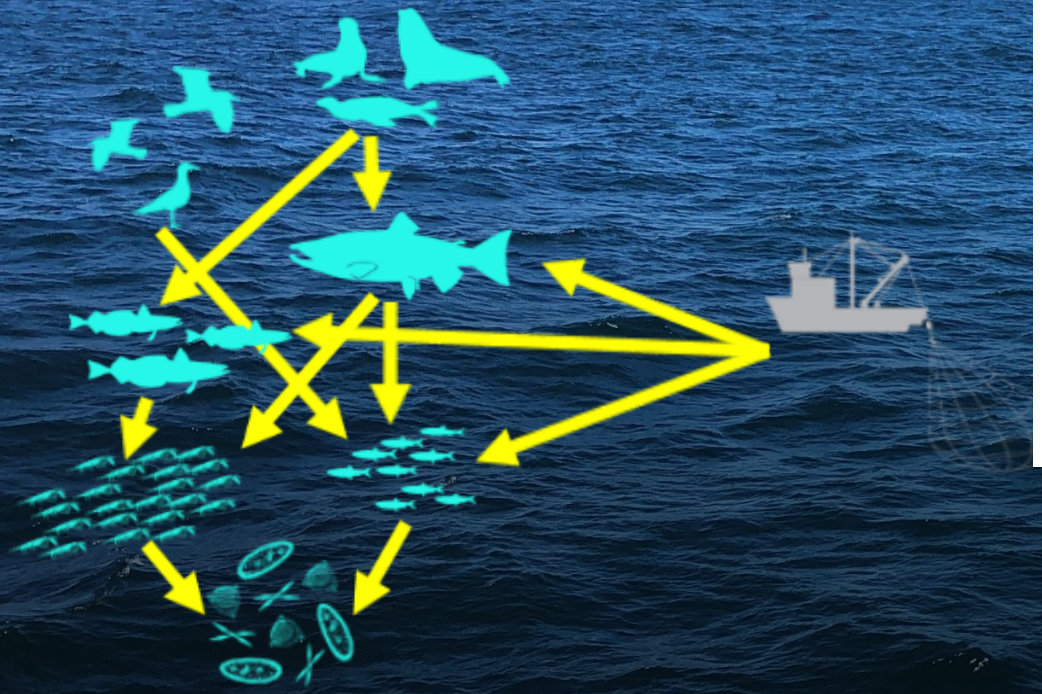


PLOS ONE

RESEARCH ARTICLE

An updated end-to-end ecosystem model of the Northern California Current reflecting ecosystem changes due to recent marine heatwaves

Dylan G. E. Gomes[1,2¤*], James J. Ruzicka[3], Lisa G. Crozier[4], David D. Huff[5], Elizabeth M. Phillips[6], Pierre-Yves Hernvann[7,8], Cheryl A. Morgan[2], Richard D. Brodeur[5], Jen E. Zamon[9], Elizabeth A. Daly[2], Joseph J. Bizzarro[10,11], Jennifer L. Fisher[5], Toby D. Auth[12]

PLoS ONE 19(1): e0280366.
https://doi.org/10.1371/journal.pone.0280366

Dylan.Gomes@noaa.gov for comments / questions

Dylan Gomes

NOAA

National Research Council NRC

Oregon State University

Global Change Biology

Global Change Biology (2013) 19, 3046–3061, doi: 10.1111/gcb.12298

Climate and ecosystem linkages explain widespread declines in North American Atlantic salmon populations

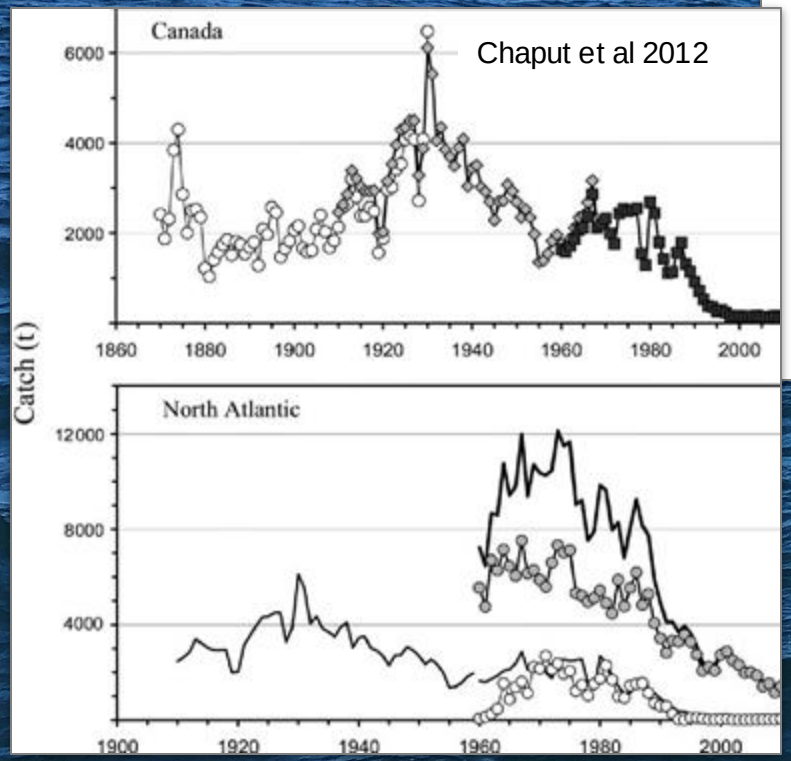
KATHERINE E. MILLS*†, ANDREW J. PERSHING*†, TIMOTHY F. SHEEHAN‡ and DAVID MOUNTAIN§

*School of Marine Sciences, University of Maine, Aubert Hall, Orono, Commercial Street, Portland, ME 04101, USA, ‡Northeast Fisheries S Street, Woods Hole, MA 02543, USA, §University of Arizona, 2707 N

RAPID COMMUNICATION / COMMUNICATION RAPIDE

A widespread decrease in productivity of sockeye salmon (*Oncorhynchus nerka*) populations in western North America

Randall M. Peterman and Brigitte Dorner



Chaput et al 2012

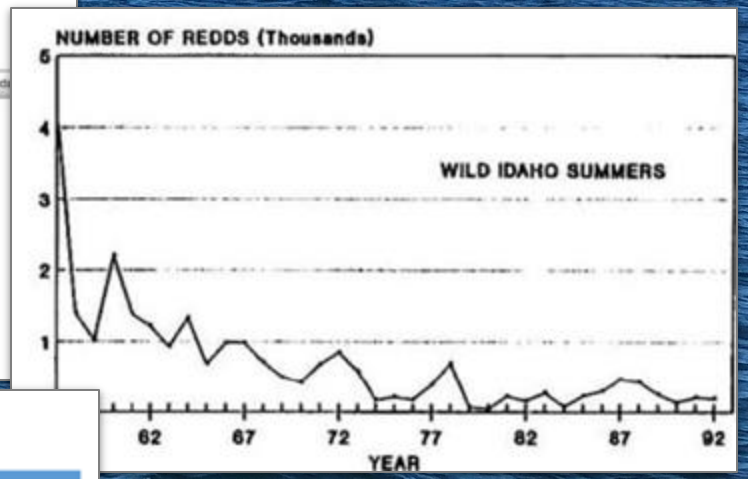
nature COMMUNICATIONS

ARTICLE

https://doi.org/10.1038/s41467-020-17726-z OPEN

Recent declines in salmon body size impact ecosystems and fisheries

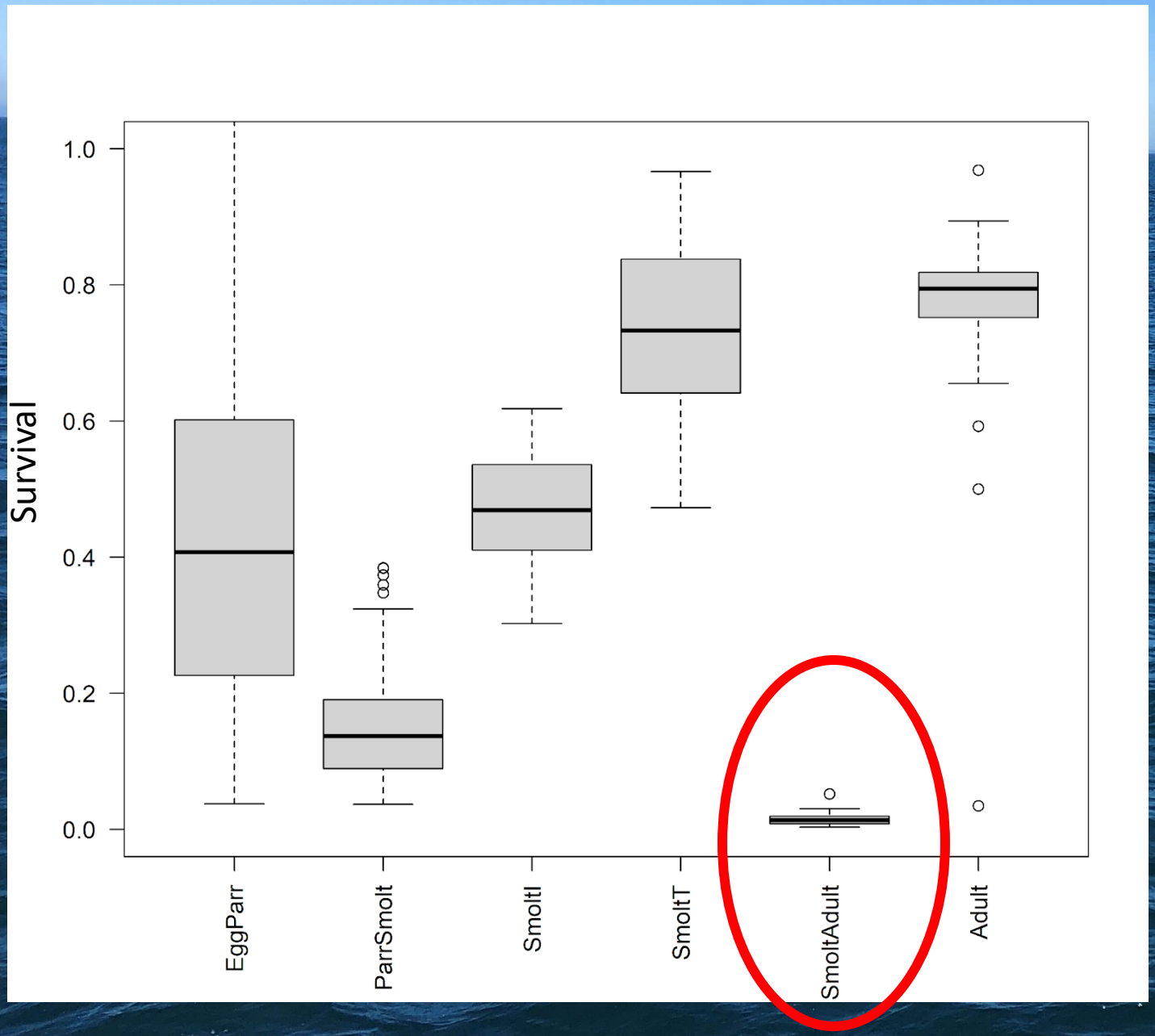
K. B. Oke[1,2✉], C. J. Cunningham[2,3], P. A. H. Westley[4✉], M. L. Baskett[5], S. M. Carlson[6], J. Clark[7], A. P. Hendry[8], V. A. Karatayev[5], N. W. Kendall[9], J. Kibele[7], H. K. Kindsvater[10], K. M. Kobayashi[1], B. Lewis[11], S. Munch[1,12], J. D. Reynolds[13], G. K. Vick[14] & E. P. Palkovacs[1✉]

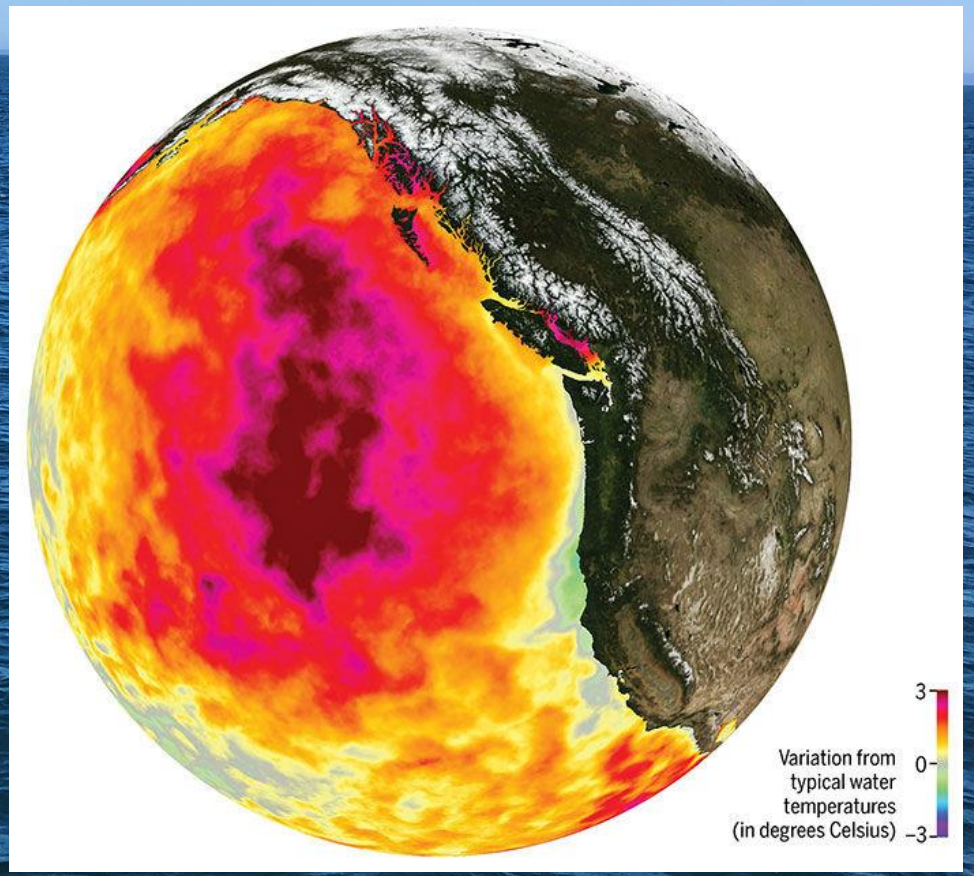


Short term salmon trends (since "the blob")

Species	Bering Sea/Yukon	Central & SE Alaska	Fraser River-Puget Sound	Columbia River	Oregon & California
Sockeye					
Pink	Even / Odd				
Chum					
Coho					
Chinook				Fall / Spring	
Steelhead					

Courtesy of Laurie Weitkamp





Source: NOAA Fisheries

2024 PLOS ONE

RESEARCH ARTICLE

An updated end-to-end ecosystem model of the Northern California Current reflecting ecosystem changes due to recent marine heatwaves

Dylan G. E. Gomes[1,2¤*], James J. Ruzicka[3], Lisa G. Crozier[4], David D. Huff[5], Elizabeth M. Phillips[6], Pierre-Yves Hernvann[7,8], Cheryl A. Morgan[2], Richard D. Brodeur[5], Jen E. Zamon[9], Elizabeth A. Daly[2], Joseph J. Bizzarro[10,11], Jennifer L. Fisher[5], Toby D. Auth[12]

2006 Progress in Oceanography

Progress in Oceanography 68 (2006) 238–270

Top-down modeling and bottom-up dynamics: Linking a fisheries-based ecosystem model with climate hypotheses in the Northern California Current

J.C. Field [a,*], R.C. Francis [b], K. Aydin [c]

2012 Progress in Oceanography

Progress in Oceanography 102 (2012) 19–41

Interannual variability in the Northern California Current food web structure: Changes in energy flow pathways and the role of forage fish, euphausiids, and jellyfish

James J. Ruzicka [a,*], Richard D. Brodeur [b], Robert L. Emmett [b], John H. Steele [c], Jeannette E. Zamon [d], Cheryl A. Morgan [a], Andrew C. Thomas [e], Thomas C. Wainwright [b]

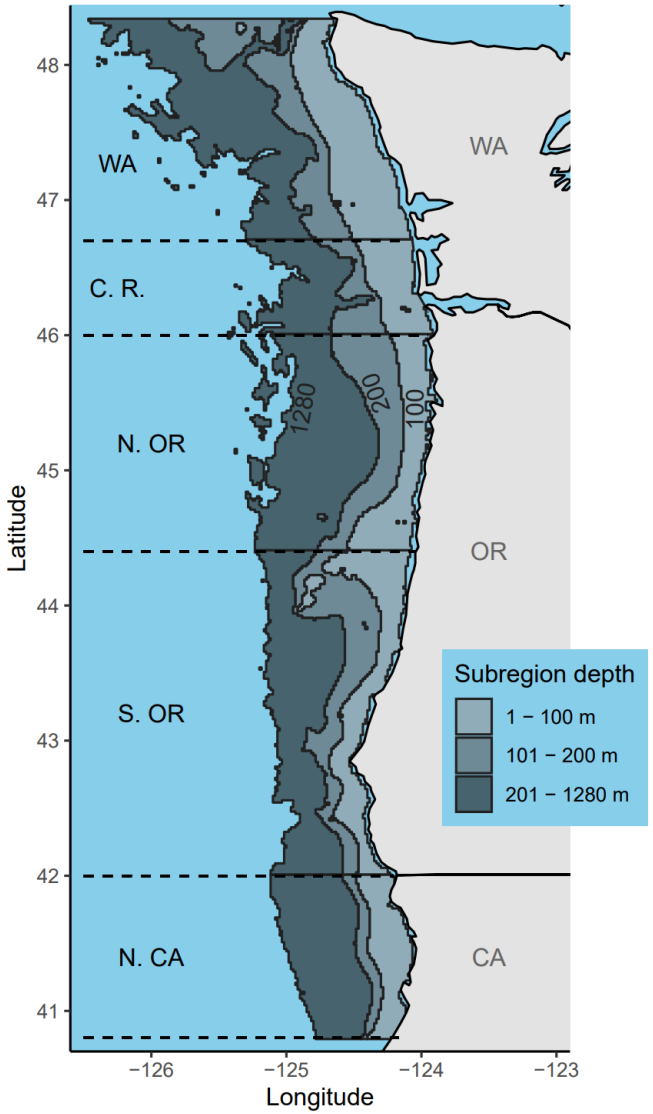
2016 Ecological Modelling

Ecological Modelling 335 (2016) 87–100

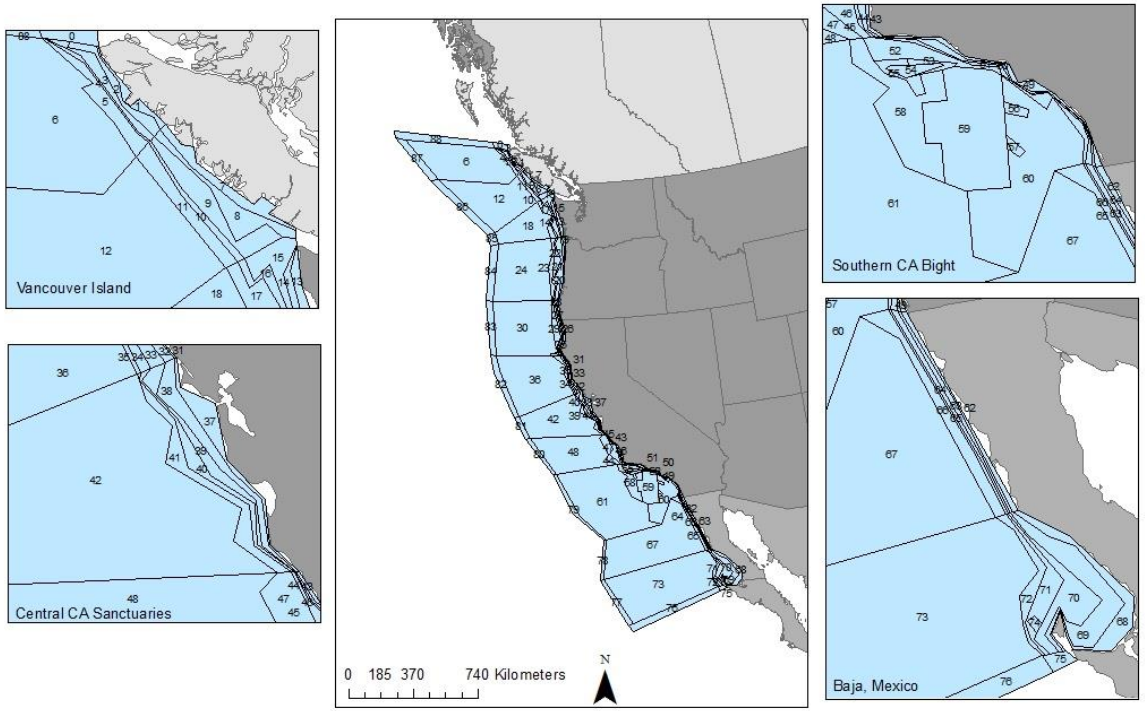
Developing a high taxonomic resolution food web model to assess the functional role of forage fish in the California Current ecosystem

Laura E. Koehn [a,*], Timothy E. Essington [a], Kristin N. Marshall [a], Isaac C. Kaplan [b], William J. Sydeman [c], Amber I. Szoboszlai [c], Julie A. Thayer [c]

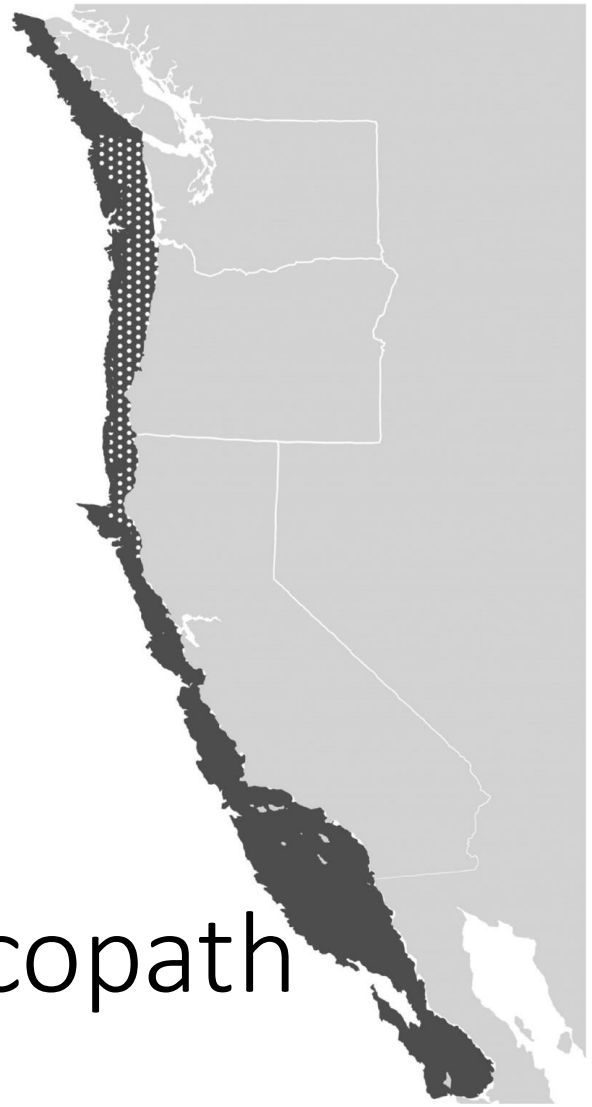
Data-hungry ecosystem models



EcoTran



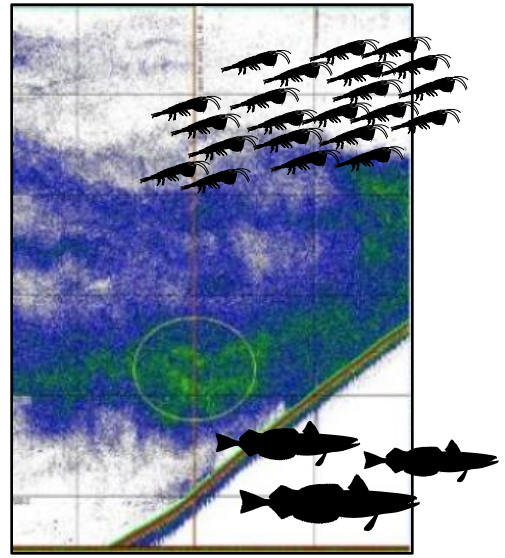
Atlantis



Ecopath

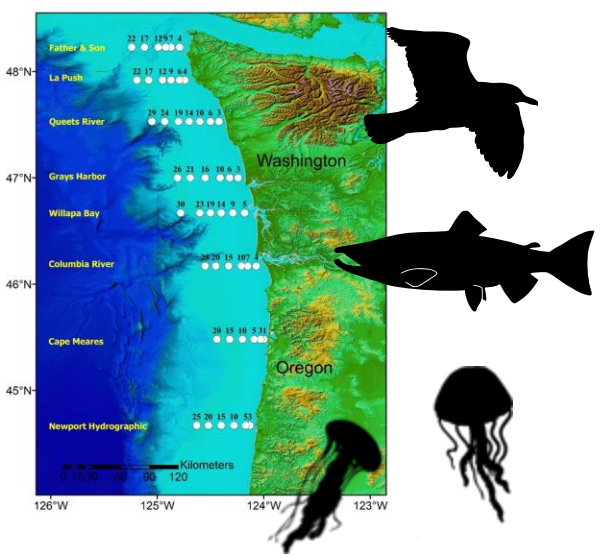
Biomass survey data

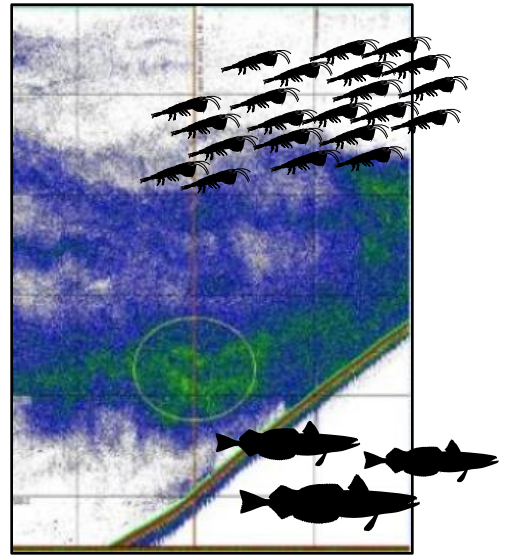
- NOAA NWFSC Hake acoustic-trawl



Biomass survey data

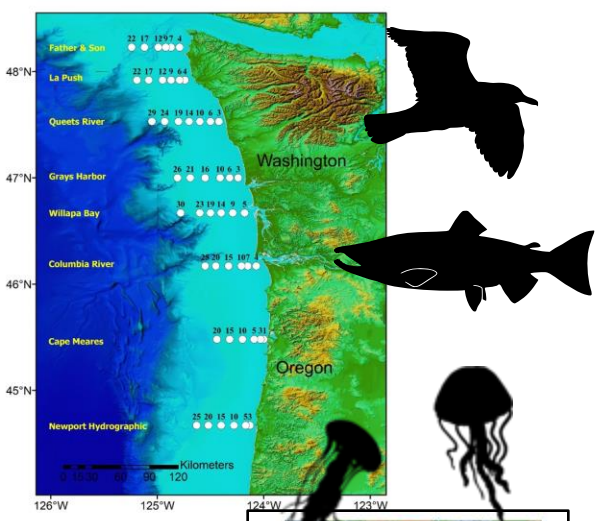
- NOAA NWFSC Hake acoustic-trawl
- NOAA NWFSC JSOES survey

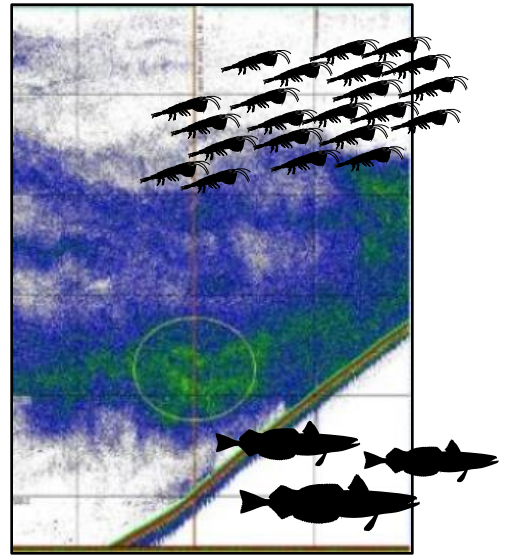


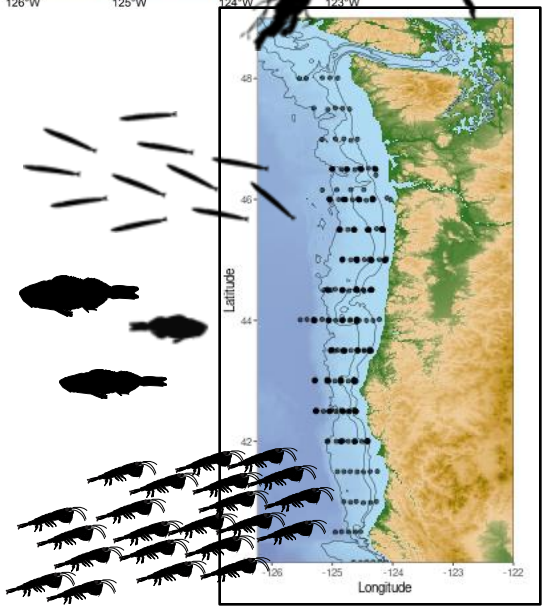


Biomass survey data

- NOAA NWFSC Hake acoustic-trawl
- NOAA NWFSC JSOES survey
- NOAA NWFSC Pre-Recruit survey

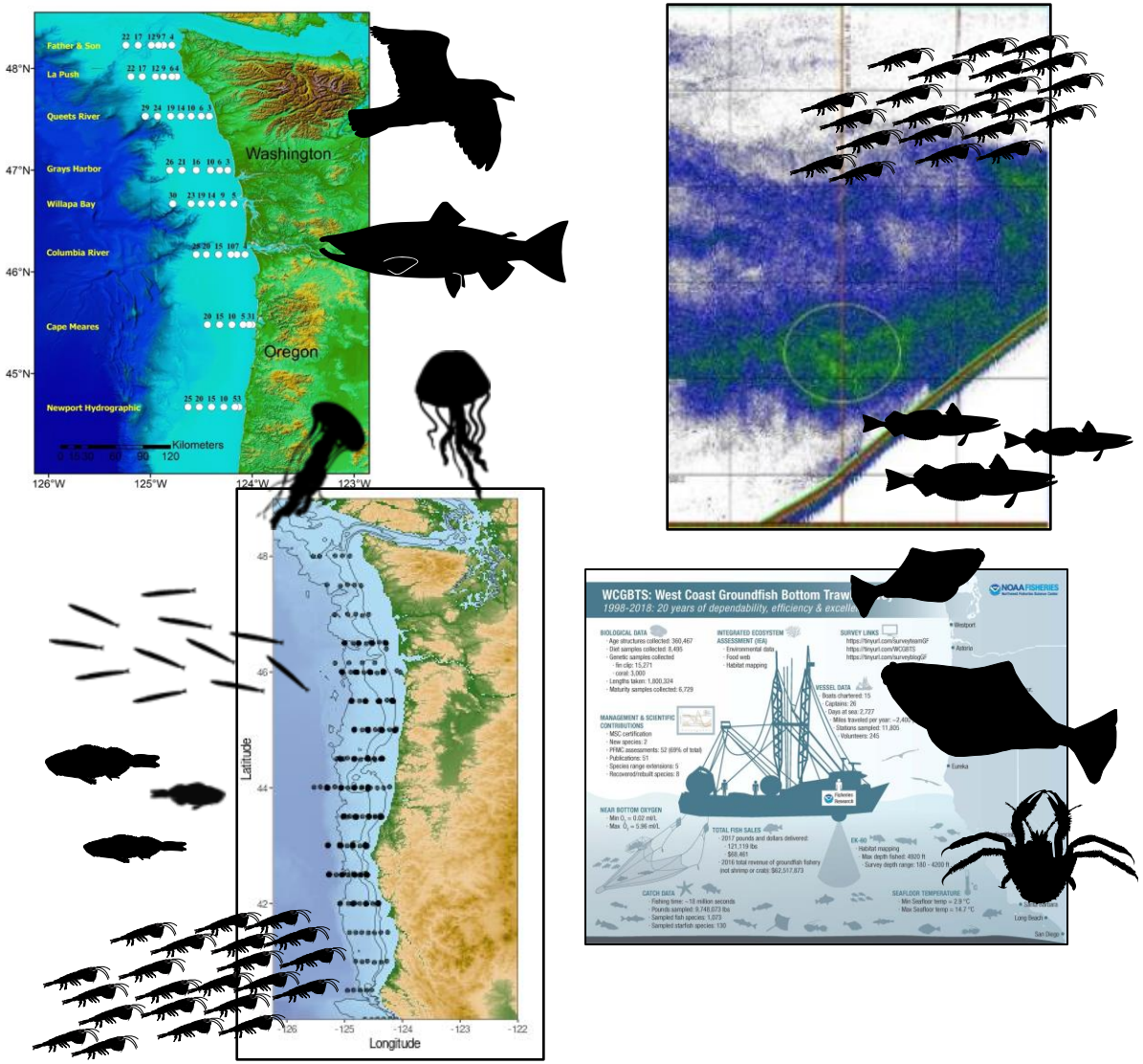






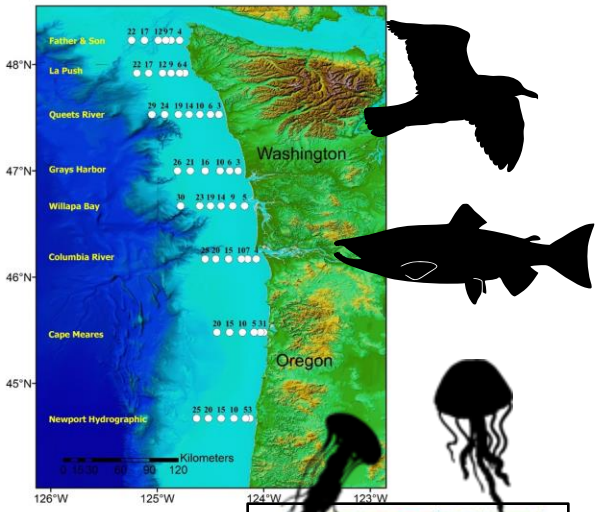
Biomass survey data

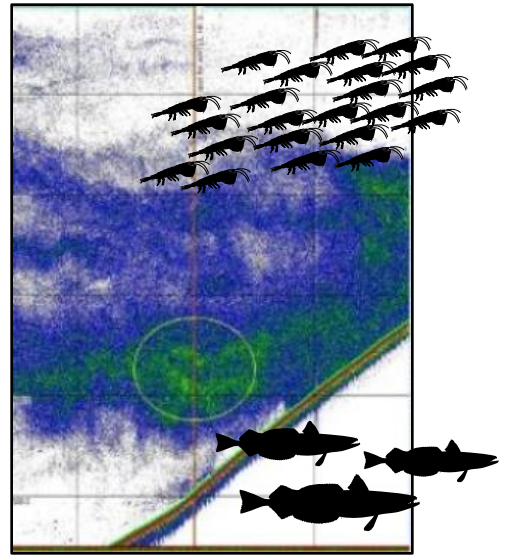
- NOAA NWFSC Hake acoustic-trawl
- NOAA NWFSC JSOES survey
- NOAA NWFSC Pre-Recruit survey
- NOAA NWFSC Groundfish survey

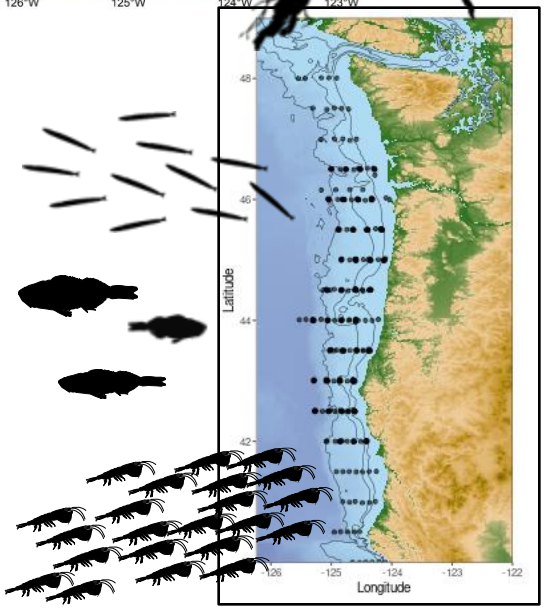


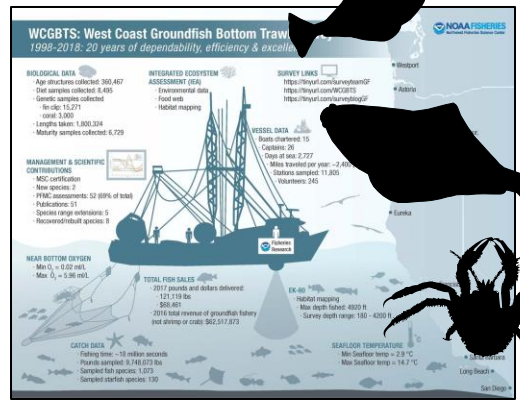
Biomass survey data

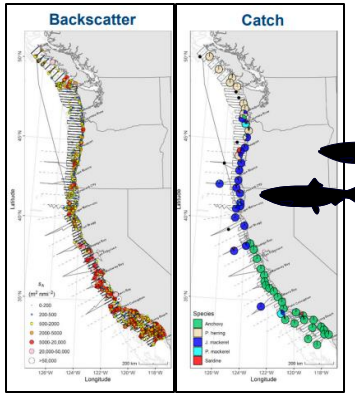
- NOAA NWFSC Hake acoustic-trawl
- NOAA NWFSC JSOES survey
- NOAA NWFSC Pre-Recruit survey
- NOAA NWFSC Groundfish survey
- NOAA SWFSC CPS acoustic-trawl





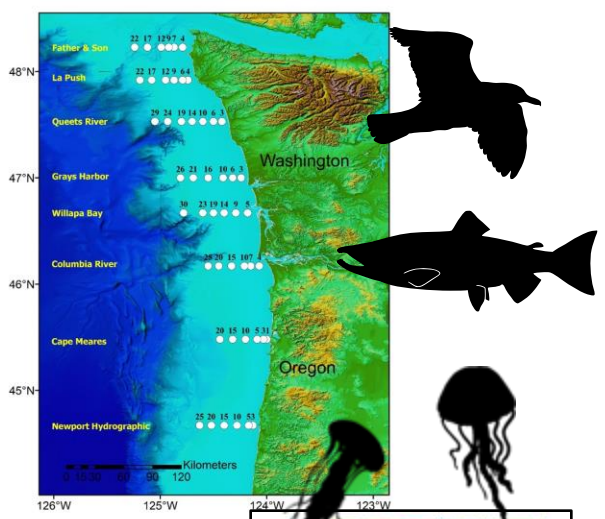


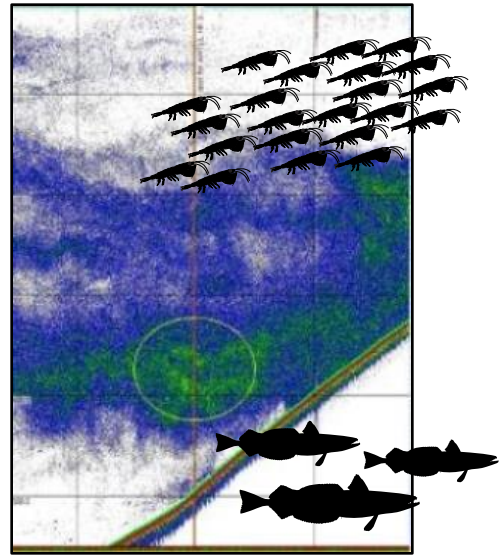


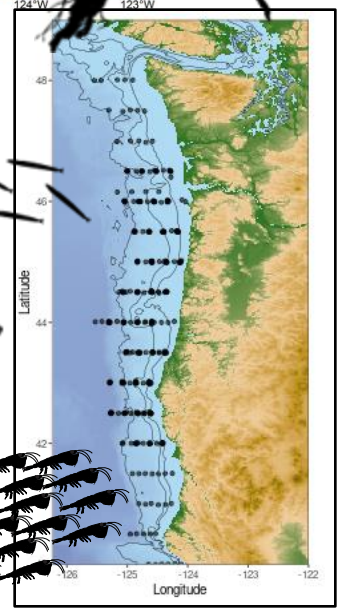


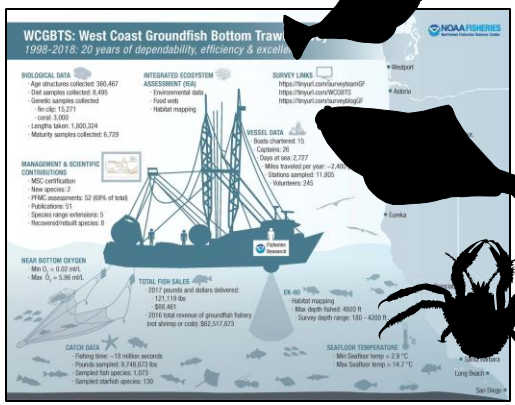
Biomass survey data

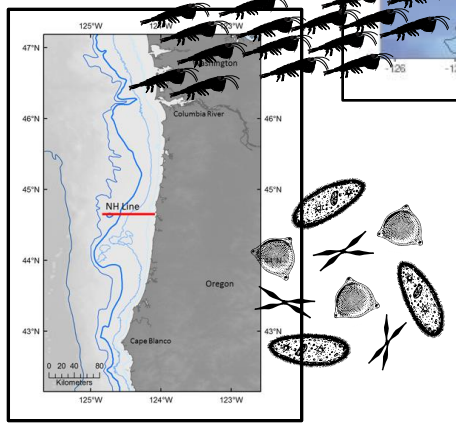
- NOAA NWFSC Hake acoustic-trawl
- NOAA NWFSC JSOES survey
- NOAA NWFSC Pre-Recruit survey
- NOAA NWFSC Groundfish survey
- NOAA SWFSC CPS acoustic-trawl
- OSU Newport Hydrographic Line

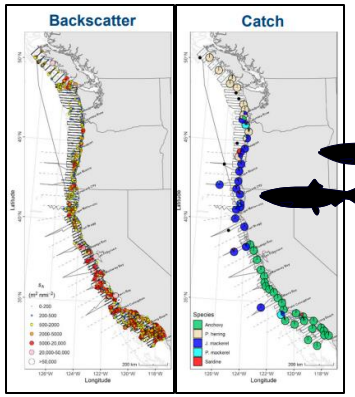






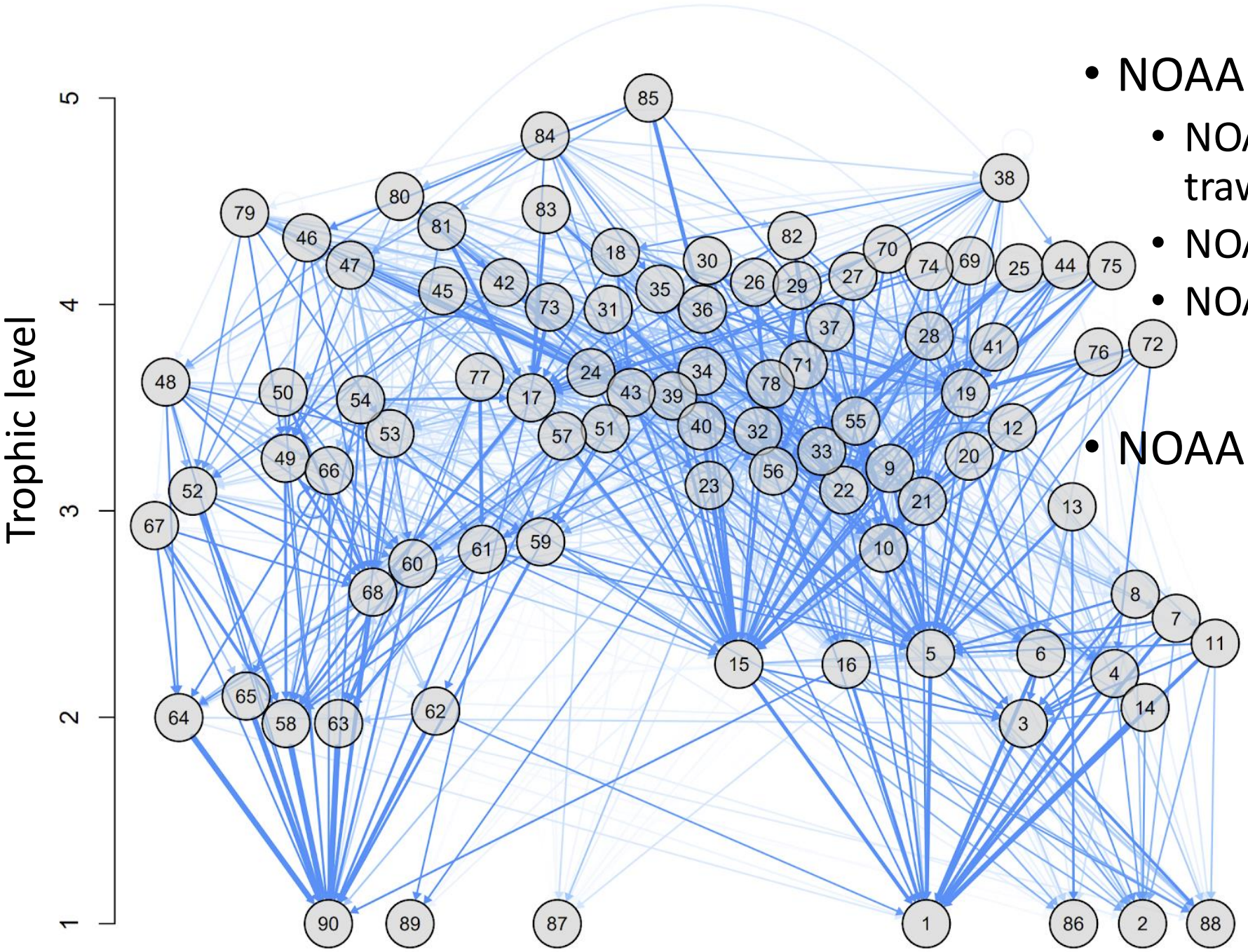






- PSMFC: Pacific Fisheries Information Network (PacFIN)
- Recreational Fisheries Information Network (RecFIN)

  - California Department of Fish & Wildlife (CDFW)
  - Oregon Department of Fish & Wildlife (ODFW)
  - Washington Department of Fish & Wildlife (WDFW)
  - National Oceanic and Atmospheric Administration (NOAA)
  - Pacific States Marine Fisheries Commission (PSMFC)
  - Pacific Fisheries Management Council (PFMC)



- NOAA SWFSC Diet database
  - NOAA NWFSC Hake acoustic-trawl
  - NOAA NWFSC JSOES survey
  - NOAA AFSC harbor seal diets
- NOAA NWFSC Groundfish

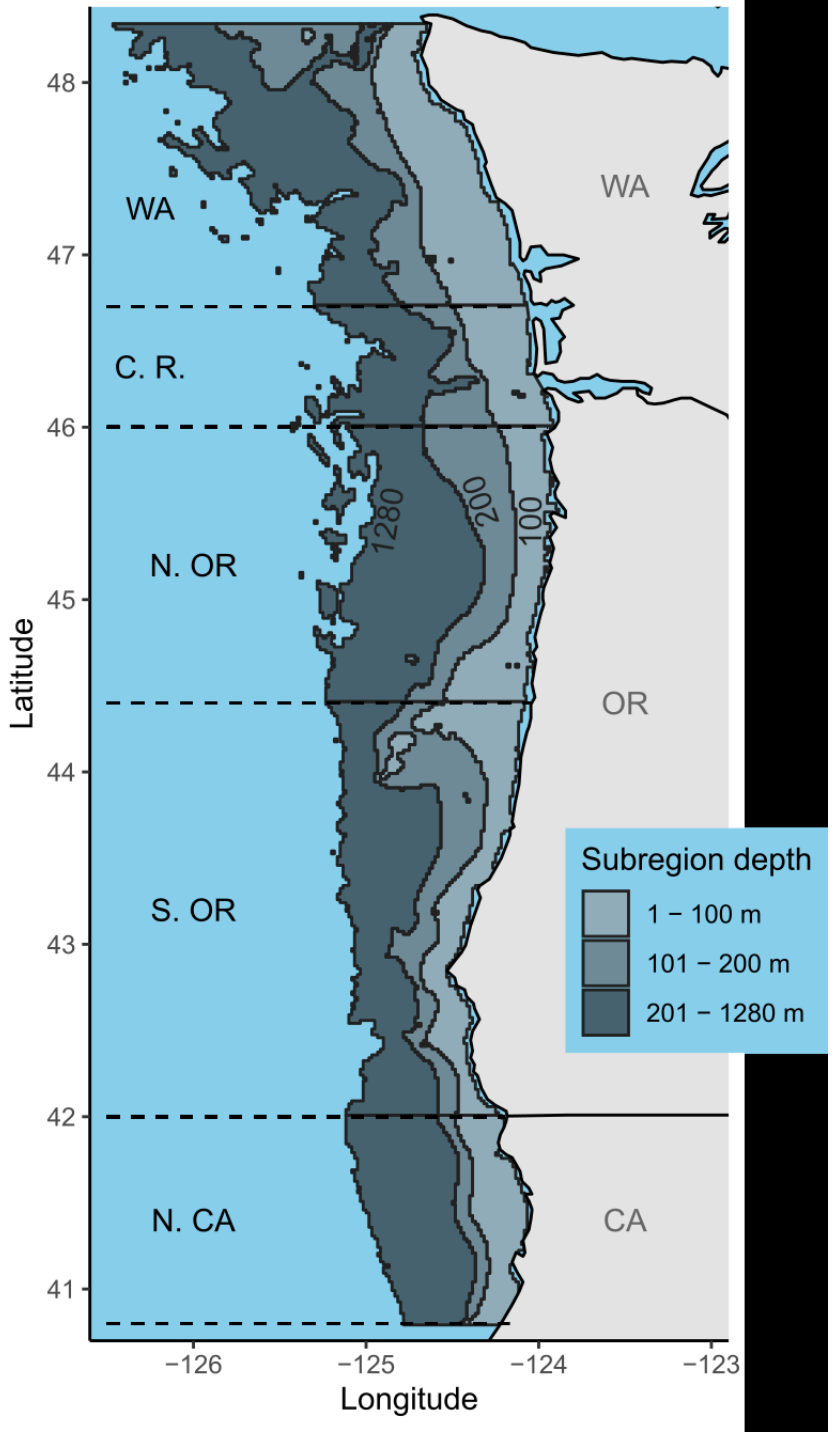
The NCC Model Domain

Five latitudinal zones:

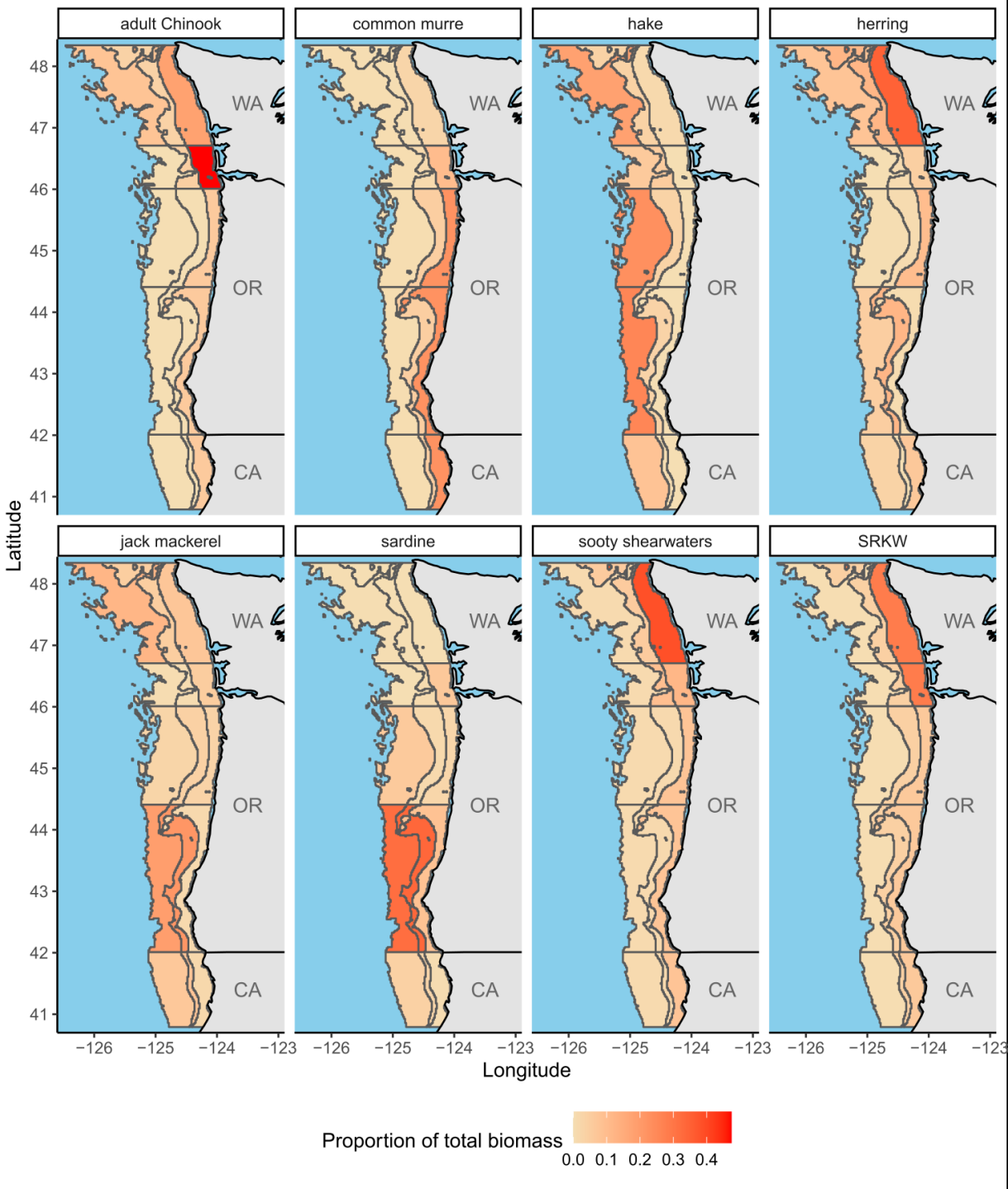
1. Washington coast: 46.7–48.34˚N
2. Columbia River zone: 46–46.7˚N
3. northern Oregon: 44.4–46˚N
4. southern Oregon: 42–44.4˚N
5. northern California: 40.8–42˚N

Three bathymetric zones:

1. inner shelf:1–100 m
2. mid shelf: 101–200 m
3. outer shelf: 201–1280 m

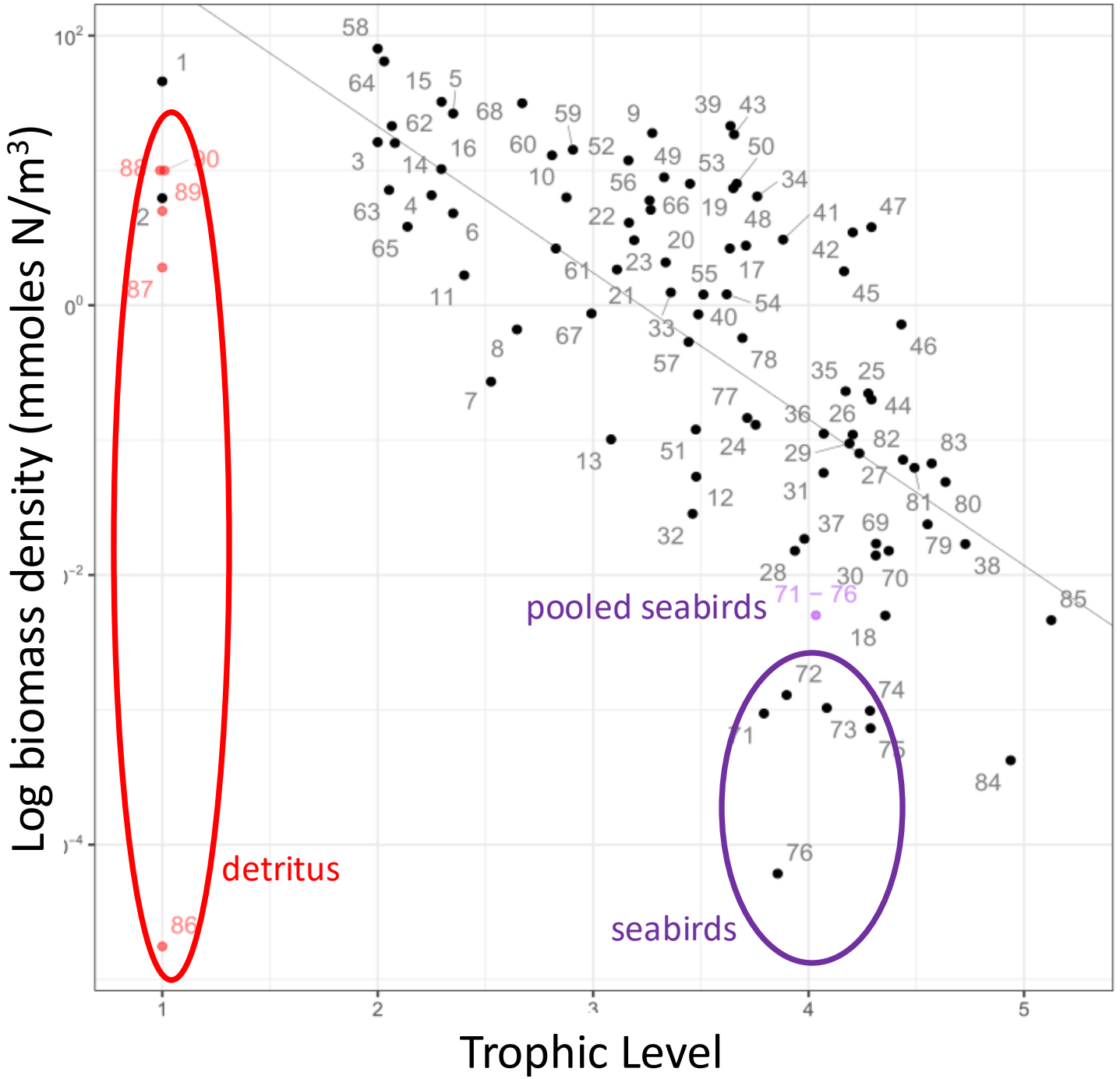


Sub-regional food webs were defined by proportion of whole-domain predation demands of each functional group



EcoTran model was consistent with ecological energetics, as suggested by the “PREBAL” criteria of Link

- Biomass densities span 6 orders of magnitude (within 5–7 suggested range)
- slope on the log scale is about an 8.5% change at each trophic level (within the 5–10% suggested range)

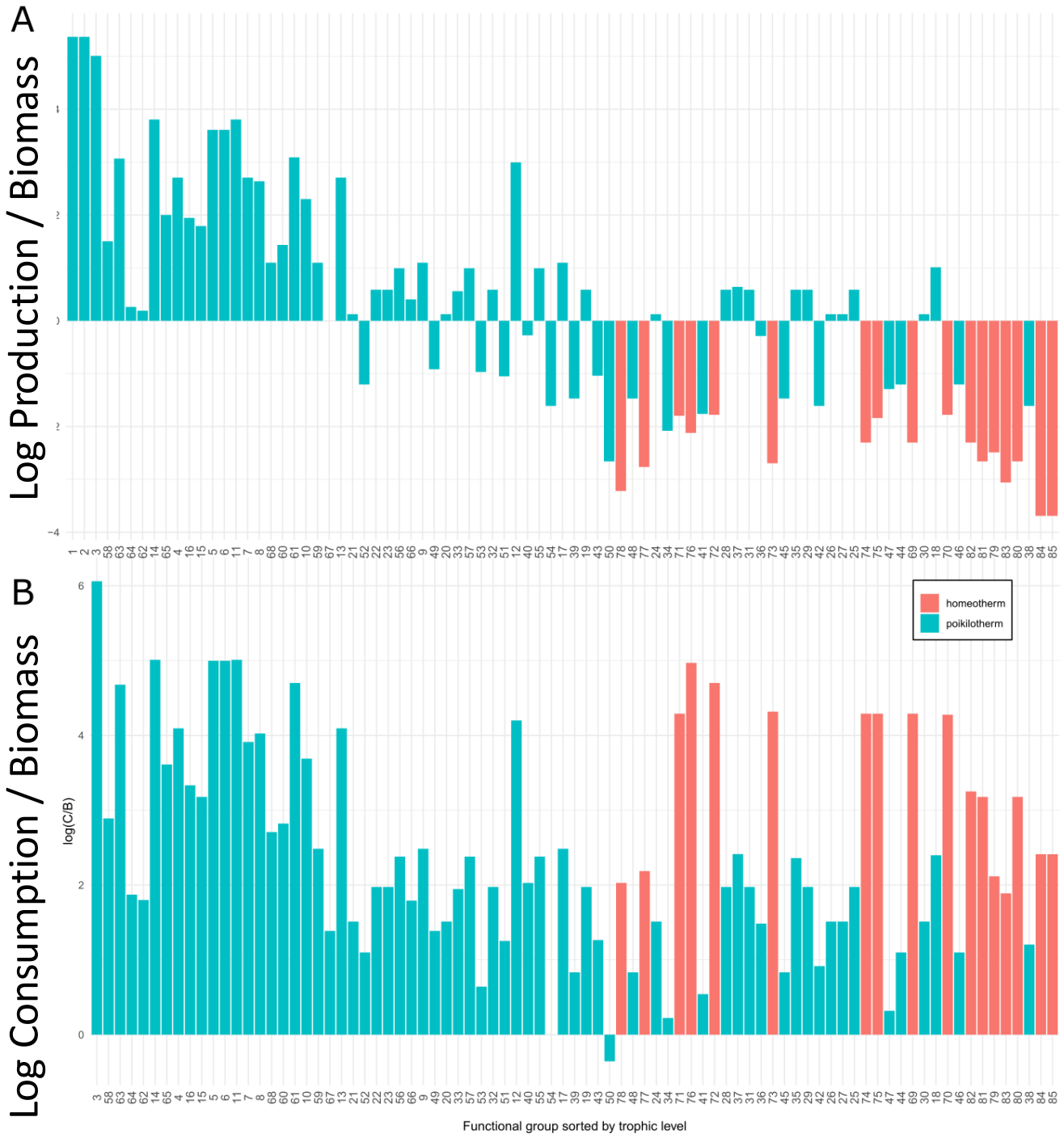


PREBAL

Link JS. Adding rigor to ecological network models by evaluating a set of pre-balance diagnostics: a plea for PREBAL. Ecological Modelling. 2010; 221: 1580–1591.

EcoTran model was consistent with ecological energetics, as suggested by the “PREBAL” criteria of Link

- Weight-specific **Production** & **Consumption** rates should decrease as trophic level (TL) increases
- homeotherms should have lower P/B and higher C/B than other groups



PREBAL

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EcoTran

Steele & Ruzicka, 2011. Constructing end-to-end models using ECOPATH data. *Journal of Marine Systems*, 87: 227-238.

consumers

producers: Q_{pc}	P_1	C_1	C_2	F_1
P_1	0	180	20	0
C_1	0	20	35	5
C_2	0	0	8	2
F_1	0	0	0	0

ECOPATH "solution"

Consumption Matrix:

Who eats how much of what?

EcoTran Trophic Matrix:

What is the fate of production?

producers

consumers: A_{cp}	P_1	C_1	C_2	F_1
P_1	0	0	0	0
C_1	0.5	0	0	0.3
C_2	0.2	0.5	0.1	0.3
F_1	0	0	0.1	0

EcoTran

Steele & Ruzicka, 2011. Constructing end-to-end models using ECOPATH data. *Journal of Marine Systems*, 87: 227-238.

consumers

producers: Q_{pc}	P_1	C_1	C_2	F_1
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ECOPATH "solution"

Consumption Matrix:

Who eats how much of what?

EcoTran Trophic Matrix:

What is the fate of production?

producers

consumers: A_{cp}	P_1	C_1	C_2	F_1	D_1	D_2
P_1	0	0	0	0	0	0
C_1	0.5	0	0	0.3	0.3	0.3
C_2	0.2	0.5	0.1	0.3	0.3	0.3
F_1	0	0	0.1	0	0	0
M0	0.3	0.2	0.4	0	0	0
feces	0	0.2	0.2	0.4	0	0

EcoTran

Steele & Ruzicka, 2011. Constructing end-to-end models using ECOPATH data. *Journal of Marine Systems*, 87: 227-238.

consumers

producers: Q_{pc}	P_1	C_1	C_2	F_1
P_1	0	180	20	0
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ECOPATH "solution"

Consumption Matrix:

Who eats how much of what?

EcoTran Trophic Matrix:

What is the fate of production?

producers

consumers: A_{cp}	P_1	C_1	C_2	F_1	D_1	D_2	NH_4
P_1	0	0	0	0	0	0	0.9
C_1	0.5	0	0	0.3	0.3	0.3	0
C_2	0.2	0.5	0.1	0.3	0.3	0.3	0
F_1	0	0	0.1	0	0	0	0
M0	0.3	0.2	0.4	0	0	0	0
feces	0	0.1	0.2	0.4	0	0	0
NH_4	0	0.2	0.2	0	0.4	0.4	0

EcoTran

Steele & Ruzicka, 2011. Constructing end-to-end models using ECOPATH data. *Journal of Marine Systems*, 87: 227-238.

consumers

producers: Q_{pc}	P_1	C_1	C_2	F_1
P_1	0	180	20	0
C_1	0	20	35	5
C_2	0	0	8	2
F_1	0	0	0	0

ECOPATH "solution"

Consumption Matrix:

Who eats how much of what?

EcoTran Trophic Matrix:

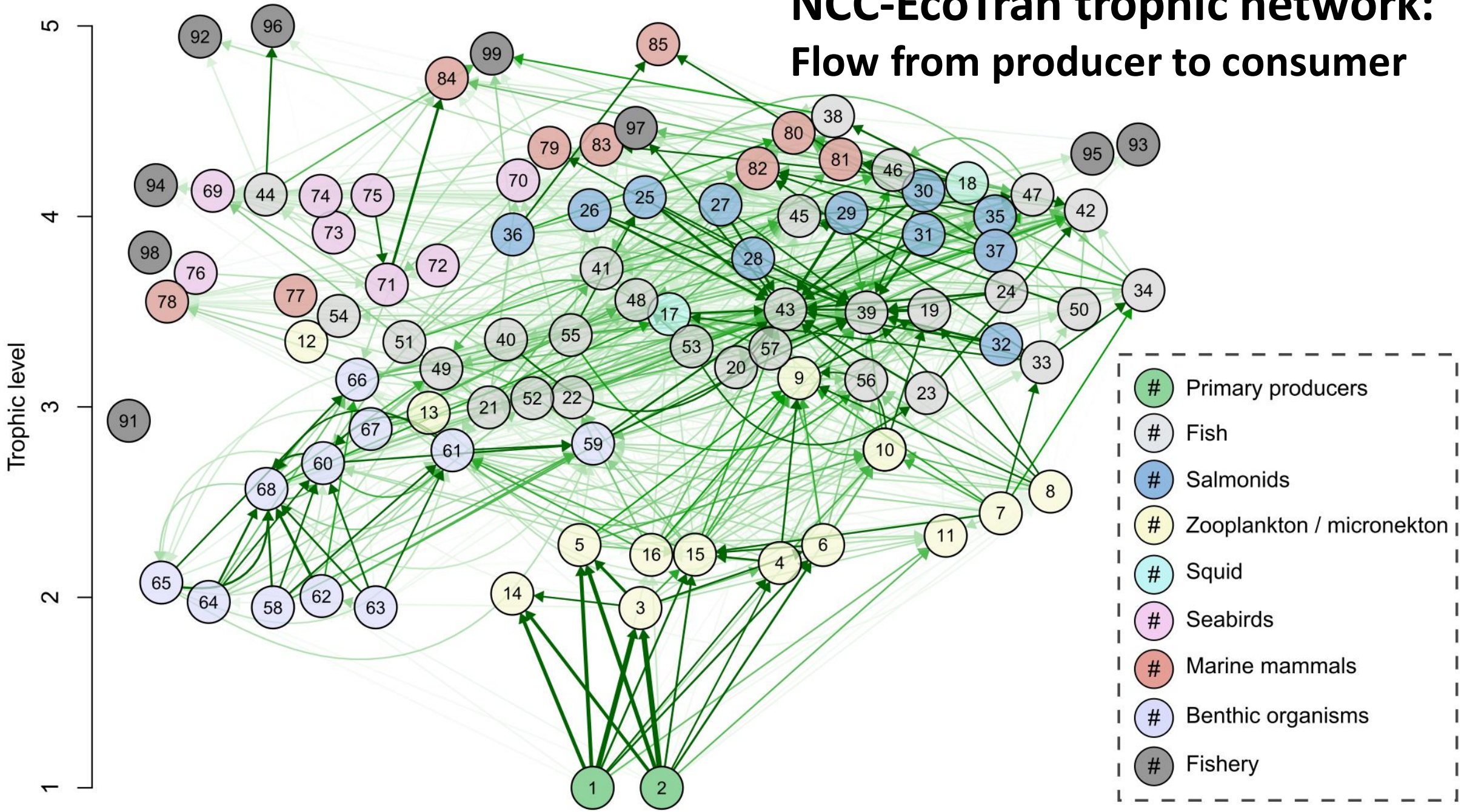
What is the fate of production?

producers

consumers

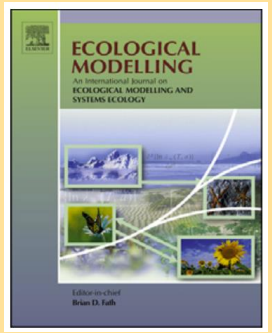
A_{cp}	NO_3	P_1	C_1	C_2	F_1	D_1	D_2	NH_4
NO_3	0	0	0	0	0	0	0	0.1
P_1	1	0	0	0	0	0	0	0.9
C_1	0	0.5	0	0	0.3	0.3	0.3	0
C_2	0	0.2	0.5	0.1	0.3	0.3	0.3	0
F_1	0	0	0	0.1	0	0	0	0
M0	0	0.3	0.2	0.4	0	0	0	0
feces	0	0	0.2	0.2	0.4	0	0	0
NH_4	0	0	0.1	0.2	0	0.4	0.4	0

NCC-EcoTran trophic network:
Flow from producer to consumer

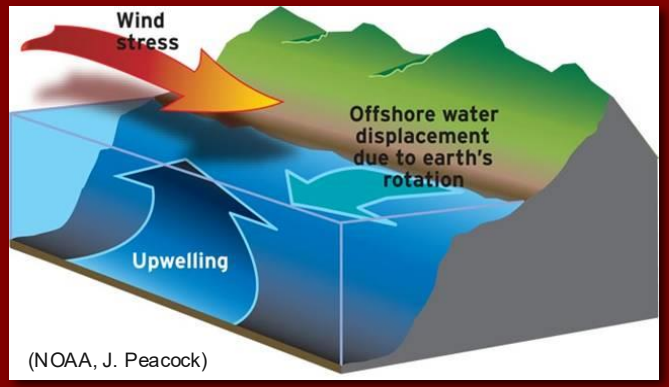


A physically coupled end-to-end model platform for coastal ecosystems: Simulating the effects of climate change and changing upwelling characteristics on the Northern California Current ecosystem

James J. Ruzicka [a,*], Kenneth H. Brink [b], Dian J. Gifford [c], Frank Bahr [b]



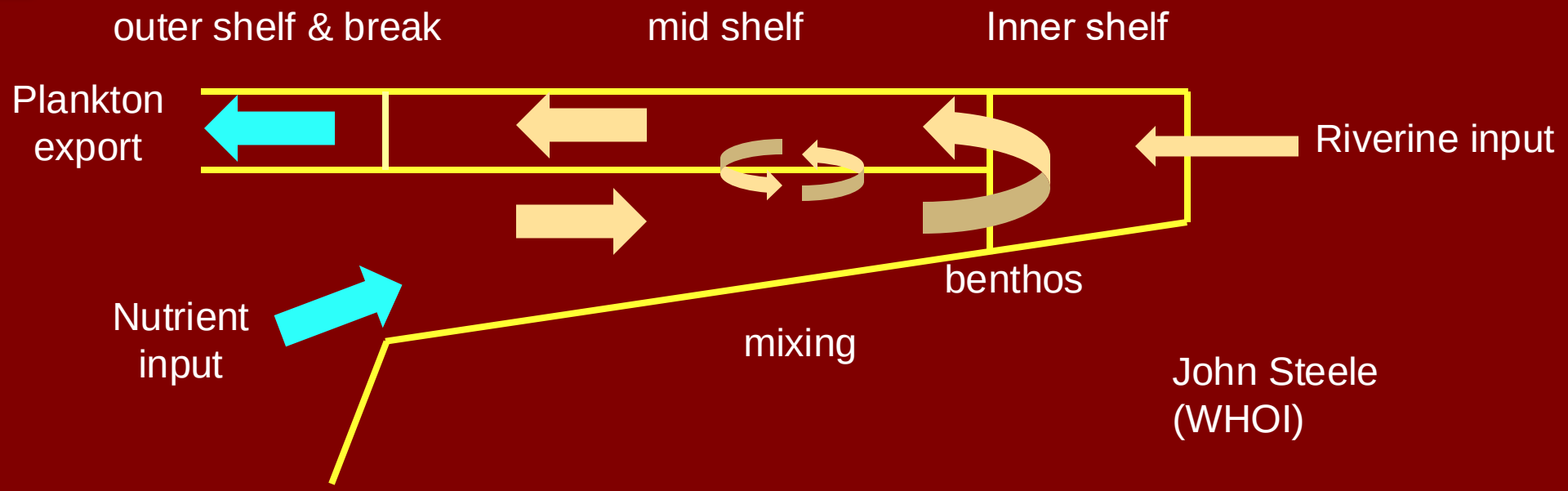
Ecological Modelling 331 (2016) 86–99



(NOAA, J. Peacock)

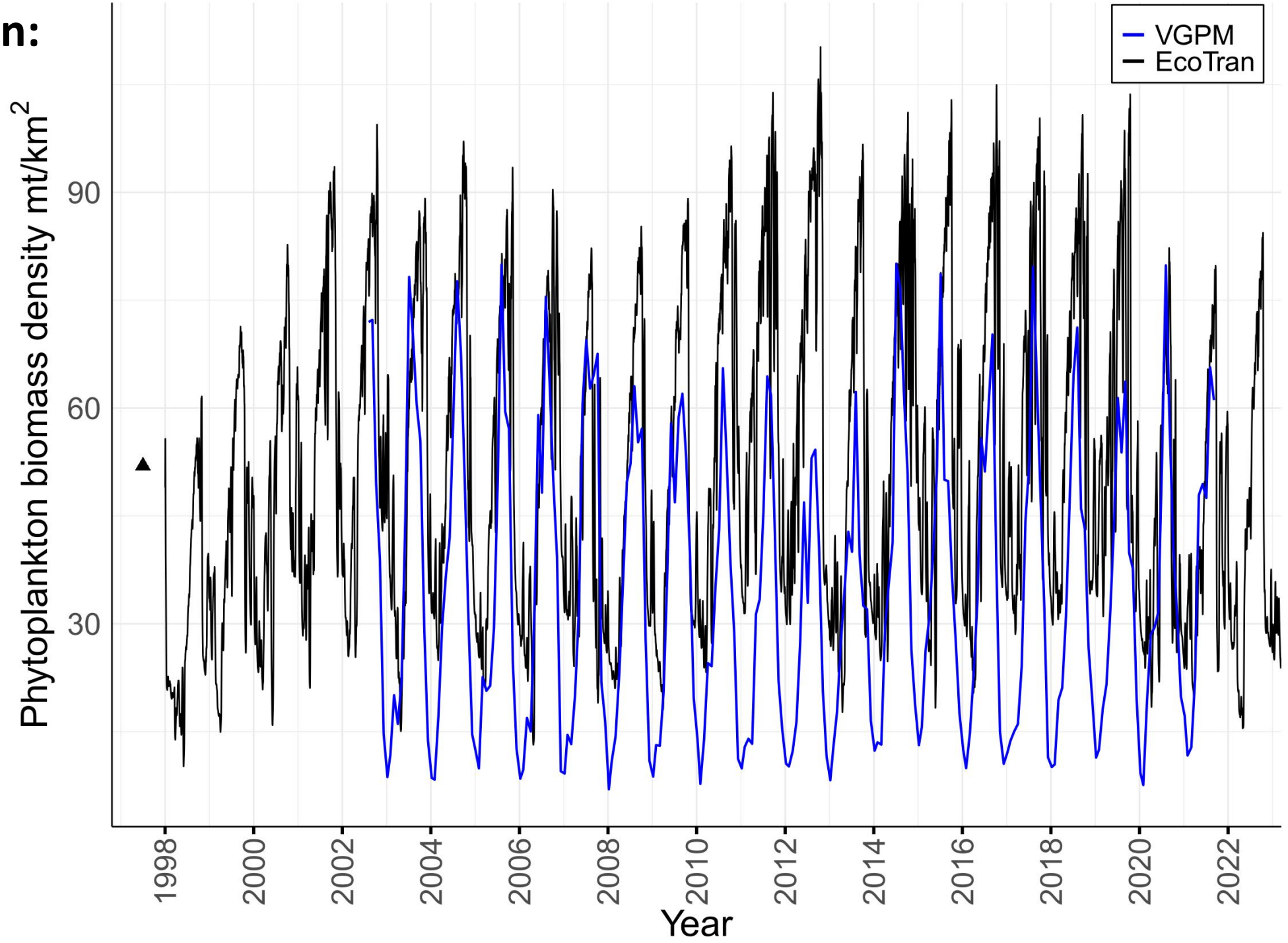
The main physical constraints on trophic fluxes:

- rate of **input** of inorganic nutrients
- **export** of planktonic production out of the system



Primary production:

NCC-EcoTran vs satellite-derived vertically generalized production model (VGPM)



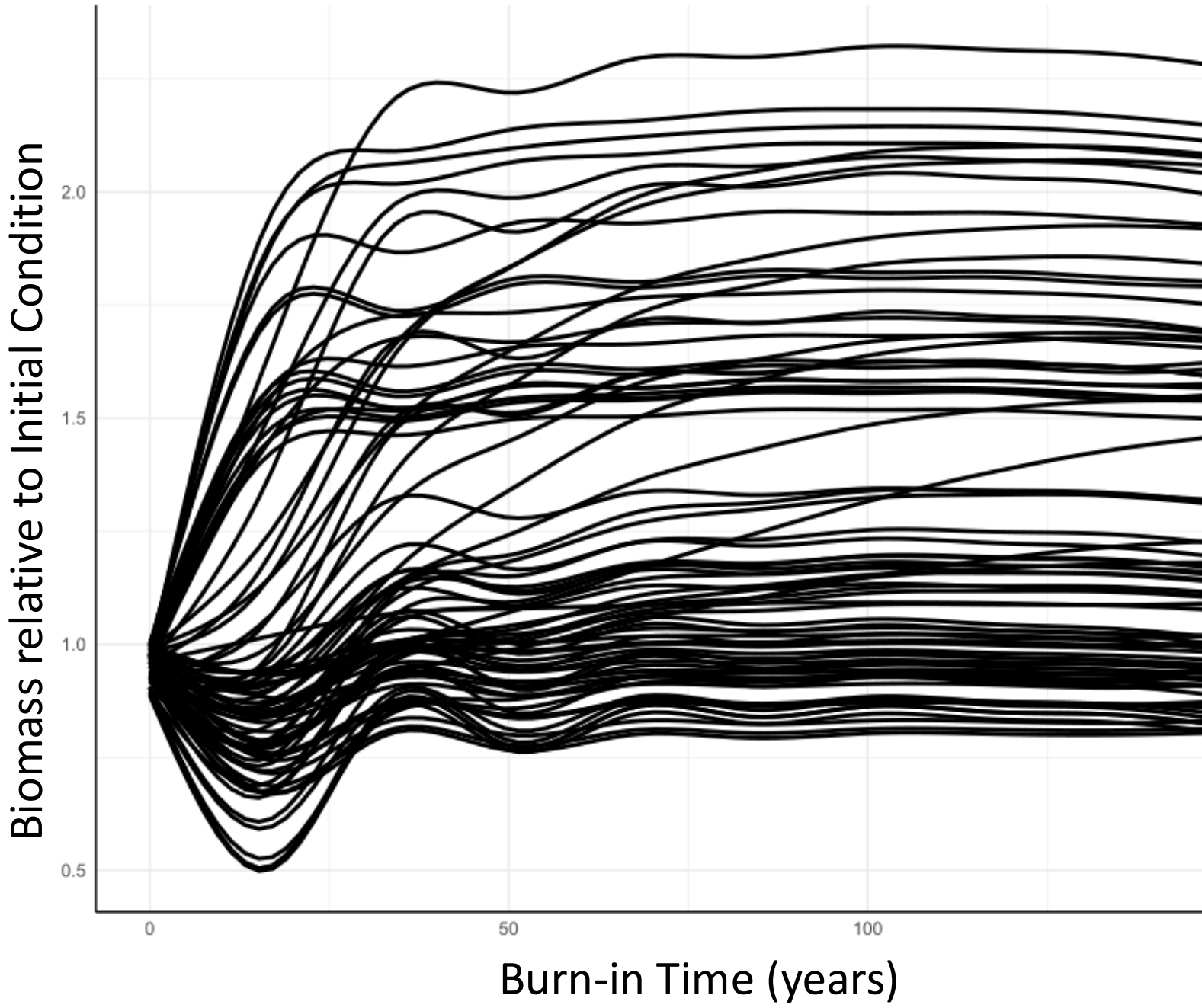
VGPM

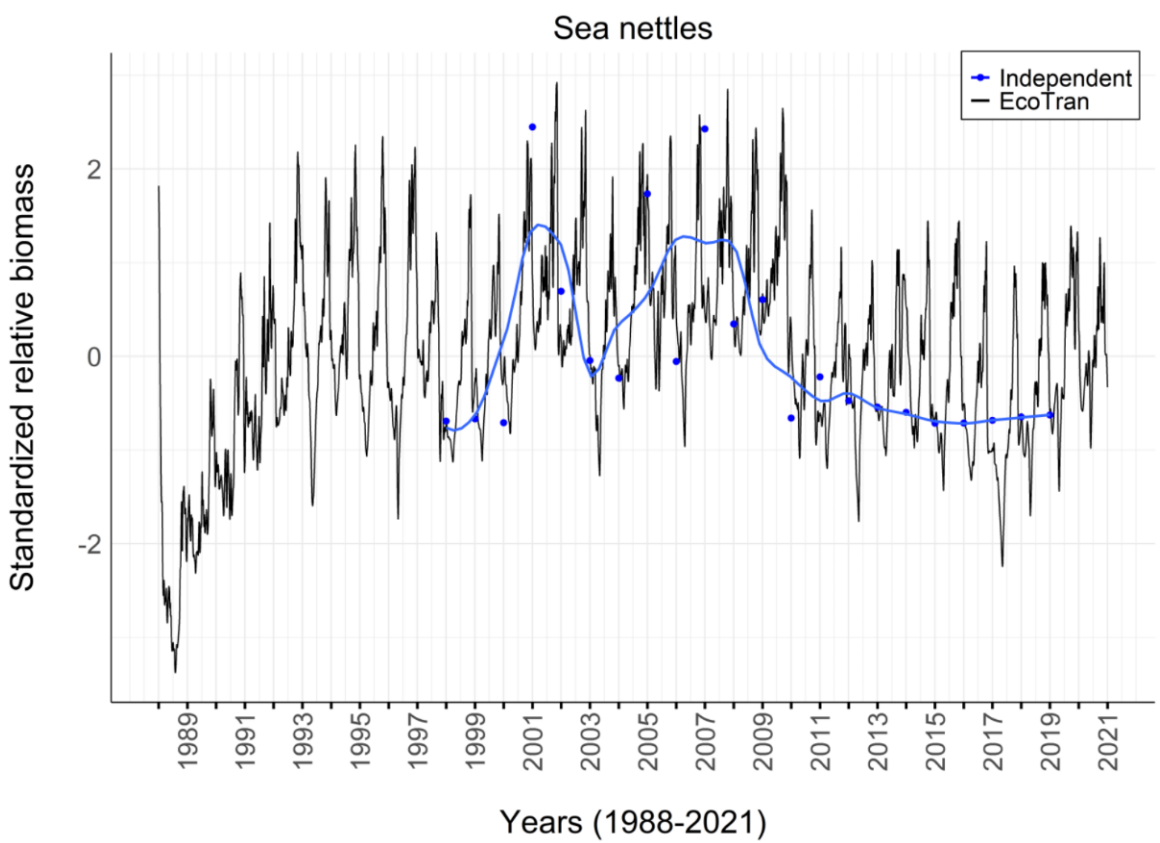
Behrenfeld & Falkowski. Photosynthetic rates derived from satellite-based chlorophyll concentration. Limnology and oceanography. 1997; 42: 1–20.

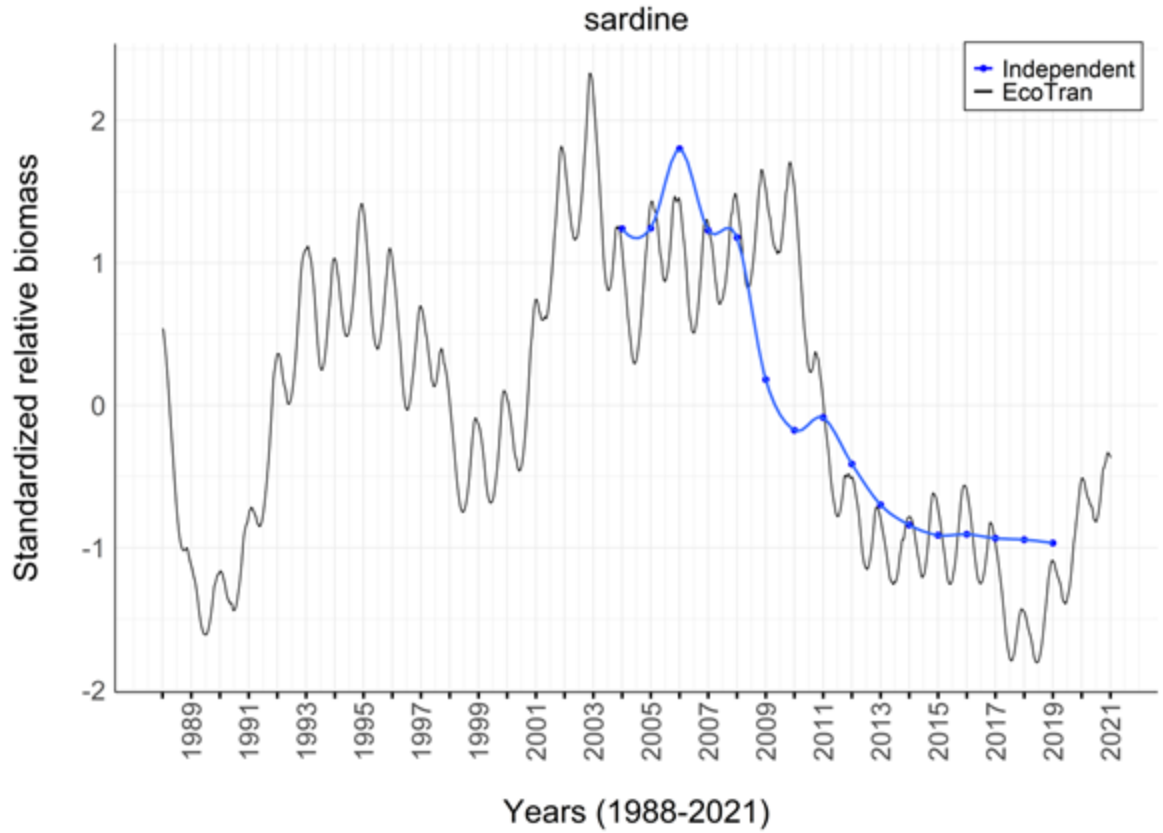
Assessing stability:

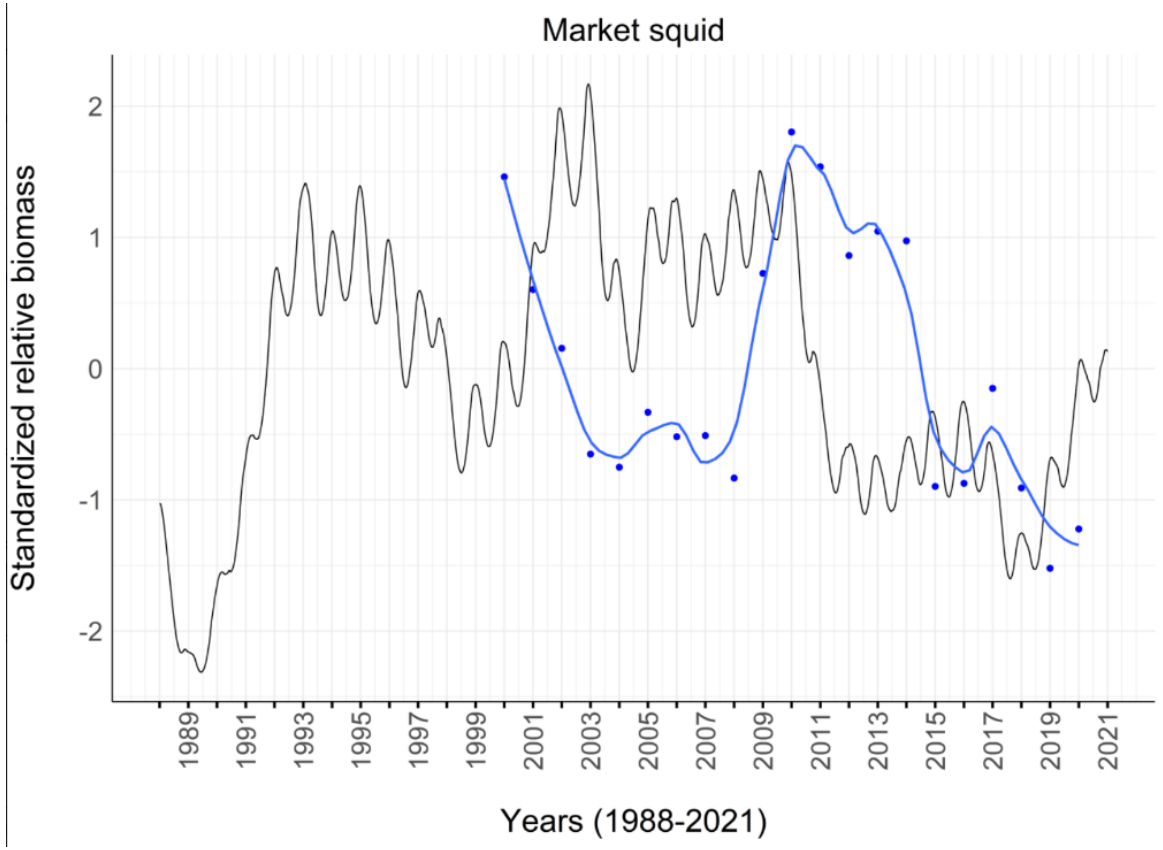
150-year model simulation driven by average upwelling time series (1988-2021)

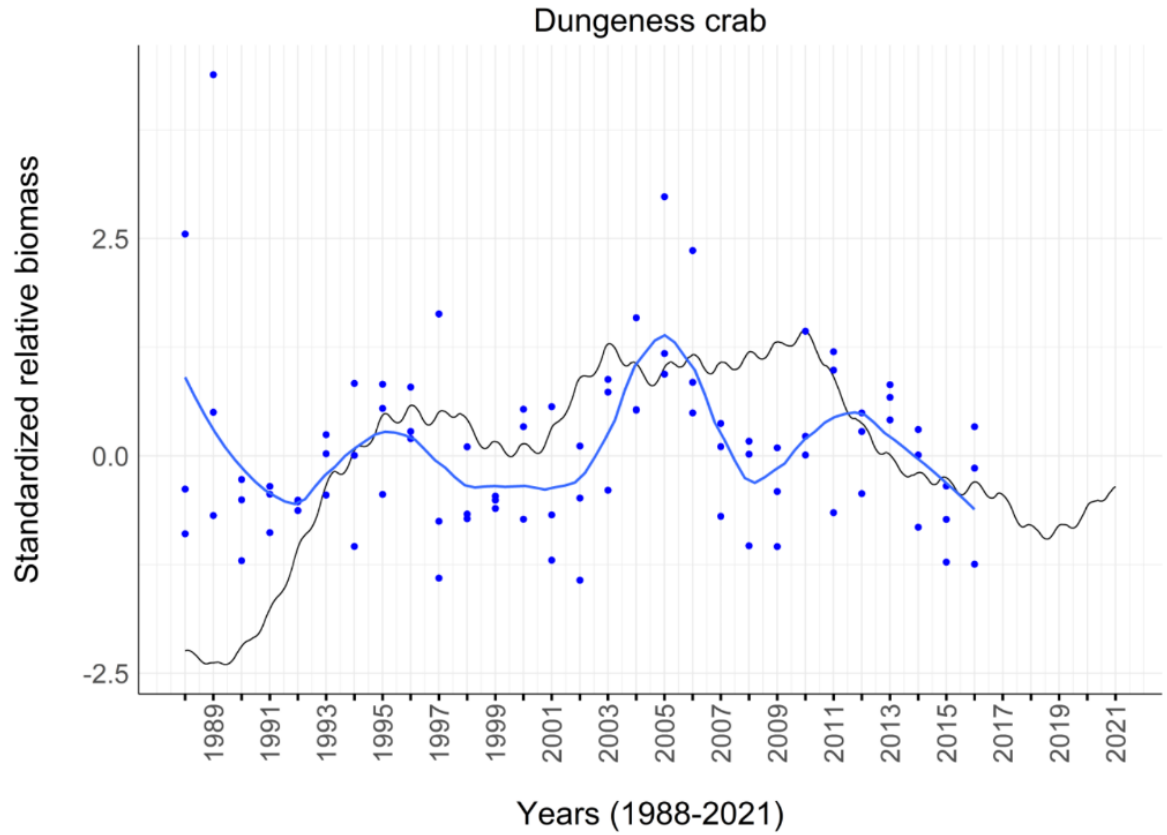
- **No extinctions**
- **none change by more than 5% in final 20 years**




Sea nettles
Independent
EcoTran
Standardized relative biomass
2
0
-2
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
2019
2021
Years (1988-2021)


sardine
Independent
EcoTran
Standardized relative biomass
2
1
0
-1
-2
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
2019
2021
Years (1988-2021)


Market squid
Standardized relative biomass
2
1
0
-1
-2
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
2019
2021
Years (1988-2021)


Dungeness crab
Standardized relative biomass
2.5
0.0
-2.5
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
2019
2021
Years (1988-2021)

Thank you!

Lisa Crozier

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Pierre-Yves Hernvann
Ric Brodeur

Anne Thompson
Barbara Muhling
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David Huff
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Isaac Kaplan
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Toby Auth

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