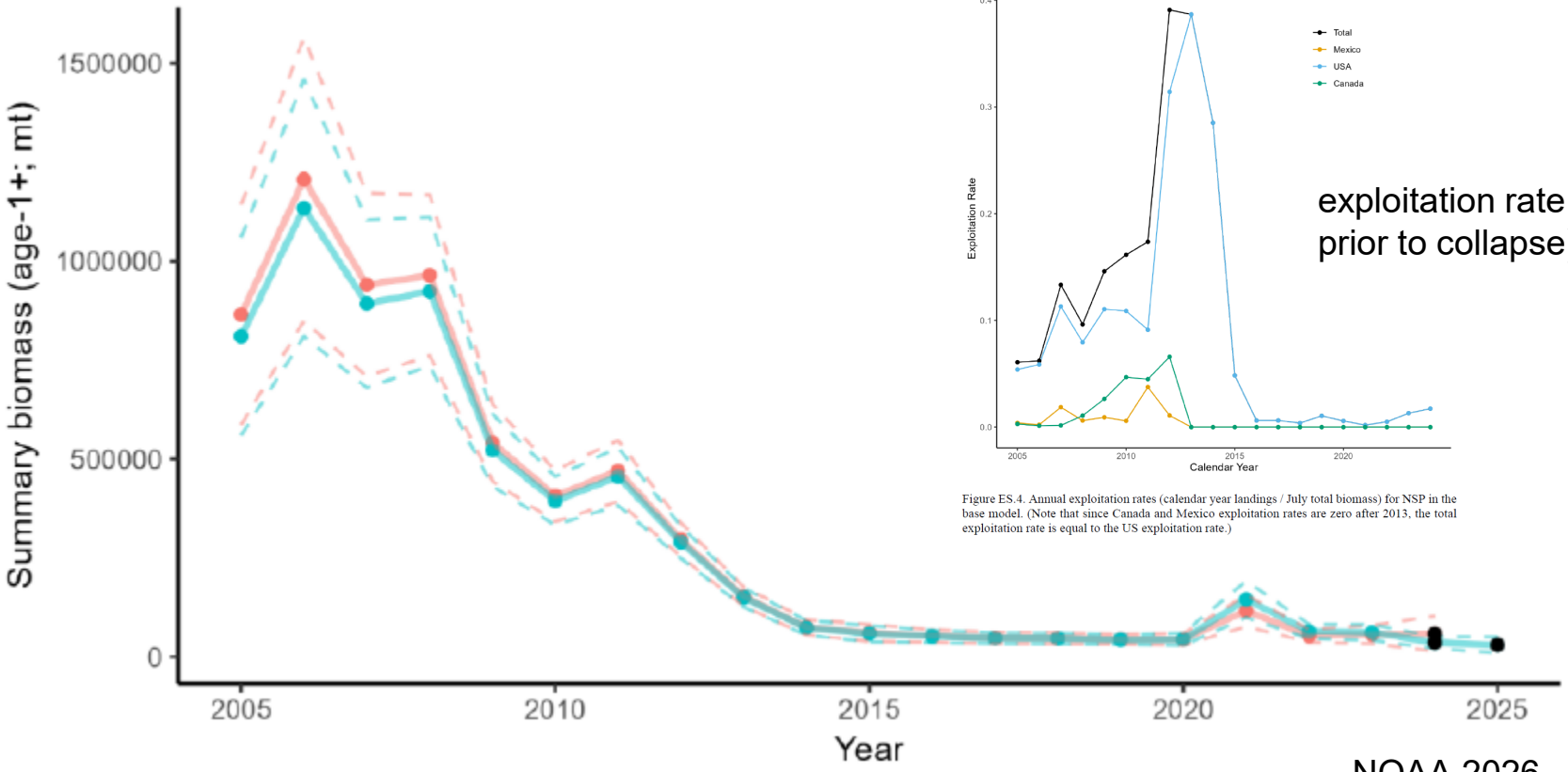


Figure ES.4. Annual exploitation rates (calendar year landings / July total biomass) for NSP in the base model. (Note that since Canada and Mexico exploitation rates are zero after 2013, the total exploitation rate is equal to the US exploitation rate.)

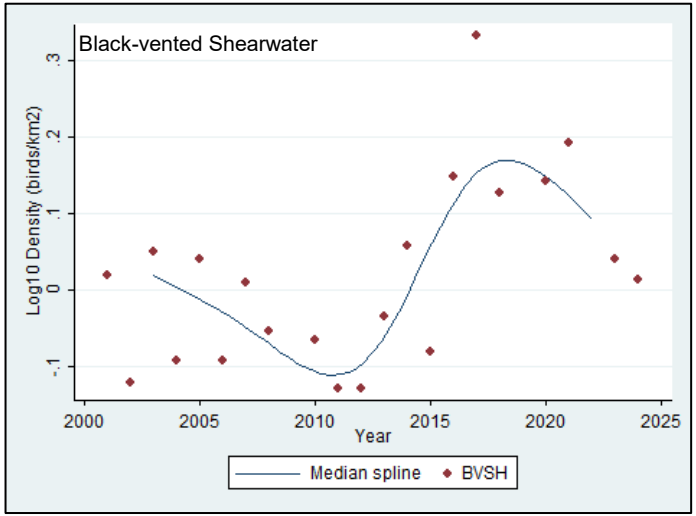
exploitation rate (~.4 prior to collapse)

NOAA 2026

Seabird Relationships to Forage (Anchovy) Biomass?

Multiannual Variability: 3 piscivorous seabirds

- these species show complementary patterns of change over the past decade, from low density during the anchovy collapse to high density in the early 2020s.

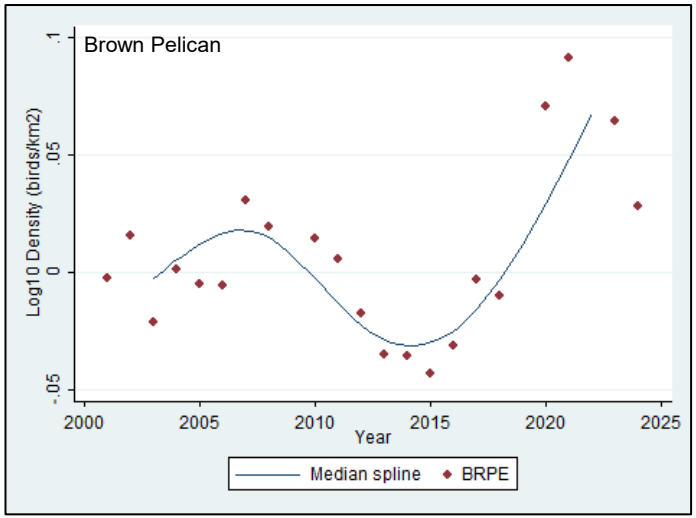


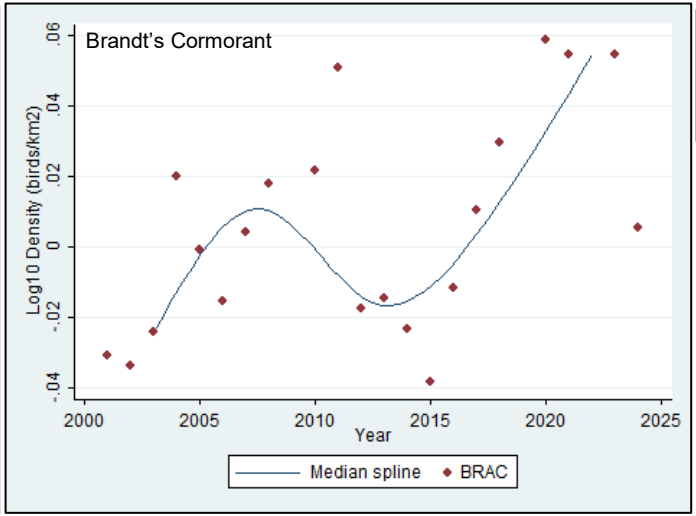


Regional Breeder/ Migrant to CalCOFI region.



Local Breeder

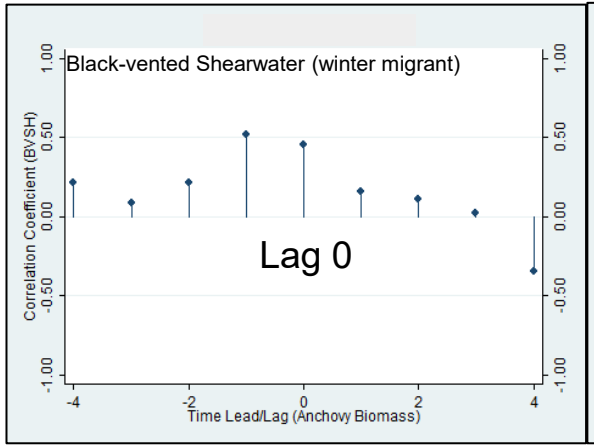


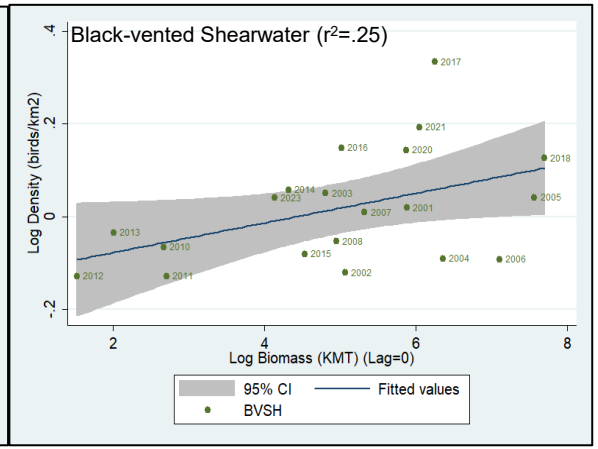




Local Breeder

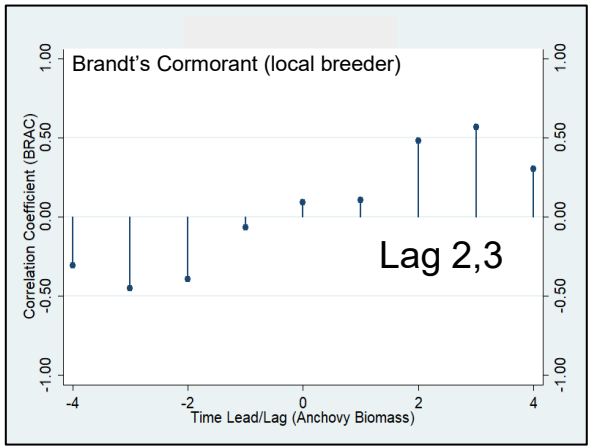
Cross Correlations: Piscivorous seabirds and anchovy biomass

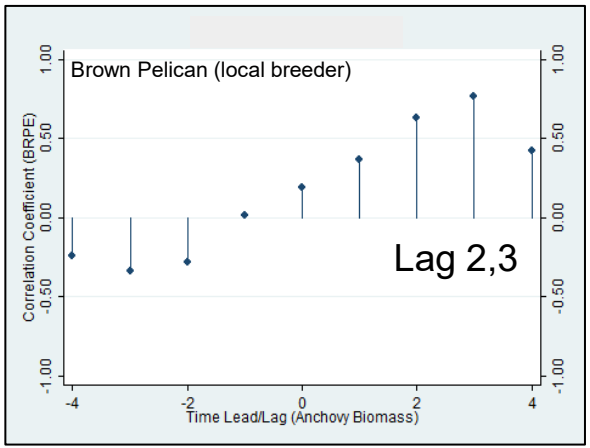




No lag, rapid response.

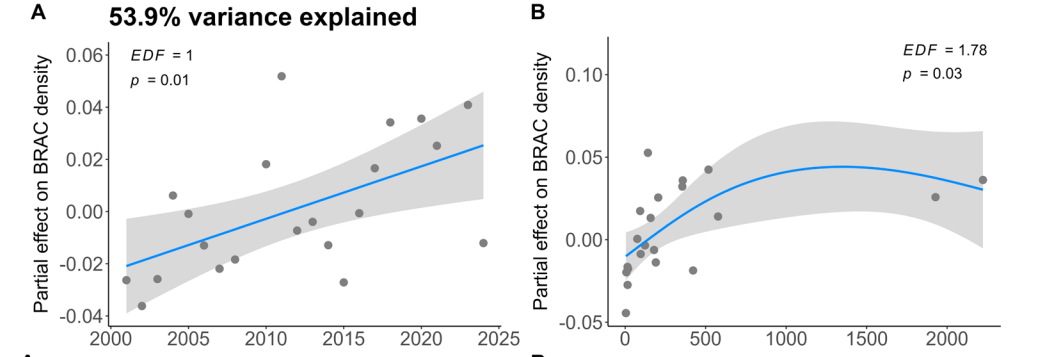
- Movement, redistribution, but explanatory power is weak.

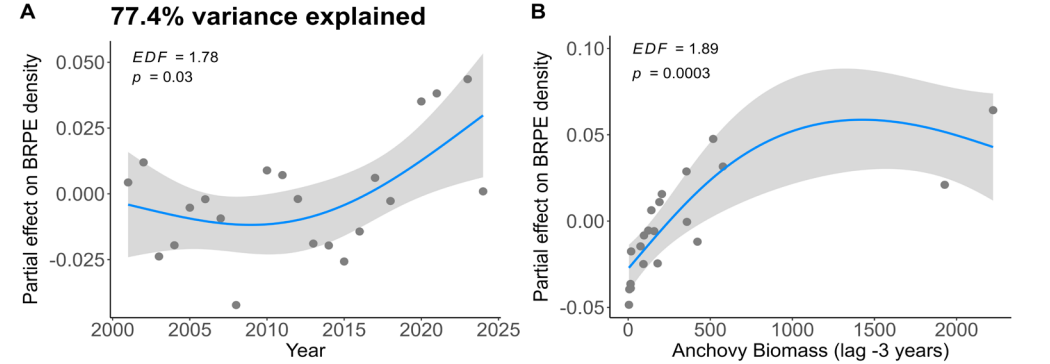


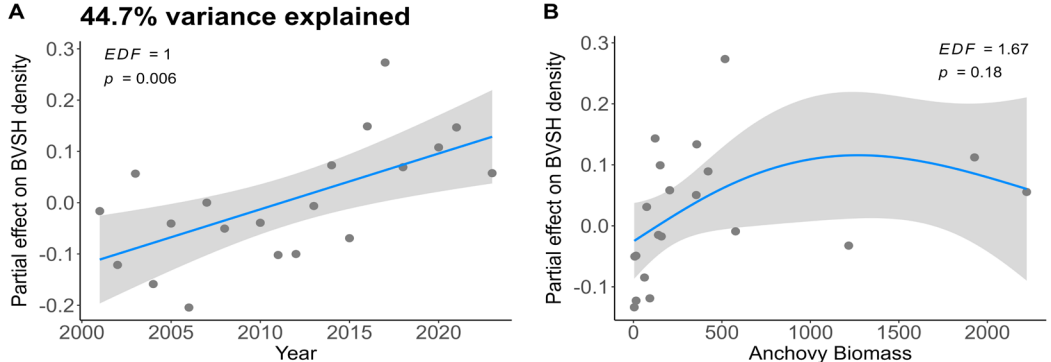


Substantial lag, delayed response. Lag matches age at first breeding

- recruitment or other demographic response is affecting population growth and density at sea.







GAMs

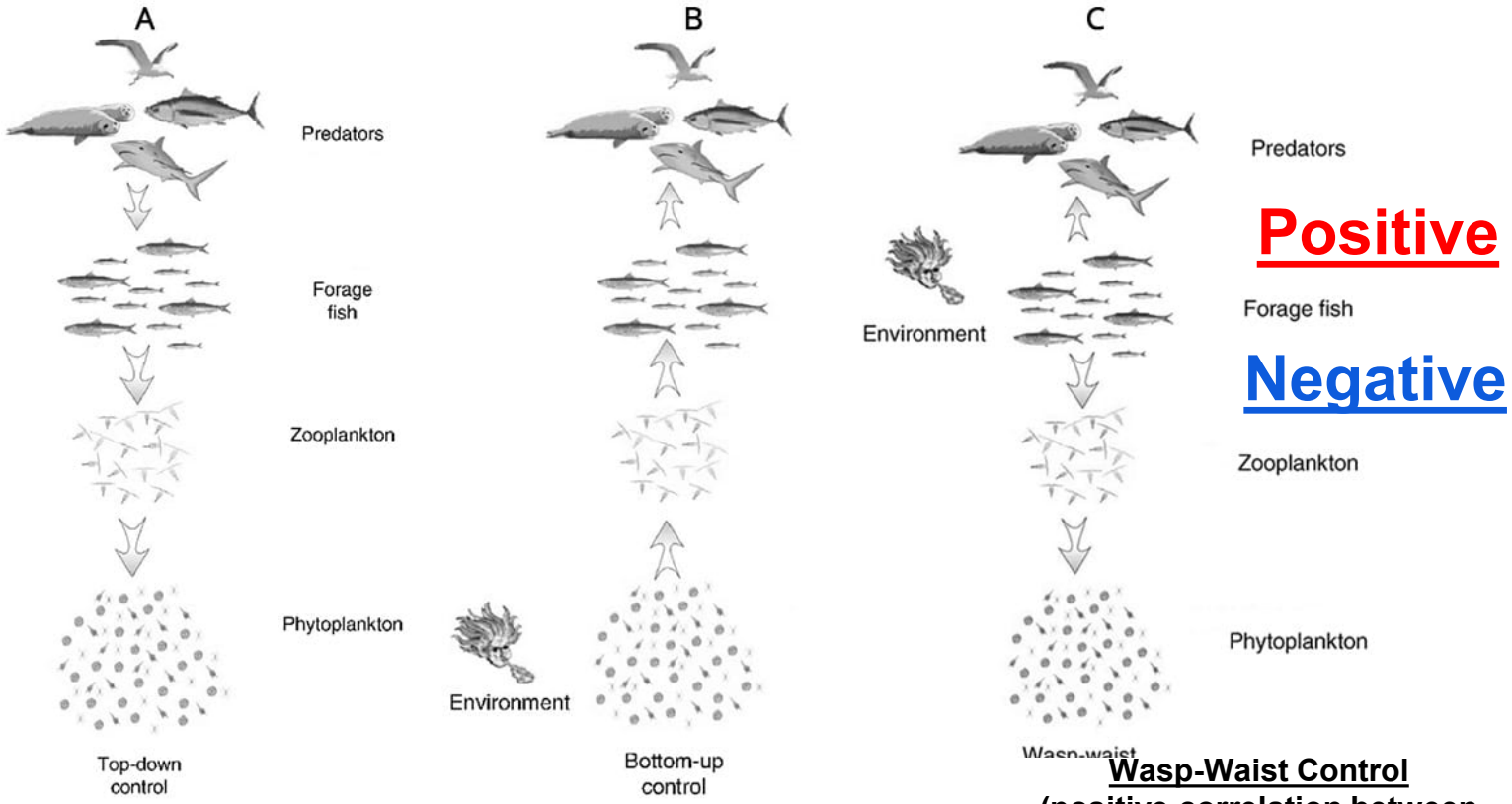
Seabird Density ~ Year + Anchovy Biomass

- Lagged by 3 years (top panels)
- No Lag (bottom panel)

➢ Type II Aggregative /Numerical Responses

Hypothesis

Hypothesis: Recent Shift to "Wasp-Waist" Food Web Dynamics



Positive

Negative

(positive effects between all trophic levels, from phytoplankton to predators)

Wasp-Waist Control
(positive correlation between forage fish and predators, but negative correlation with zooplankton biomass)

Summary – Why Wasp-Waist Control?

i) **Contrasting responses by guild: post 2015: decreasing density at sea of offshore obligate planktivorous seabirds; also, increasing abundance of neritic piscivorous seabirds, strongly related to variability in regional anchovy biomass; omnivores – no change.**

- **local breeders (pelican, cormorant) related to prey availability, but lagged by 2-3 years, suggesting relationship to seabird breeding success and a delayed population-level response, measured by density at sea.**

ii) **observed a fundamental change in food web structure (collapse of sardine), with simultaneous very high (PERHAPS RECORD) abundance of a single dominant forage fish spp. (anchovy) in the S-CCE.**

iii) **Anchovy take over; with no/few sardine in offshore/pelagic environment (notably where the planktivorous seabirds reside), zooplanktivorous anchovy can expand offshore, and consume zooplankton there, exerting "top-down)" and impacting prey availability of pelagic seabirds in this domain.**

iv) **WINTER – key season for interesting predator-prey dynamics; sets the stage for spring and summer productivity; can provide informative and interpretable results on seabirds as responders and indicators of major shifts in coastal-pelagic food webs and prey availability to predators.**

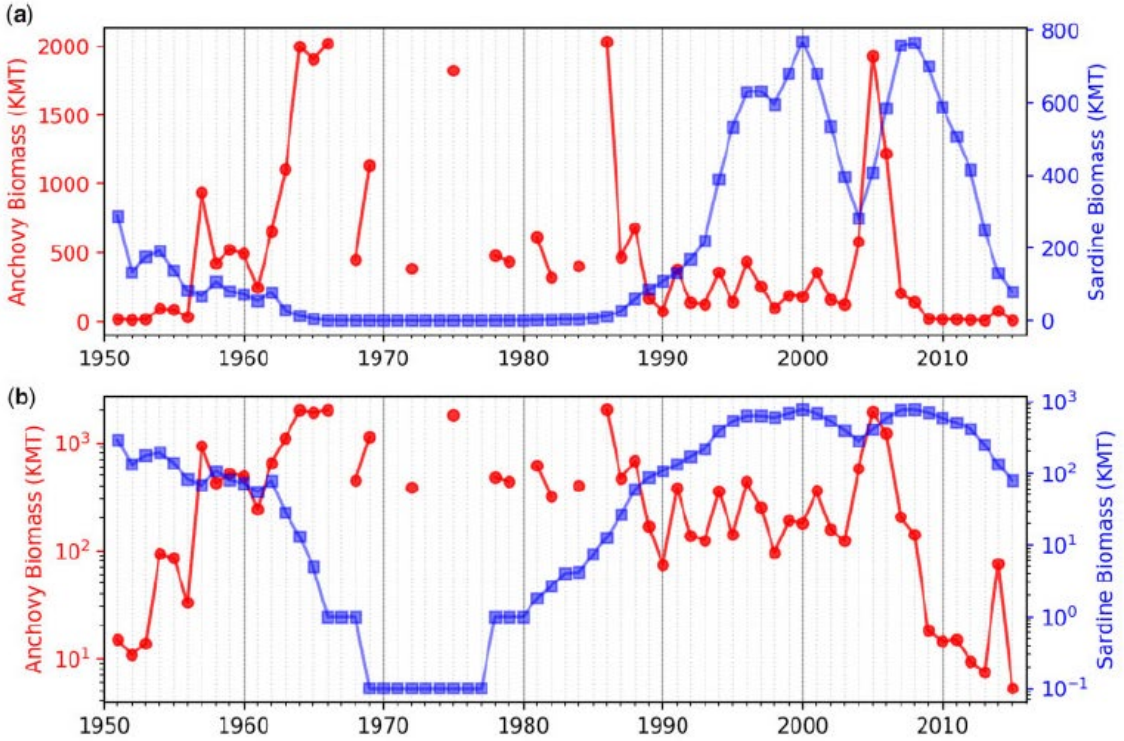
Seabirds as indicators of change in marine ecosystems

Interactive Webstory

https://seabirds.farralloninstitute.org/



Anchovy (red) and Sardine (blue) Biomass, 1951-2015



- **Collapse of anchovy ~2009-2015**
- **Collapse of sardine ~2015-present;**
- **CA sardine fishery currently closed**

Sydeman et al. 2020 ICES JMS

Figure 2. Biomass of CSNA and Pacific sardine 1951–2015 on (a) linear and (b) logarithmic scales. CSNA data are from MacCall *et al.* (2016) and were updated by Thayer *et al.* (2017). Sardine data are from Hill *et al.* (2017), with early data standardized by ADM (unpublished data).