Evaluation of the impact of forage fish fishing on upper predators

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Thanks to collaborators

Thanks to funders

- Hilborn, Amoroso, Szuwalski -- IFFO and SNP and other industries
- Jensen
- Parma – none
- Walters

Forage fish are important

- The largest fisheries in the world
- Provide 50% of fish inputs to aquaculture
- Are important elements of marine food chains

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MARINE ECOLOGY PROGRESS SERIES
Mar Ecol Prog Ser

Published October 9

Contribution to the Theme Section 'Trophodynamics in marine ecology'

FREE ACCESS

A century of fish biomass decline in the ocean

Villy Christensen[1,*], Marta Coll[2,3], Chiara Piroddi[4], Jeroen Steenbeek[3], Joe Buszowski[3], Daniel Pauly[1]

This study allowed us to predict the biomass trends for higher trophic level fish, i.e. the larger predatory fish', as well as for the lower trophic level prey fish, such as small pelagic fish (e.g. sardines, anchovies, capelins),

Our results predicted that the biomass of predatory fish in the world oceans has declined by two thirds over the last 100 years.

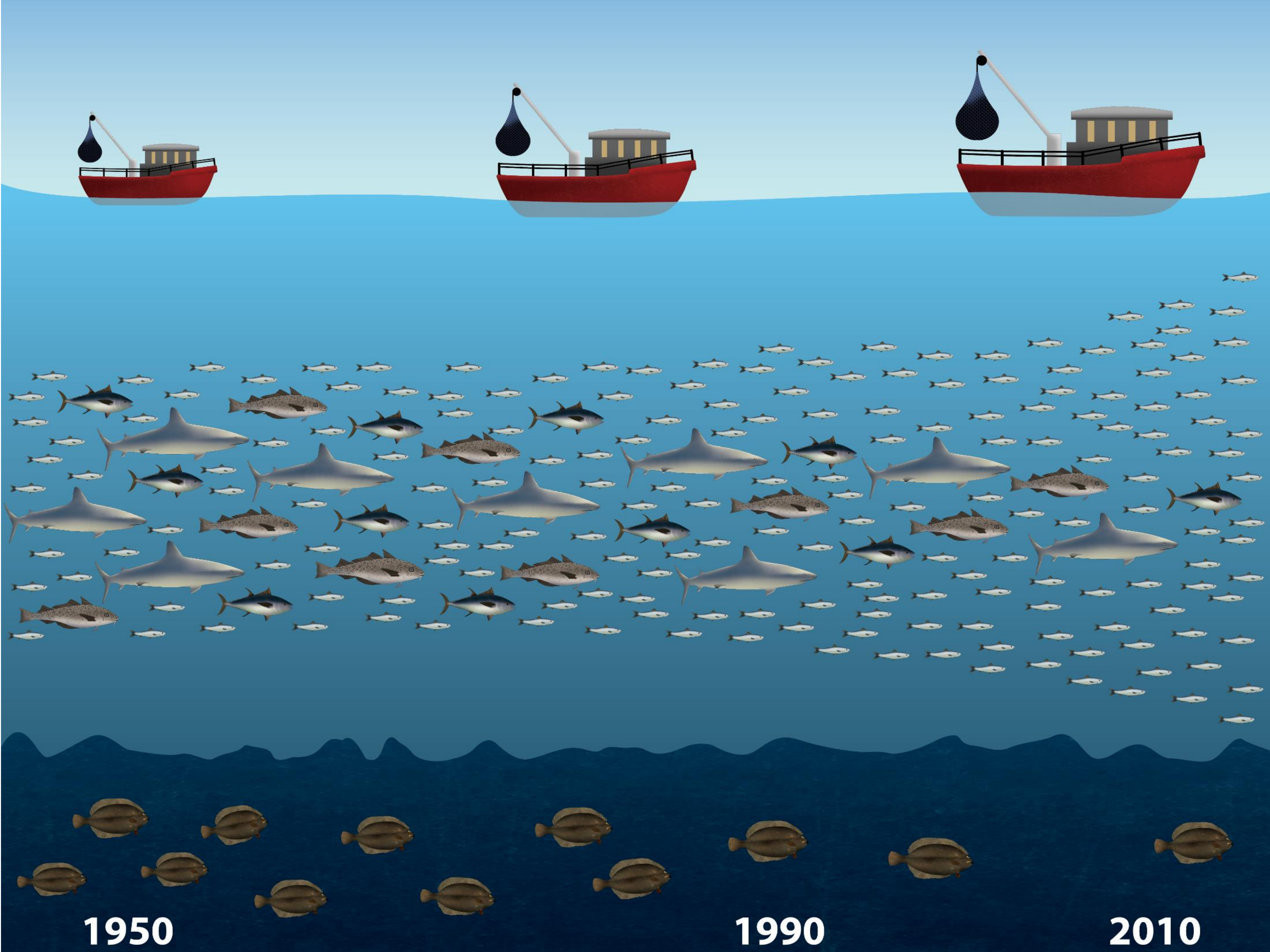
The biomass of prey fish had been increasing over time .. this corresponds to a 130% increase, suggesting that there are now more than twice as many prey fish in the global ocean as there were a century ago,

Some simple calculations

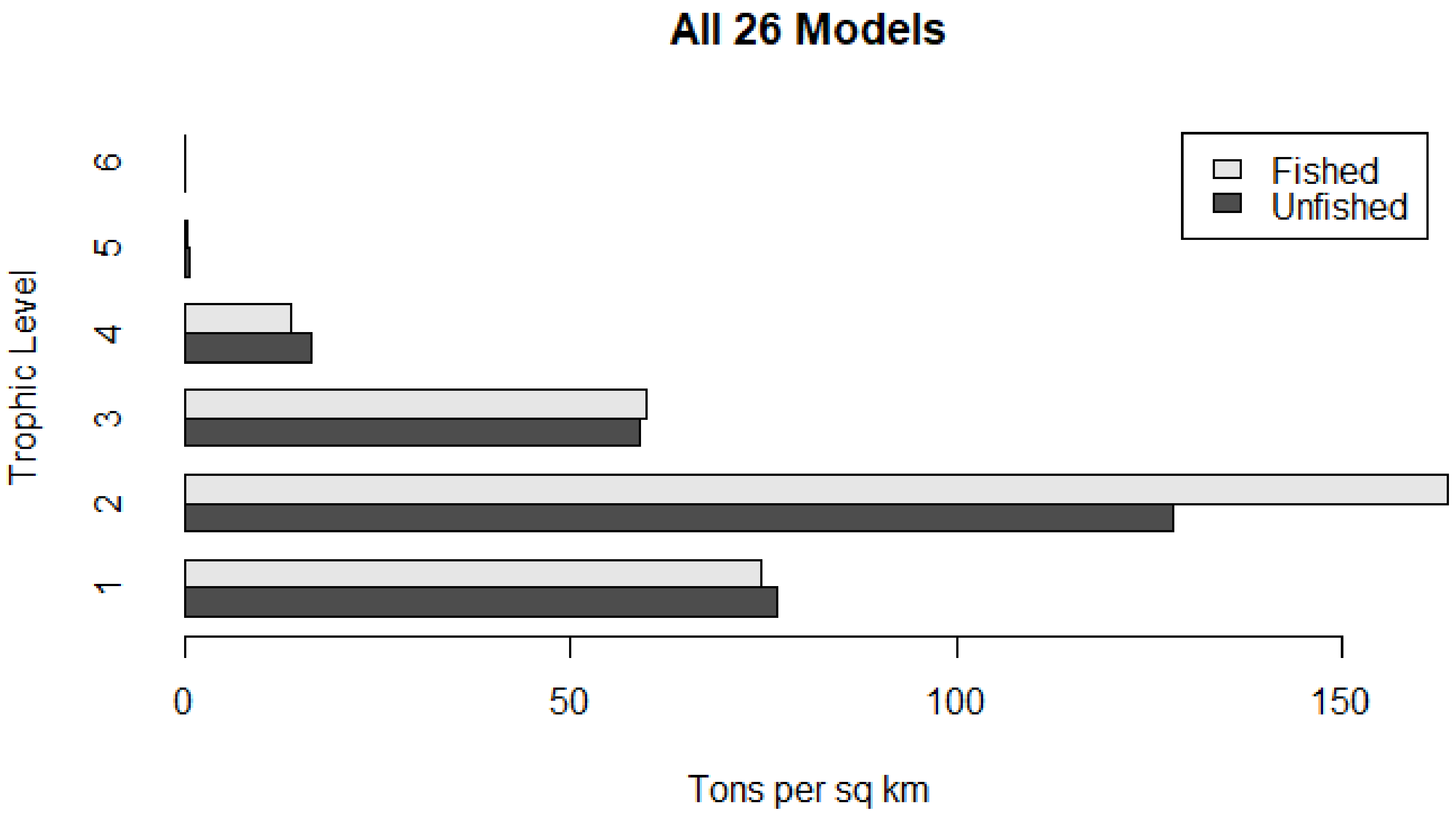
- Predator fish (trophic level 3.5 and higher) down by 2/3 (at BMSY)
- Prey fish (trophic level 2.5 to 3.5) more than double
- Total abundance goes down several fold for each trophic level

WOW

- There are more fish in the oceans now than before fishing began (whether in numbers of tons)
- AND a lot more prey fish for predators

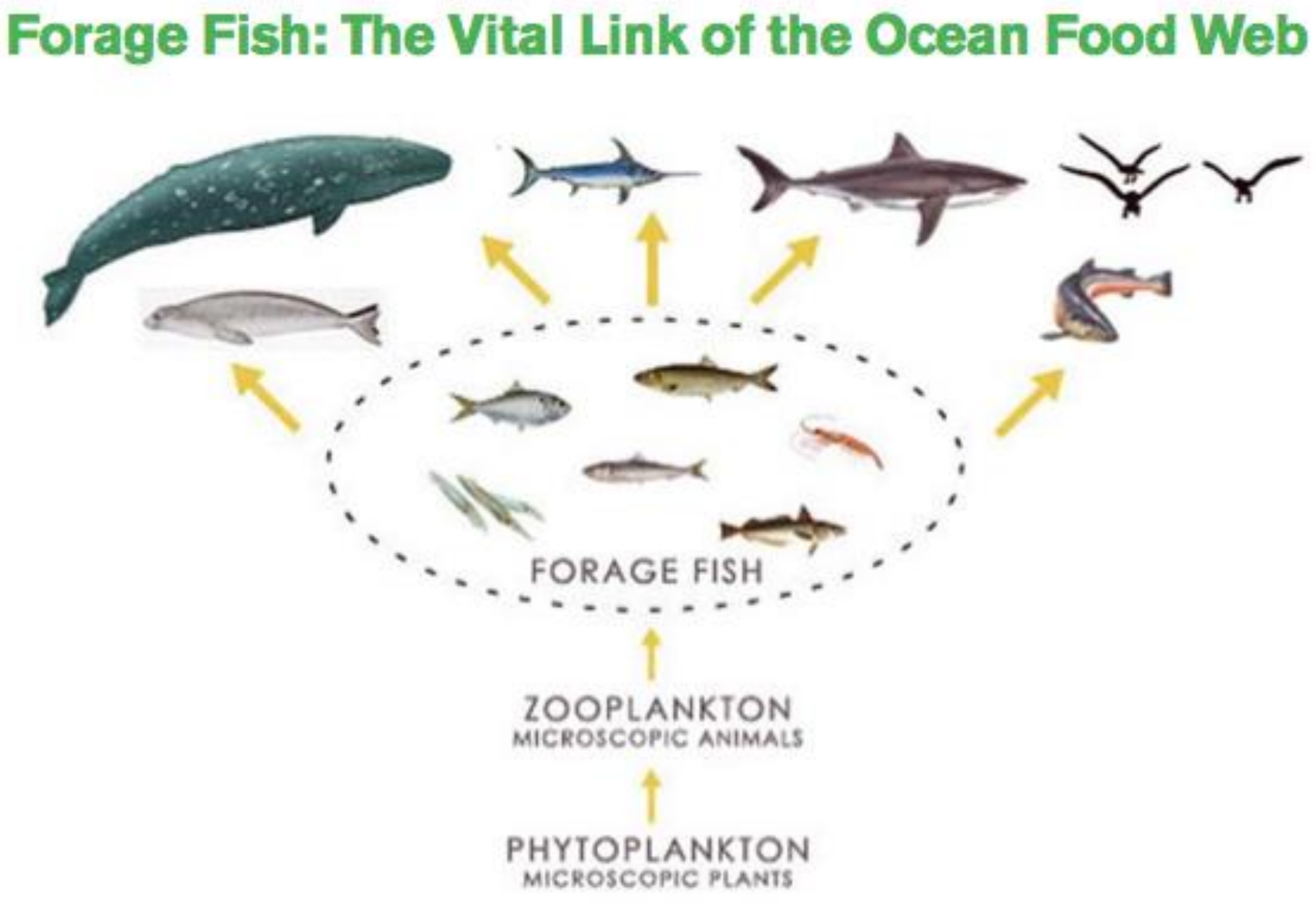

1950
1990
2010

26 Ecosim Models from Beth Fulton



goo
news for the
predators of
forage fish
predators – isn’t
it?

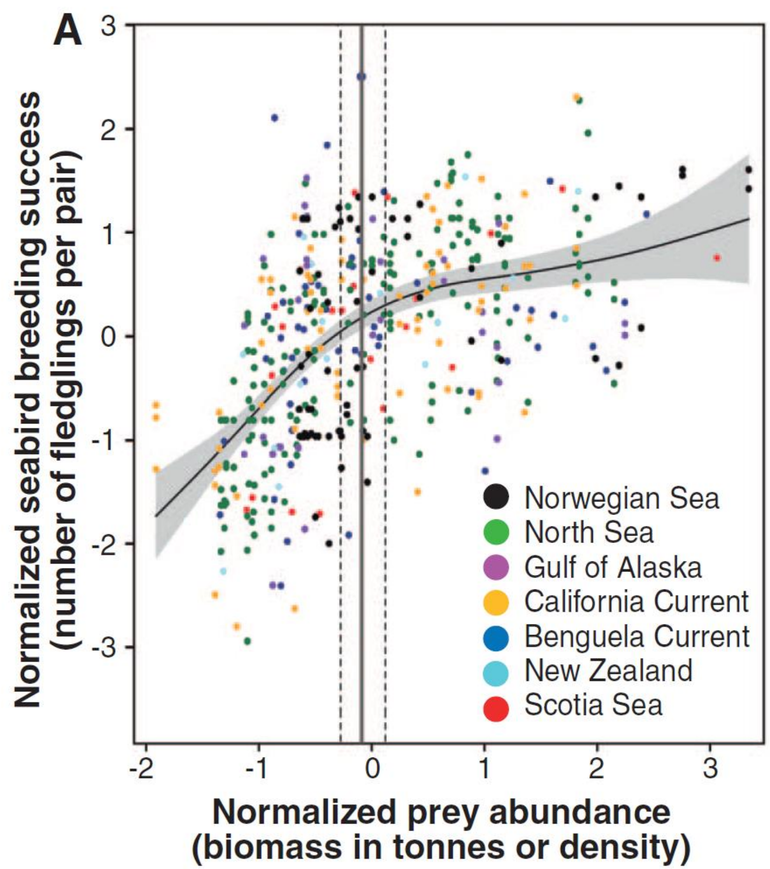
The Sea Around US



https://allyouneedisbiology.wordpress.com/2015/05/07/forage-fish/

Global Seabird Response to Forage Fish Depletion—One-Third for the Birds

Philippe M. Cury,[1*] Ian L. Boyd,[2*] Sylvain Bonhommeau,[3] Tycho Anker-Nilssen,[4] Robert J. M. Crawford,[5] Robert W. Furness,[6] James A. Mills,[7] Eugene J. Murphy,[8] Henrik Österblom,[9] Michelle Paleczny,[10] John F. Piatt,[11] Jean-Paul Roux,[12,13] Lynne Shannon,[14] William J. Sydeman[15]



A SUMMARY OF NEW SCIENTIFIC ANALYSIS

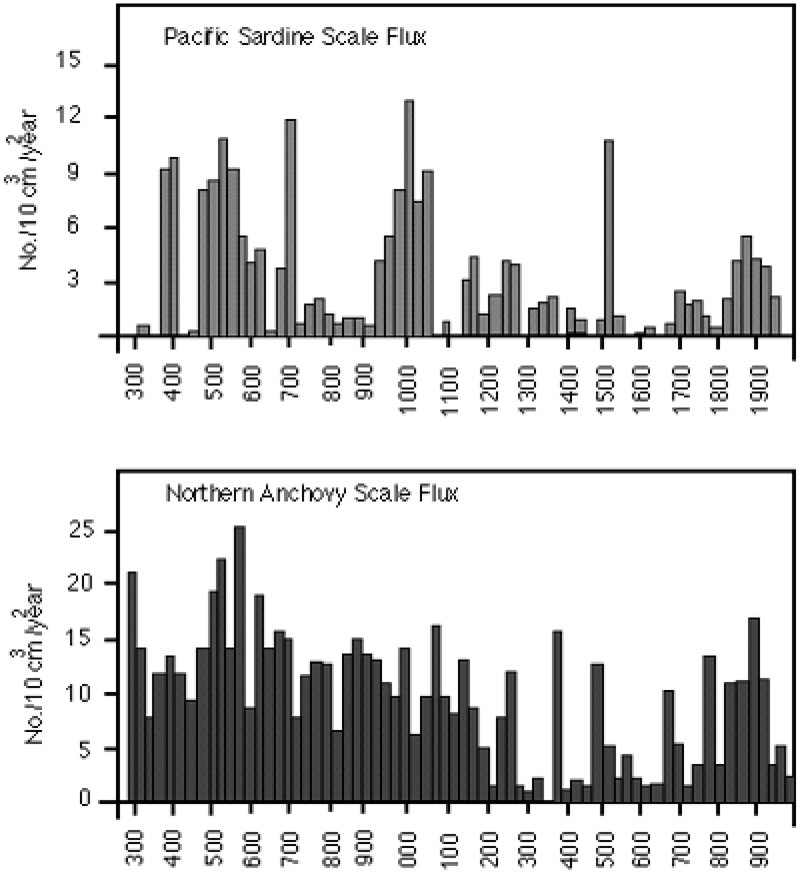
Managing a crucial link in ocean food webs

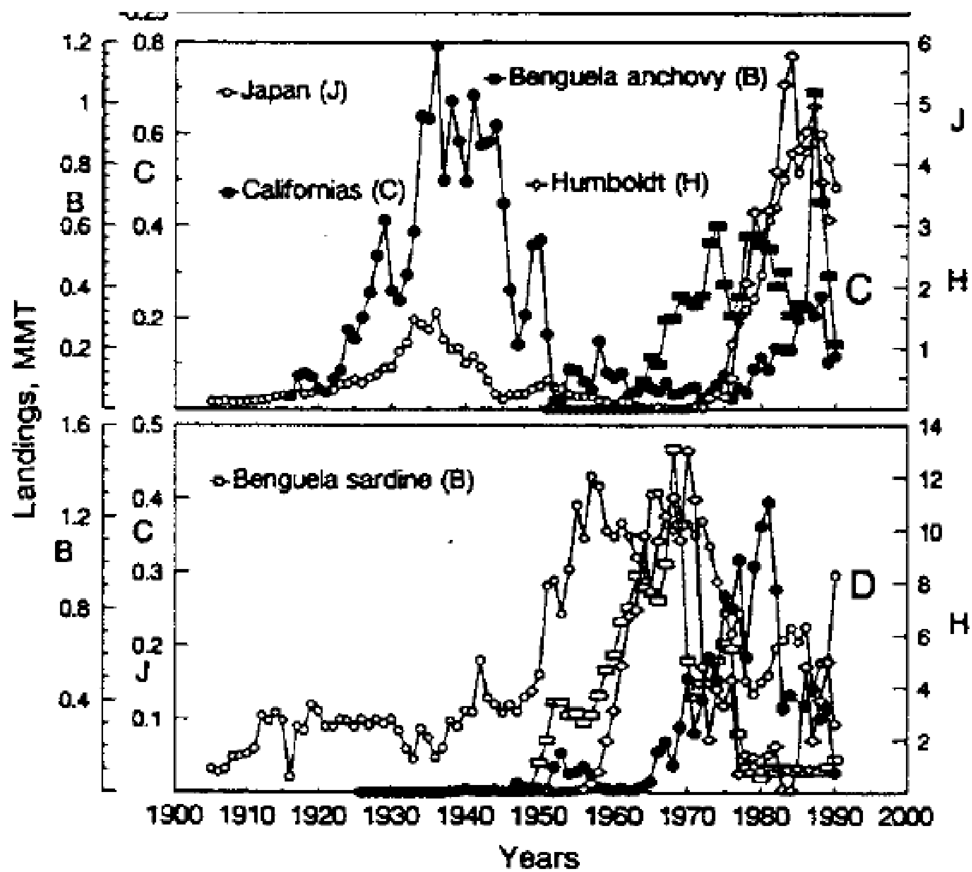
Summary of a report from the Lenfest Forage Fish Task Force

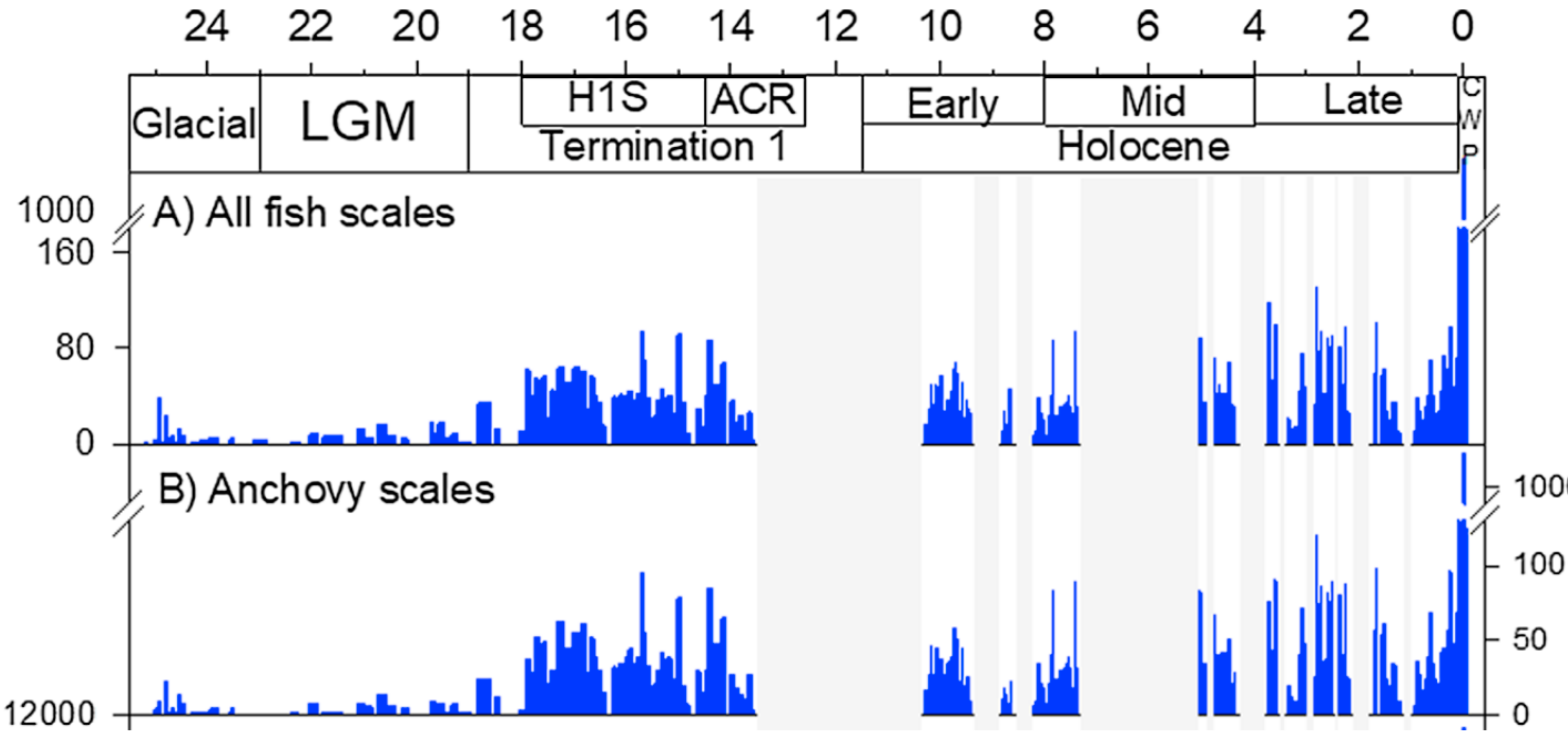
Key Characteristics of Forage Fish Population Dynamics

- Great natural variability in recruitment and productivity
- Range contraction and expansion with abundance and range shifts due to natural factors
- Recruitment largely unrelated to population size

Great Natural Variability

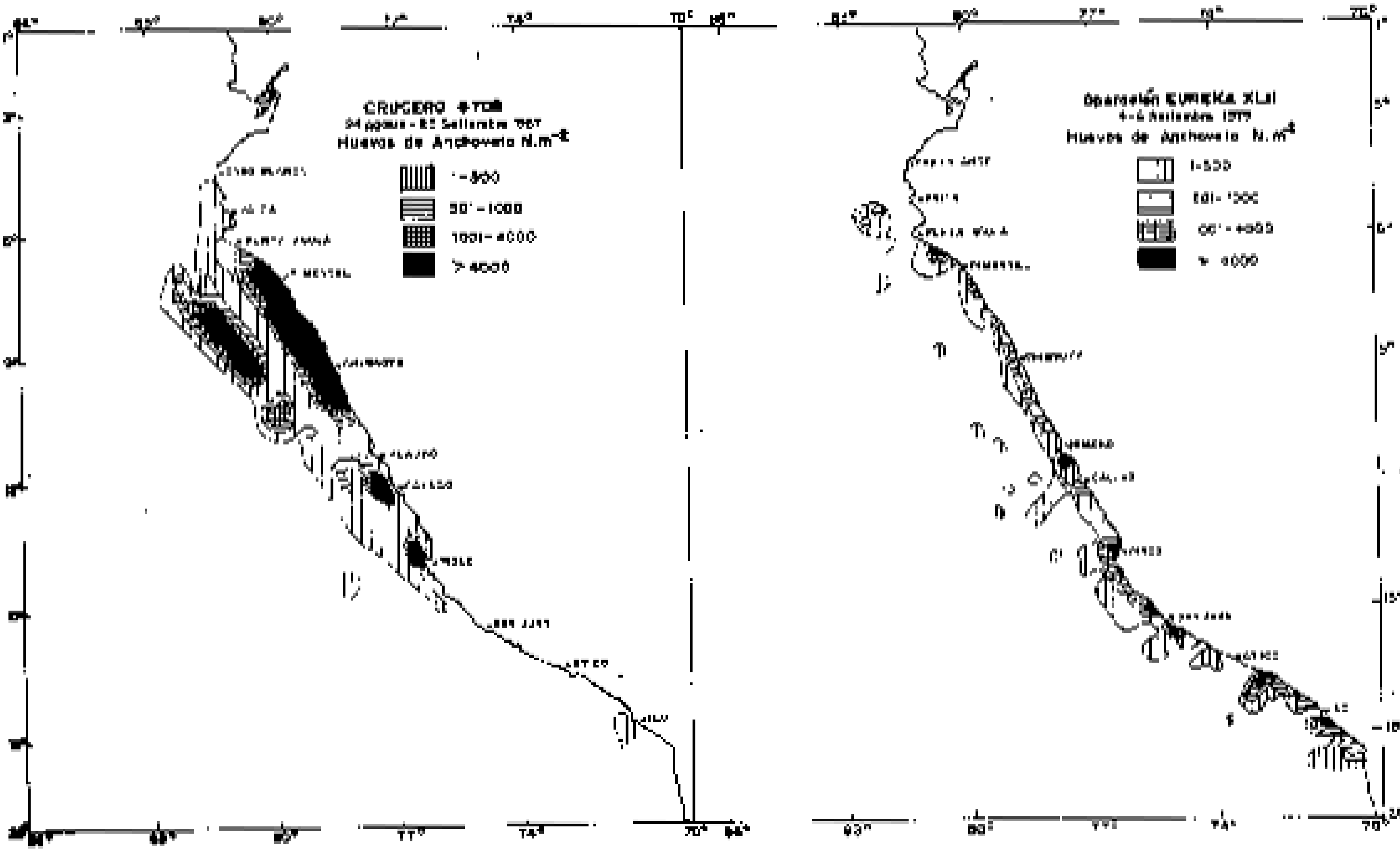






Salvatteci R, Gutierrez D, Field D, Sifeddine A, Ortlieb L, Caquineau S, et al. Fish debris in sediments from the last 25 kyr in the Humboldt Current reveal the role of productivity and oxygen on small pelagic fishes. Prog Oceanogr. 2019.

Range contraction and expansion



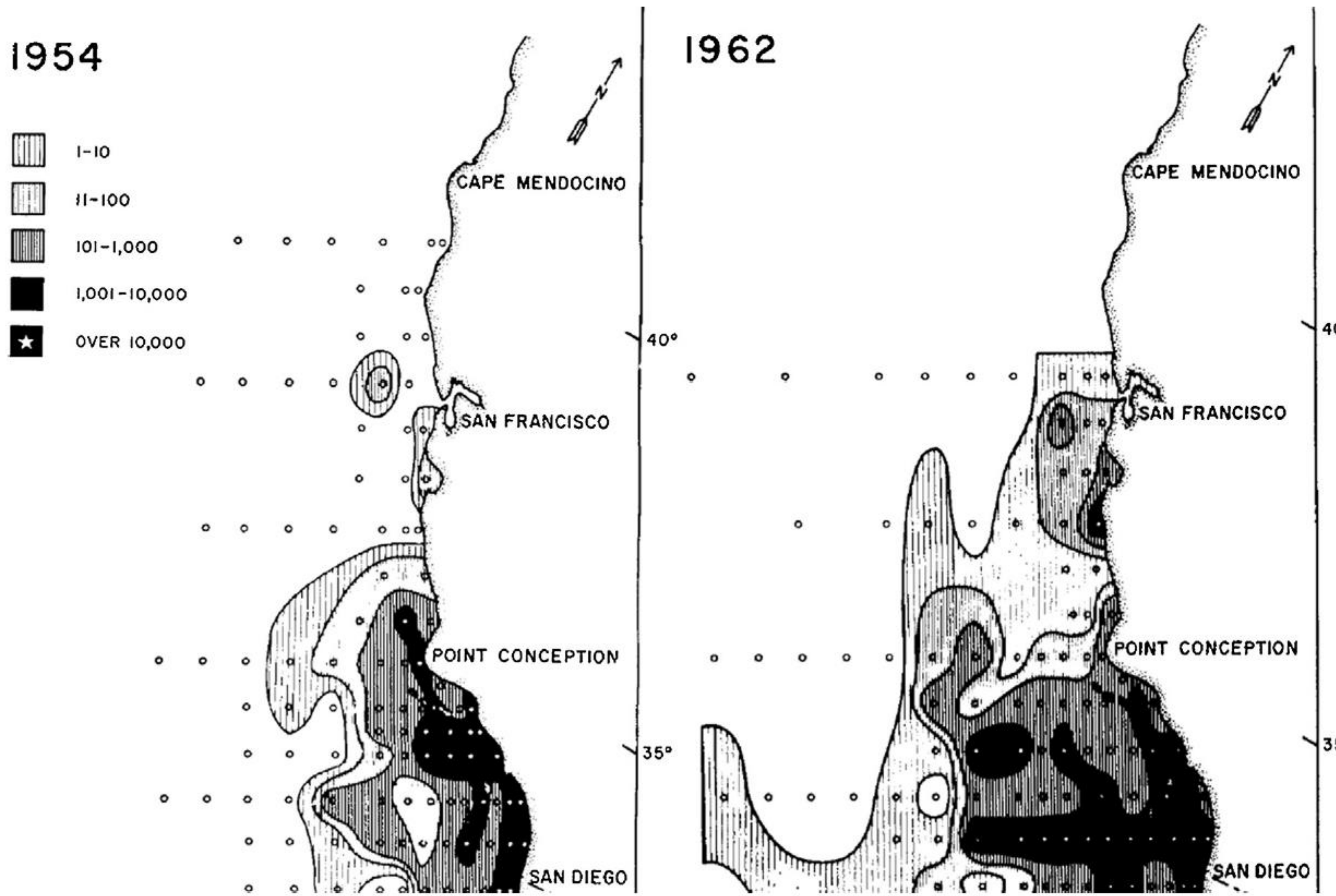
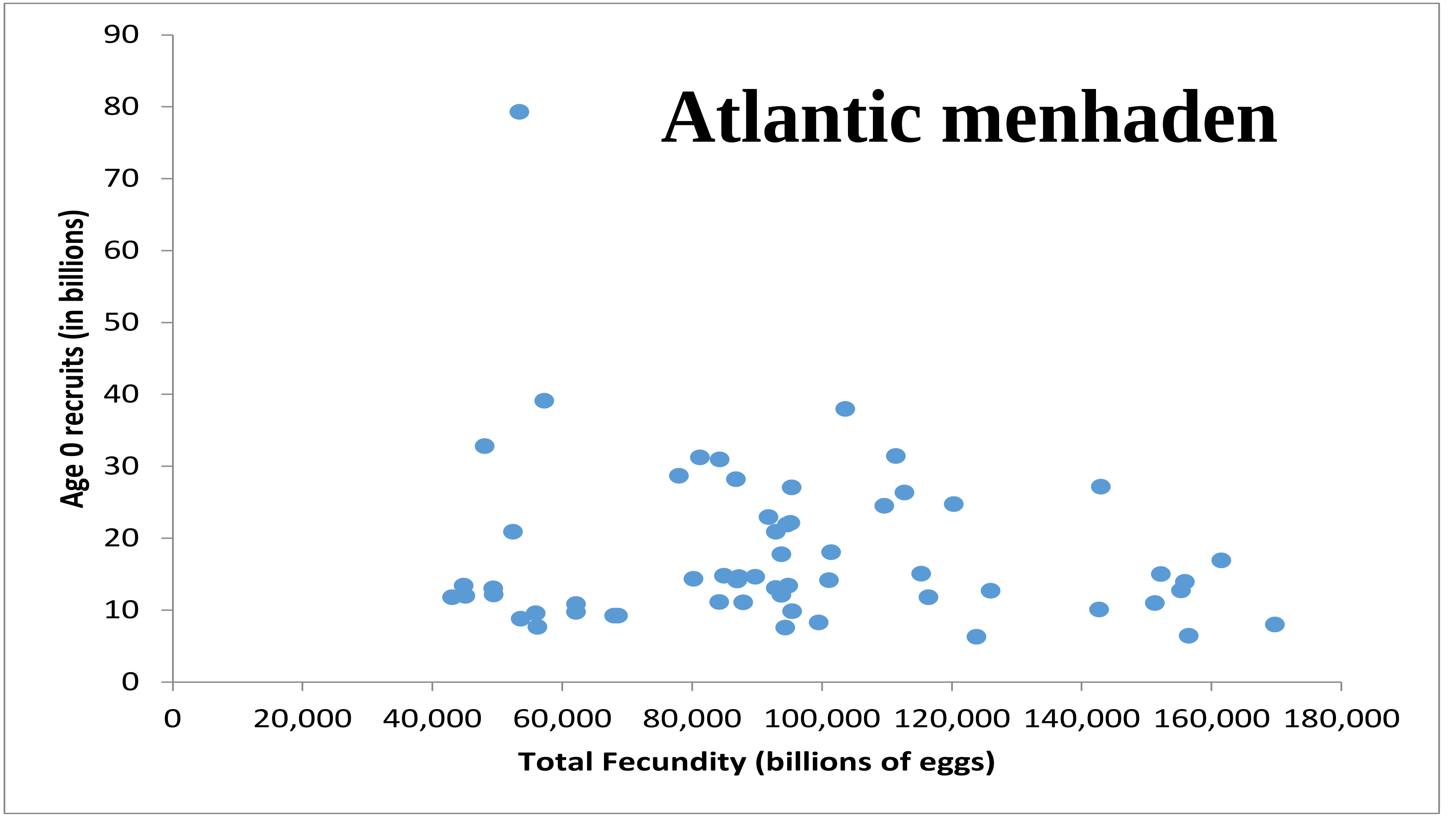


Fig. 2. Comparison of southern California anchovy larval distributions at low population size (left) and high population size (right) showing areal expansion when the is more abundant. Taken from Kramer and Ahlstrom (1968).

Recruitment largely unrelated to population size



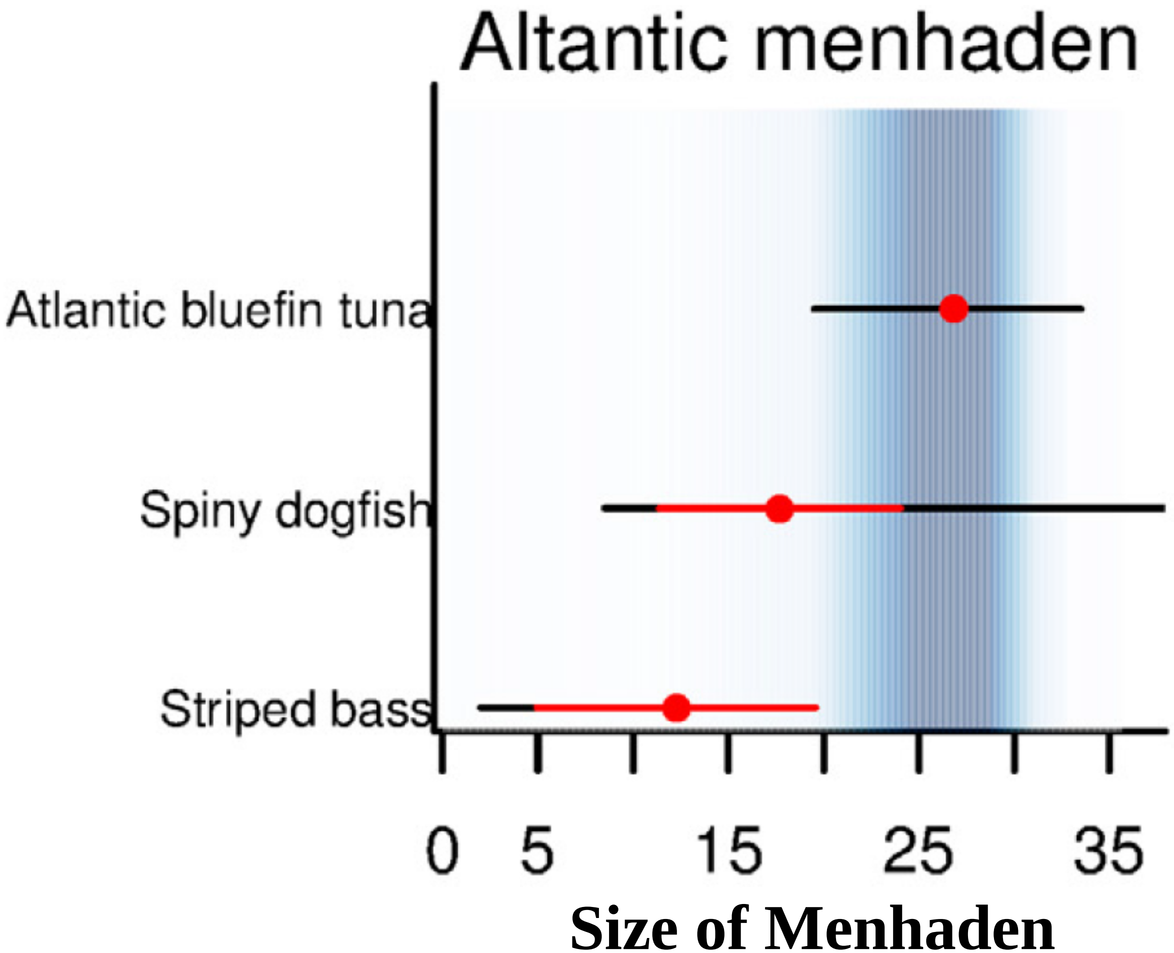
What this means for impact of fishing on predators

- Great natural variability
  - Predators have evolved to survive periods of low abundance and will fluctuate naturally
- Range contraction and expansion
  - Predators breeding in areas of most stable abundance
- Recruitment largely unrelated to population
  - Fishing has little impact on the recruitment

Key Characteristics of Predator Population Dynamics

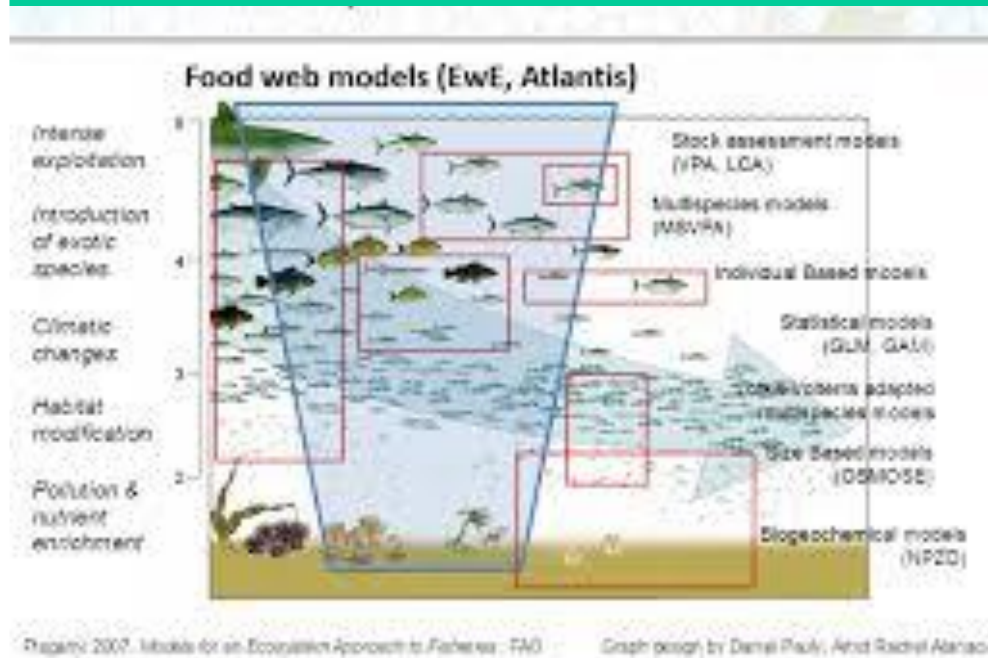
- Flexible diets to adapt to changes in abundance of different prey
- Breeding sites in locations of most stable food supply
- Eat specific sizes of the prey

Many predators eat smaller forage fish than the fishery takes



Approaches to understand the impact of fishing forage fish on their predators

Models



Global Seabird Response to Forage Fish Depletion—One-Third for the Birds

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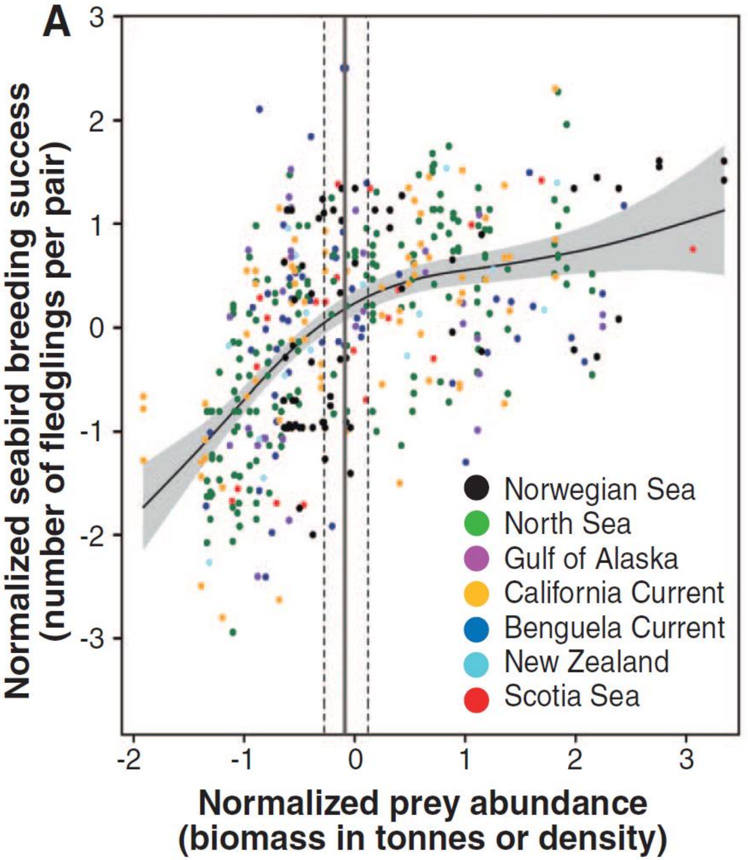
Many of the case studies used local abundance around breeding sites or actual foraging success as measures of prey abundance

A



What the data tell us

- There has been no systematic evaluation of the relationship between forage fish abundance and predator population rates of change
- We did such an analysis for U.S. forage fisheries and found no evidence that lower forage fish abundance was associated with predator declines

Fisheries Research 191 (2017) 211–221

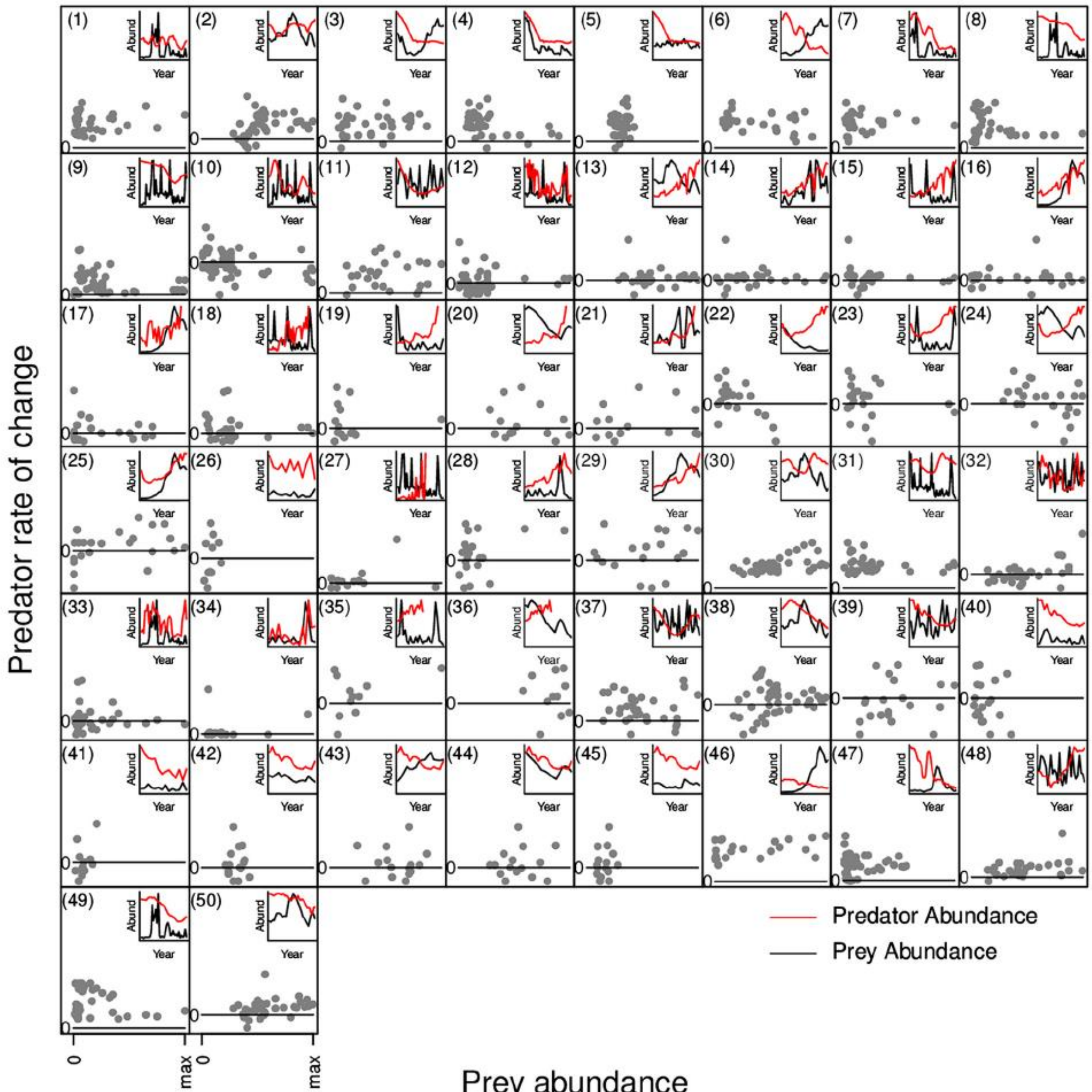
Contents lists available at ScienceDirect

Fisheries Research

journal homepage: www.elsevier.com/locate/fishres

When does fishing forage species affect their predators?

Ray Hilborn [a,*], Ricardo O. Amoroso [a], Eugenia Bogazzi [a], Olaf P. Jensen [b], Ana M. Parma [c], Cody Szuwalski [d], Carl J. Walters [e]



Predator rate of change
Prey abundance
Predator Abundance
Prey Abundance
Abund
Year
0
max
(1)
(2)
(3)
(4)
(5)
(6)
(7)
(8)
(9)
(10)
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Ecosystem models: what is considered

Biological factor	Ecosim	ATLANTIS	MICE
Natural Variability	NO	YES	YES
Lack of Spawner recruit relationship	NO	YES	YES
Size selectivity	Very limited	YES	YES
Shifts in spatial distribution	NO	YES	YES

Moving forward: MICE models

Contents lists available at ScienceDirect

Ecological Modelling

journal homepage: www.elsevier.com

Exploring the implications of the harvest control rule for Pacific sardine, accounting for predator dynamics: A MICE model

André E. Punt,[a,*] Alec D. MacCall,[b] Timothy E. Essington,[a] Tessa B. Francis,[c] Felipe Hurtado-Ferro,[a] Kelli F. Johnson,[a] Isaac C. Kaplan,[d] Laura E. Koehn,[a] Phillip S. Levin,[d] William J. Sydeman [b]

Key model elements

- Sardines, Anchovy and other prey
- Sea Lions and Pelicans
- Impact of prey availability on recruitment and survival of predators
- Spatial expansion of prey at times of high abundance

Results of MICE model

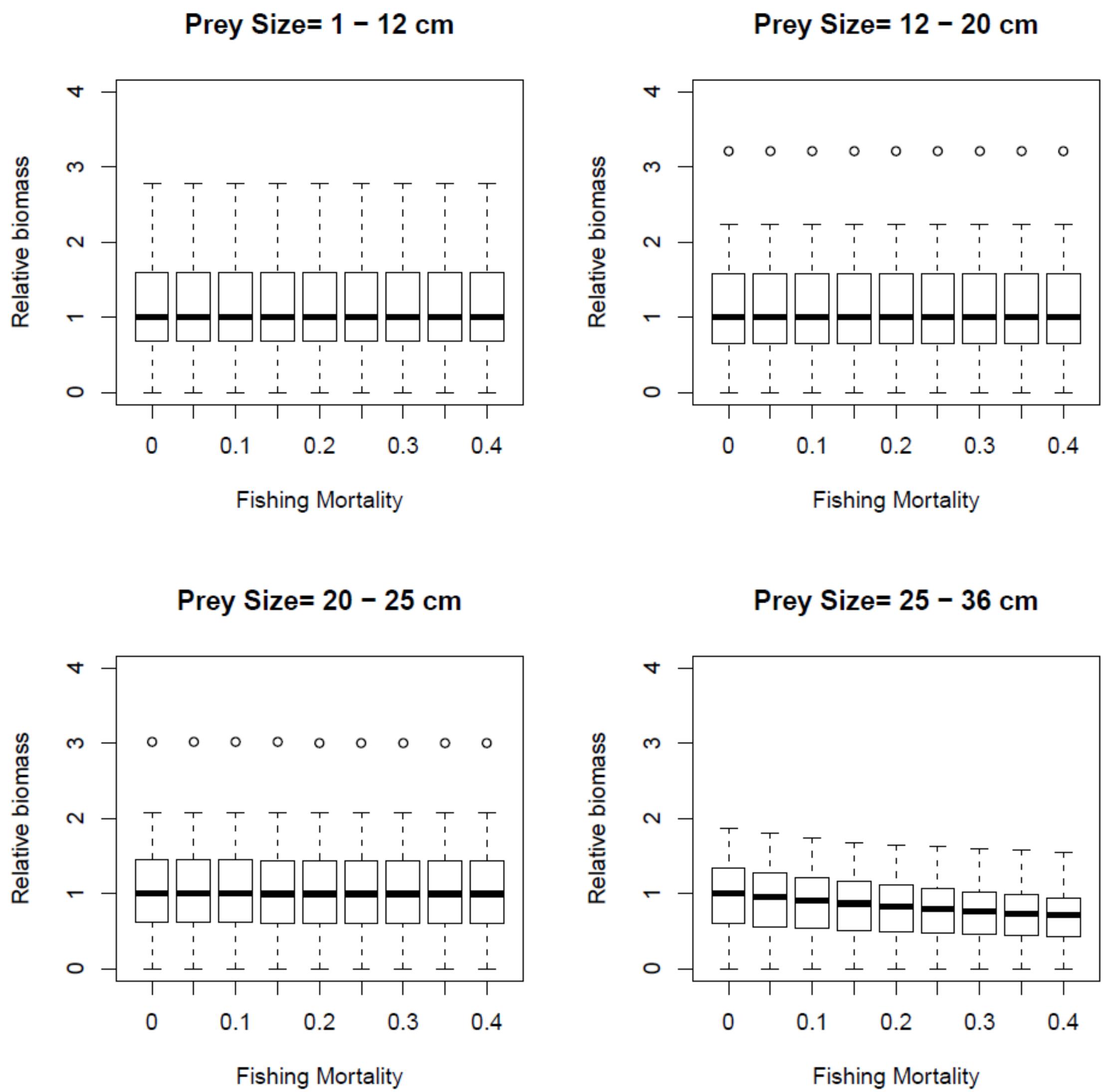
Species and policy	Average population size	Proportion of time < 0.5 K	Proportion of time < 0.1 K
Pelican without fishing	0.942	0.042	0.009
Pelican with Fishing	0.925	0.053	0.011

They found no impact of fishing on California sea lions

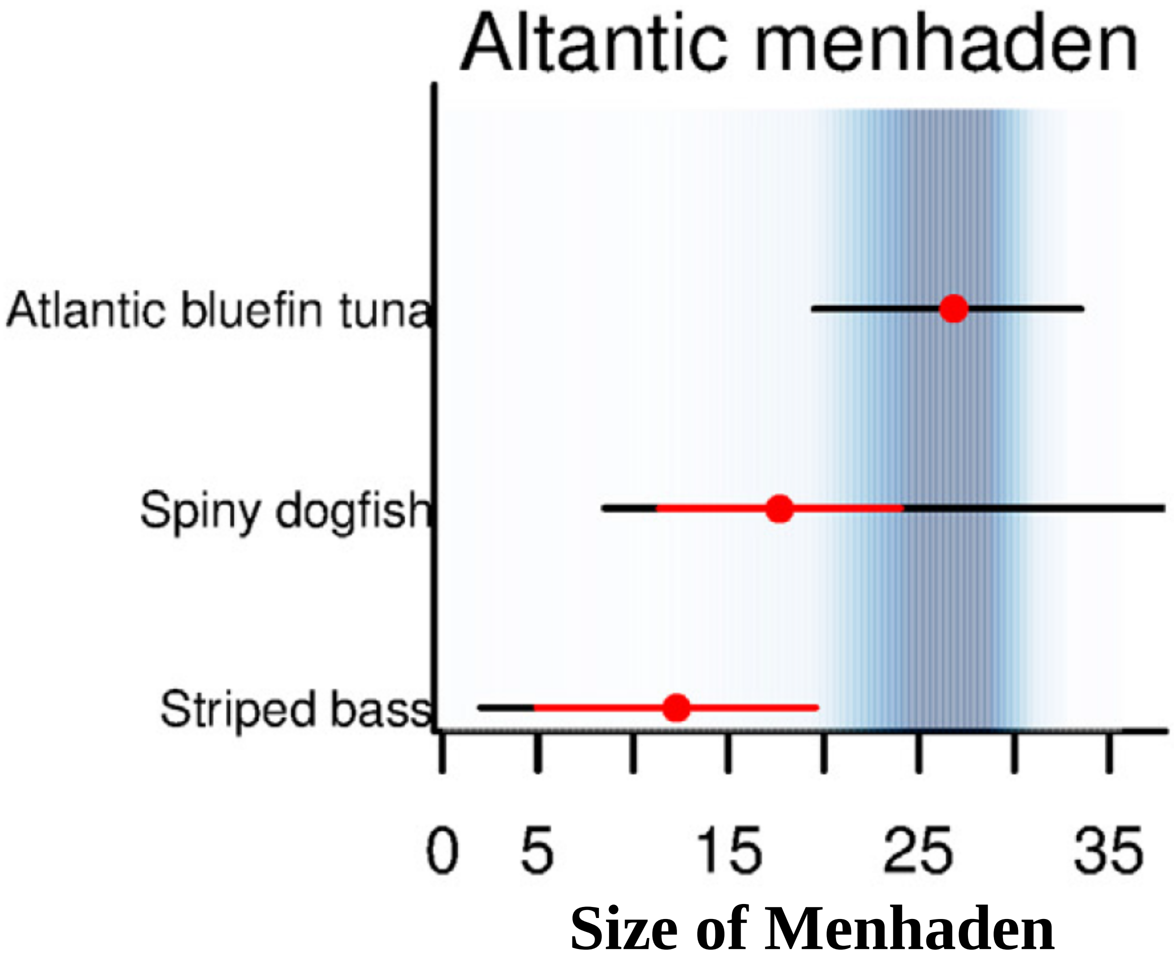
Atlantic menhaden population model

Age	M	F	Size (mm)	Number Without Fishing	Number With Fishing	Reduction by fishing'
0	1.115	0.001		573	572	0.0%
1	0.813	0.057	159	218	212	2.9%
2	0.635	0.351	216	106	84	20.8%
3	0.532	0.390	254	59	32	45.3%
4	0.468	0.269	281	36	14	60.7%
5	0.431	0.109	303	23	7	67.4%
Total 1+				442	350	20.9%

Atlantic Menhaden: impact of fishing on size groups



Thus striped bass and spiny dogfish will be largely unaffected



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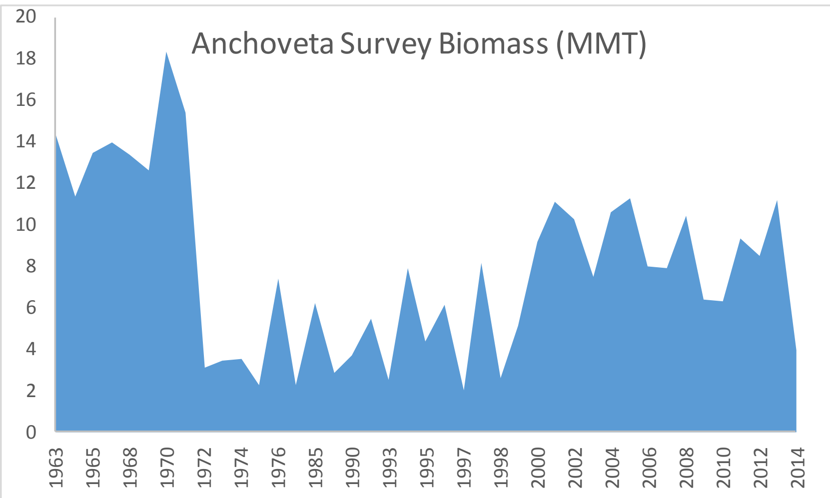
Our conclusions

- Model analysis must include key biology
- Each ecosystem has unique features
- Some species of predators may be totally unaffected by fishing forage fish: other species may be quite sensitive
- Models uniquely designed for the specific ecosystem are required for any policy recommendation

Next steps

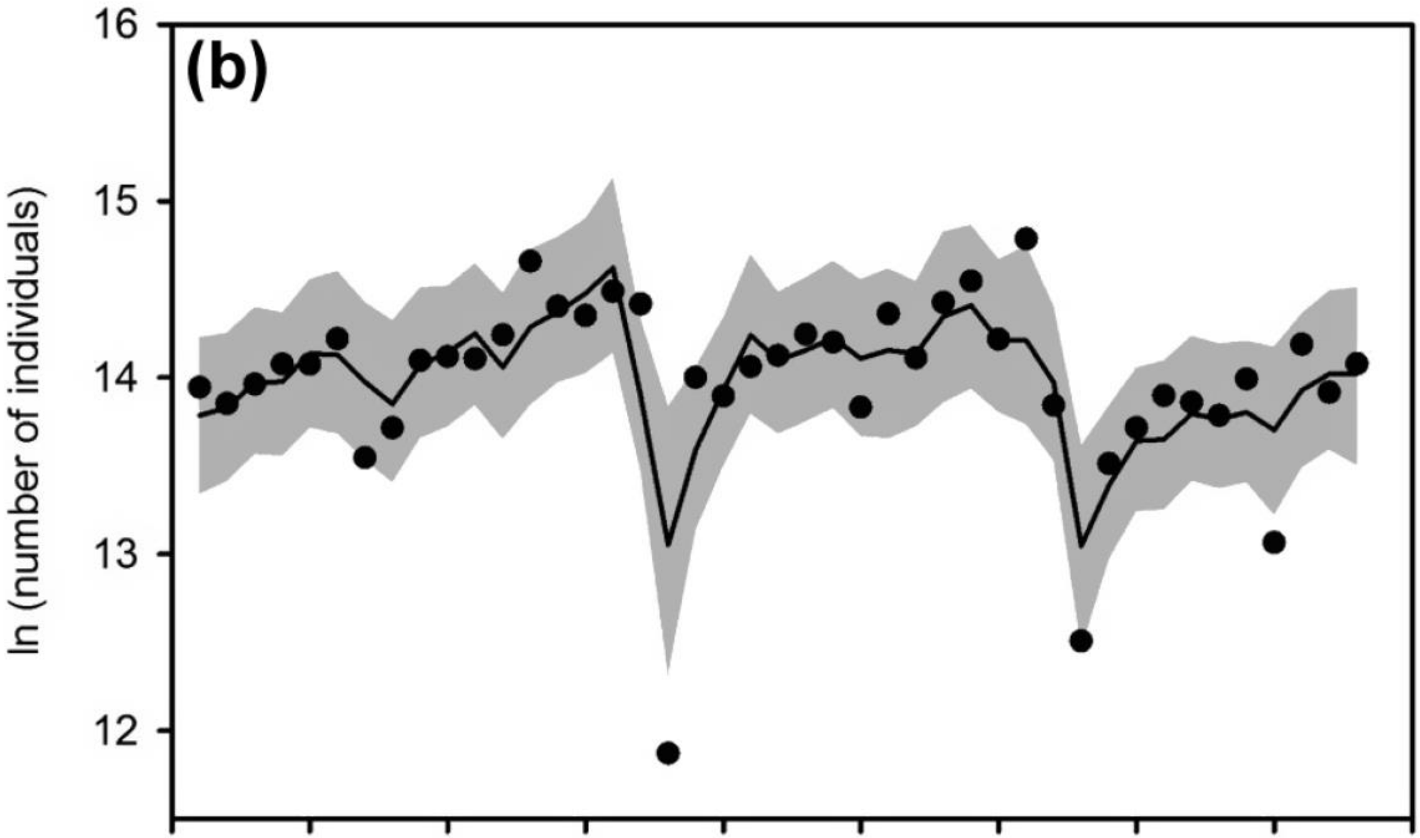
- Global analysis of empirical data on relationship between forage fish abundance and predator abundance
- Global analysis of recruitment patterns
- Development of MICE models for different ecosystems
- Evaluation of alternative harvest strategies impact on food production and predators

The Peruvian Anchoveta Fishery



Density dependence, prey accessibility and prey depletion by fisheries drive Peruvian seabird population dynamics

Christophe Barbraud, Arnaud Bertrand, Marilú Bouchón, Alexis Chaigneau, Karine Delord, Hervé Demarcq, Olivier Gimenez, Mariano Gutiérrez Torero, Dimitri Gutiérrez, Ricardo Oliveros-Ramos, Giannina Passuni, Yann Tremblay and Sophie Bertrand



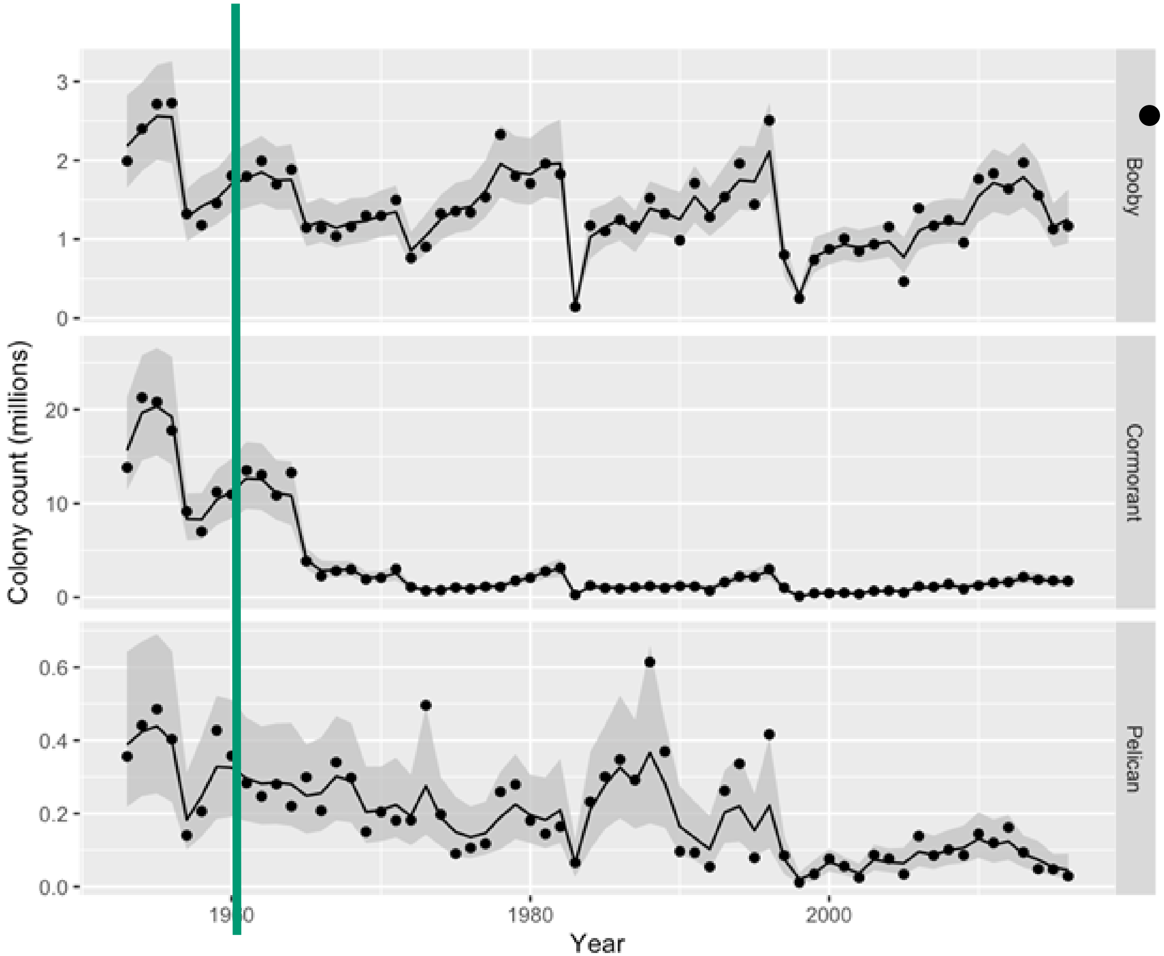
Elements considered

- Anchoveta and three guano birds
- Impact of El Nino, fishing mortality, and depth of oxygen minimum layer on biomass dynamics model

Their result

- Elimination of fishing leads to
  - 53% more cormorants
  - 42% more boobies
  - Same number of pelicans

Our model analysis

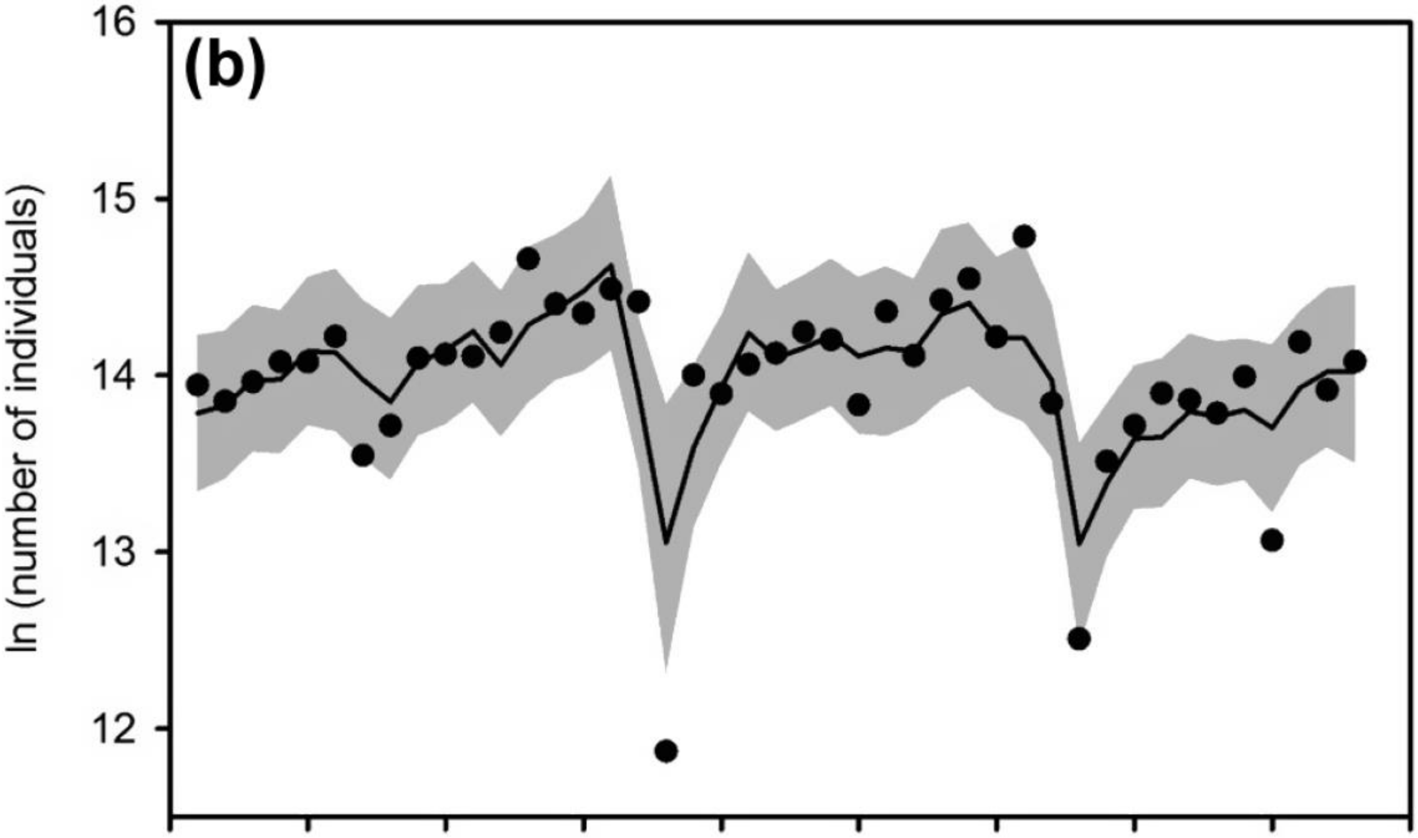


- We consider entire time series of available bird data – major declines before fishery began

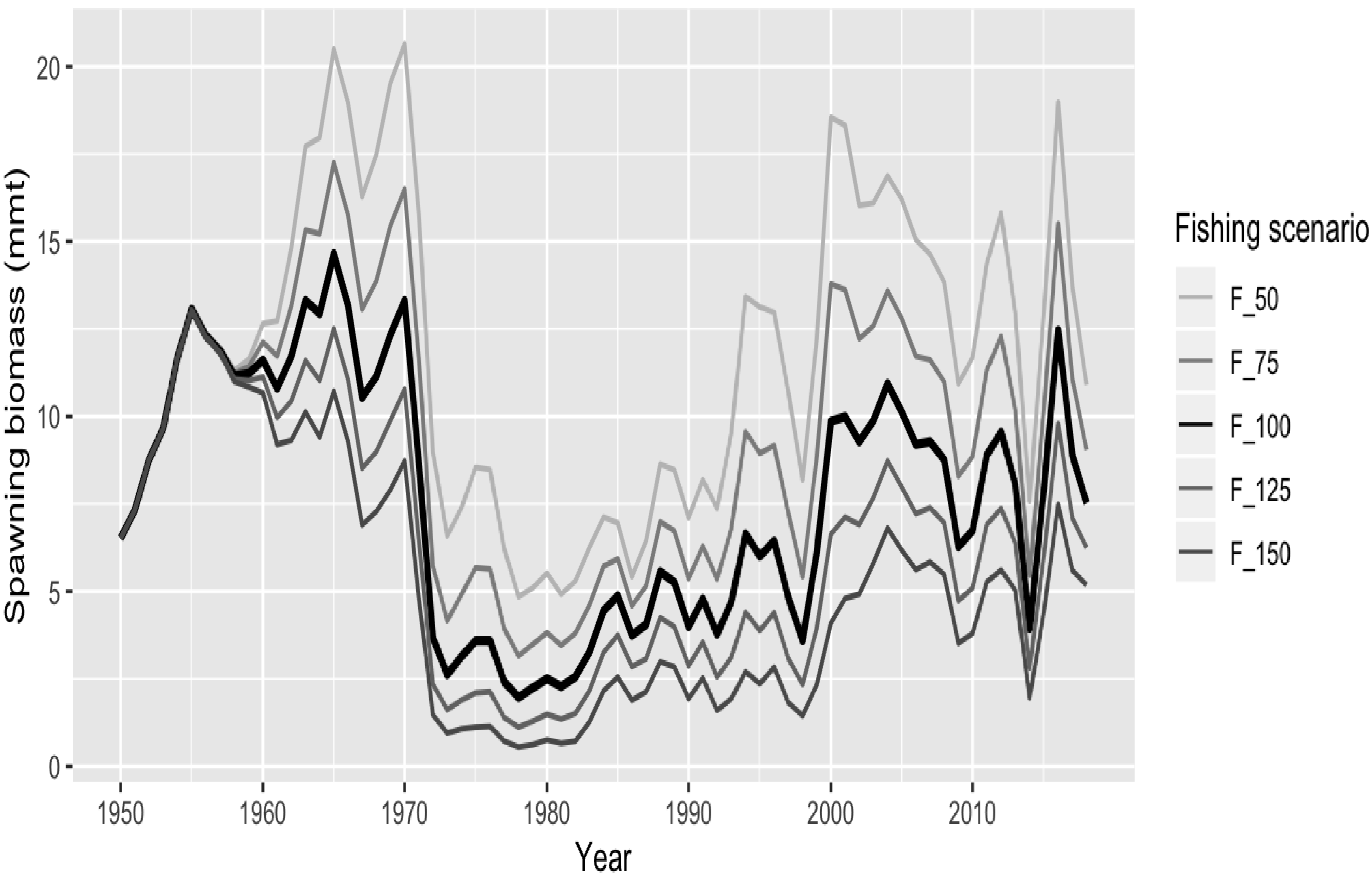
Modeled relationships

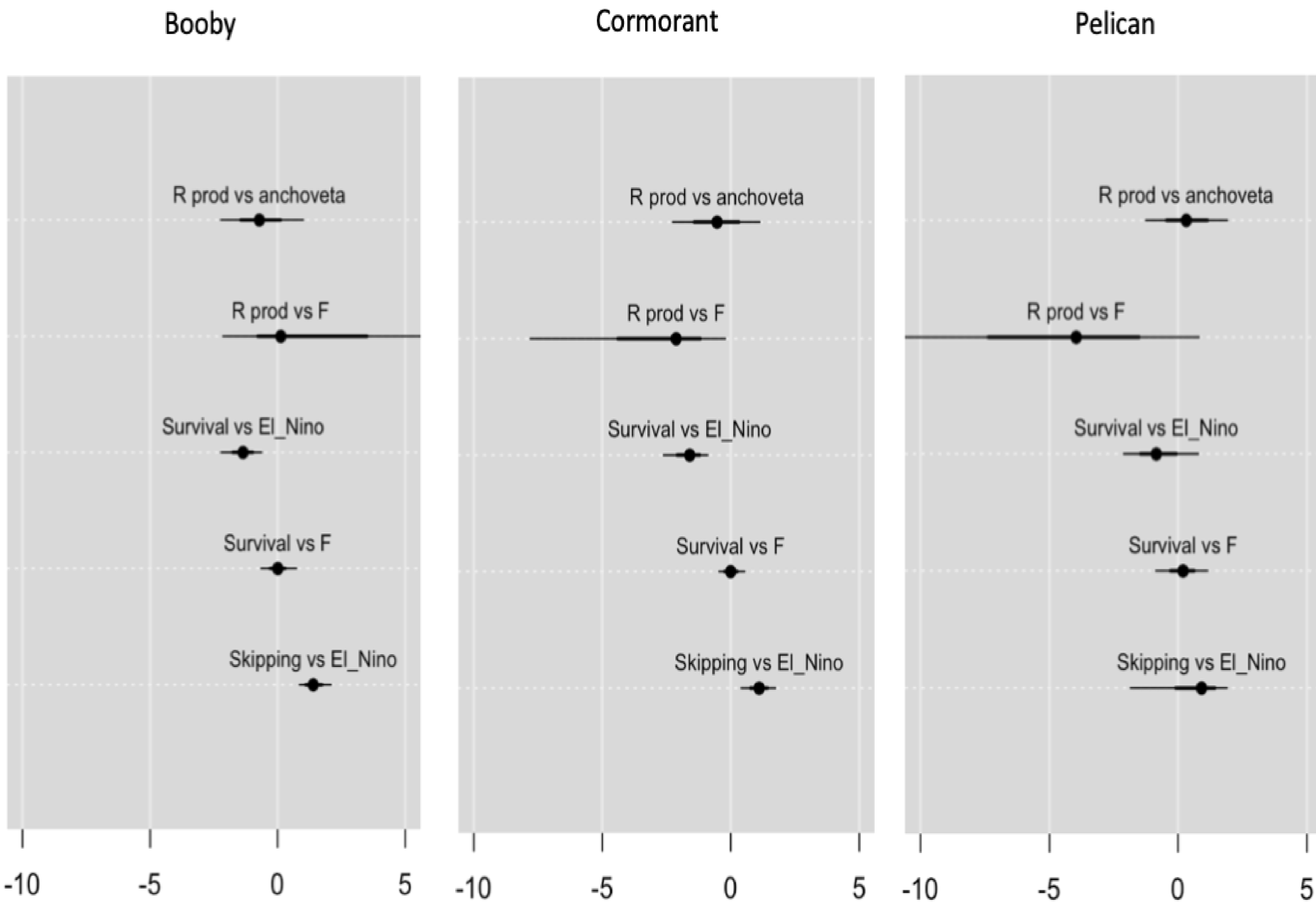
- Age structure of bird populations
- Recruitment carrying capacity as impacted by El Nino, anchoveta abundance, fishing mortality
- Chick survival as impacted by El Nino, anchoveta abundance, fishing mortality
- Adult survival as impacted by El Nino, anchoveta abundance, fishing mortality

Adult bird skipping reproduction

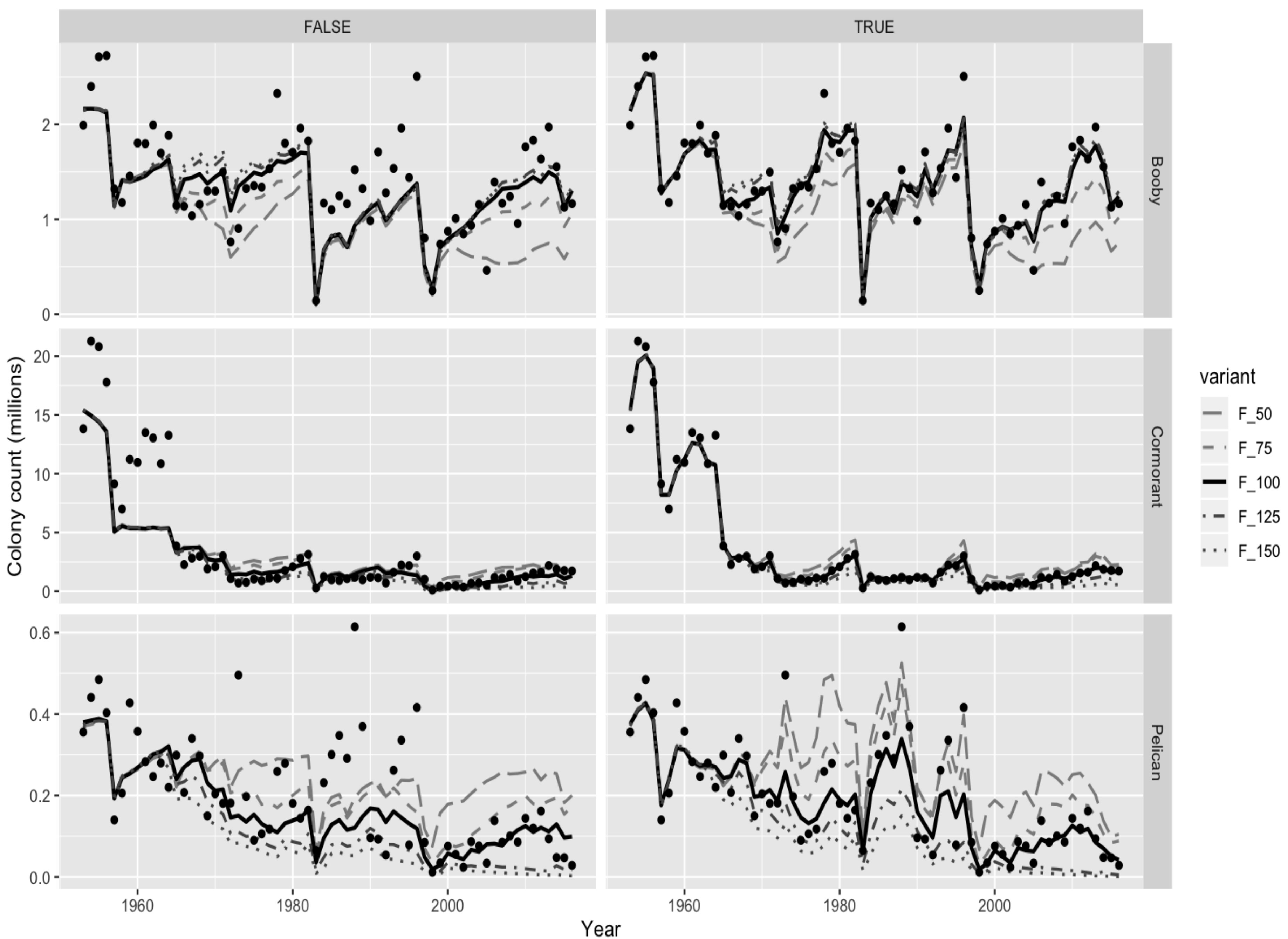


Anchoveta abundance changes

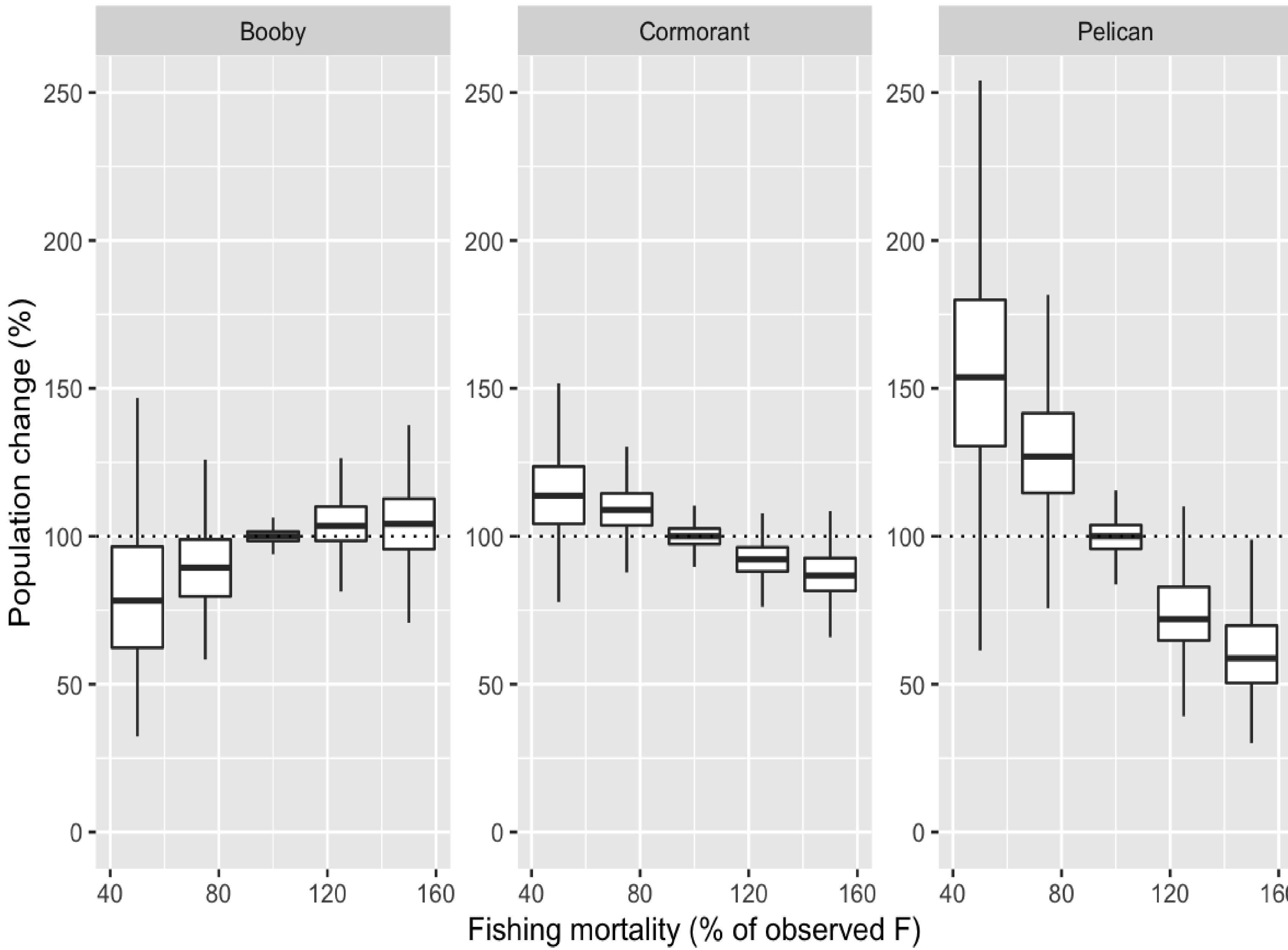




Booby
Cormorant
Pelican
R prod vs anchoveta
R prod vs F
Survival vs El_Nino
Survival vs F
Skipping vs El_Nino
-10
-5
0
5



FALSE
TRUE
Booby
Cormorant
Pelican
Colony count (millions)
Year
variant
F_50
F_75
F_100
F_125
F_150



Booby
Cormorant
Pelican
Population change (%)
250
200
150
100
50
0
40
80
120
160
Fishing mortality (% of observed F)

Impact of a 50% reduction in fishing pressure

Model	Relative fishing pressure	Cormorant	Booby	Pelican
Barbraud	50%	1.24	1.19	1.0
Our analysis	50%	1.48	0.76	1.54

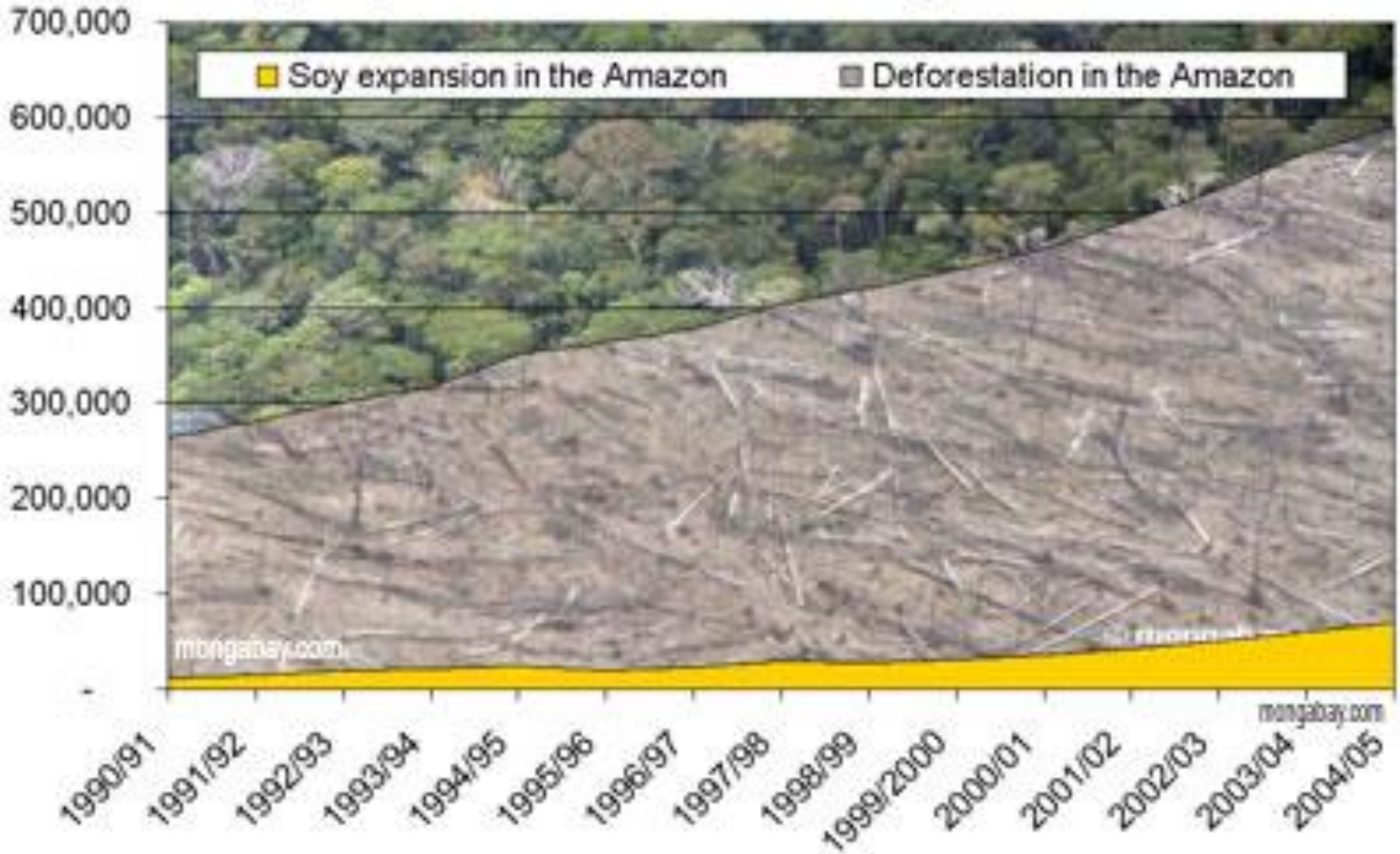
Conclusions so far

- Estimated impacts are sensitive to model structure
- We are trying to evaluate impacts of policies that take anchoveta abundance far beyond the range of data used to estimate parameters

Further thoughts

- The environmental impacts of how hard we fish forage fish include a major terrestrial component
- If we reduce forage fish harvest
  - aquaculture will increasingly draw on crops

Soy expansion in the Amazon, 1990-2005



What happens if we replaced forage fish protein for aquaculture with soy?

- Over 60,000 square kilometers of Brazilian natural habitat would be needed to grow soybeans to produce the same protein
- This would mean the loss of billions of plants and animals –
- And some more sea birds
- Which is a better choice?


That's all Folks!