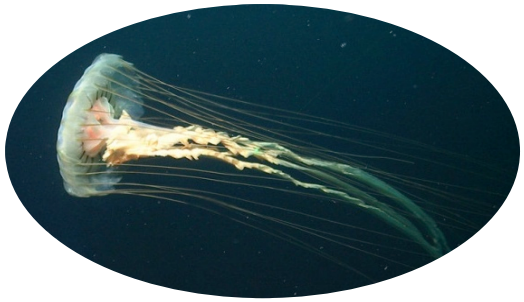
Do jellyfish blooms affect small pelagic fishes in coastal marine environments?



James Ruzicka[1], Richard Brodeur[2], Mary Beth Decker[3], Kristin Cieciel[4]

[1] Oregon State University, Newport, OR
[2] Northwest Fisheries Science Center, Newport, OR
[3] Department of Ecology and Evolutionary Biology, Yale University
[4] Alaska Fisheries Science Center, Auke Bay, AK

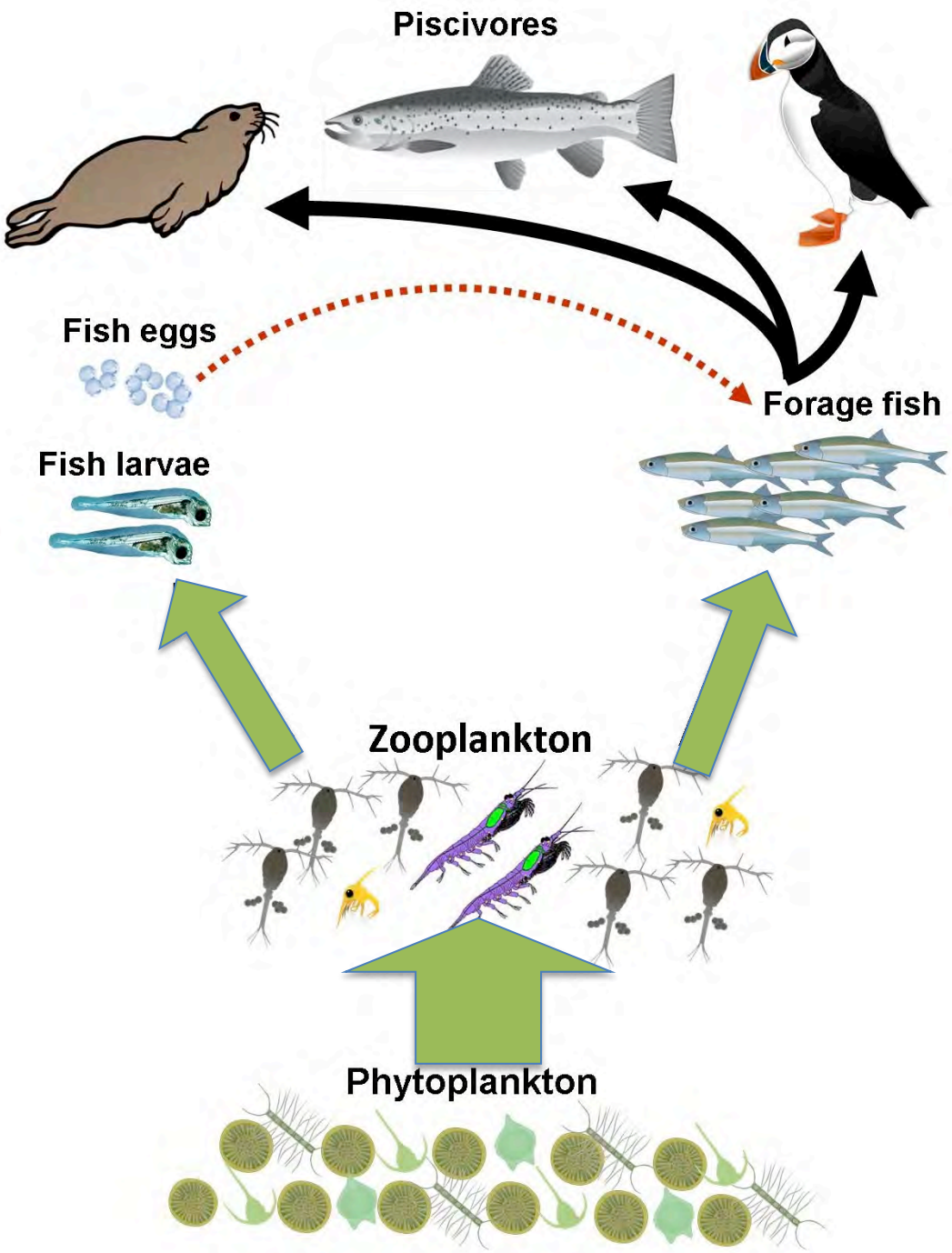


figure: Kelly Robinson

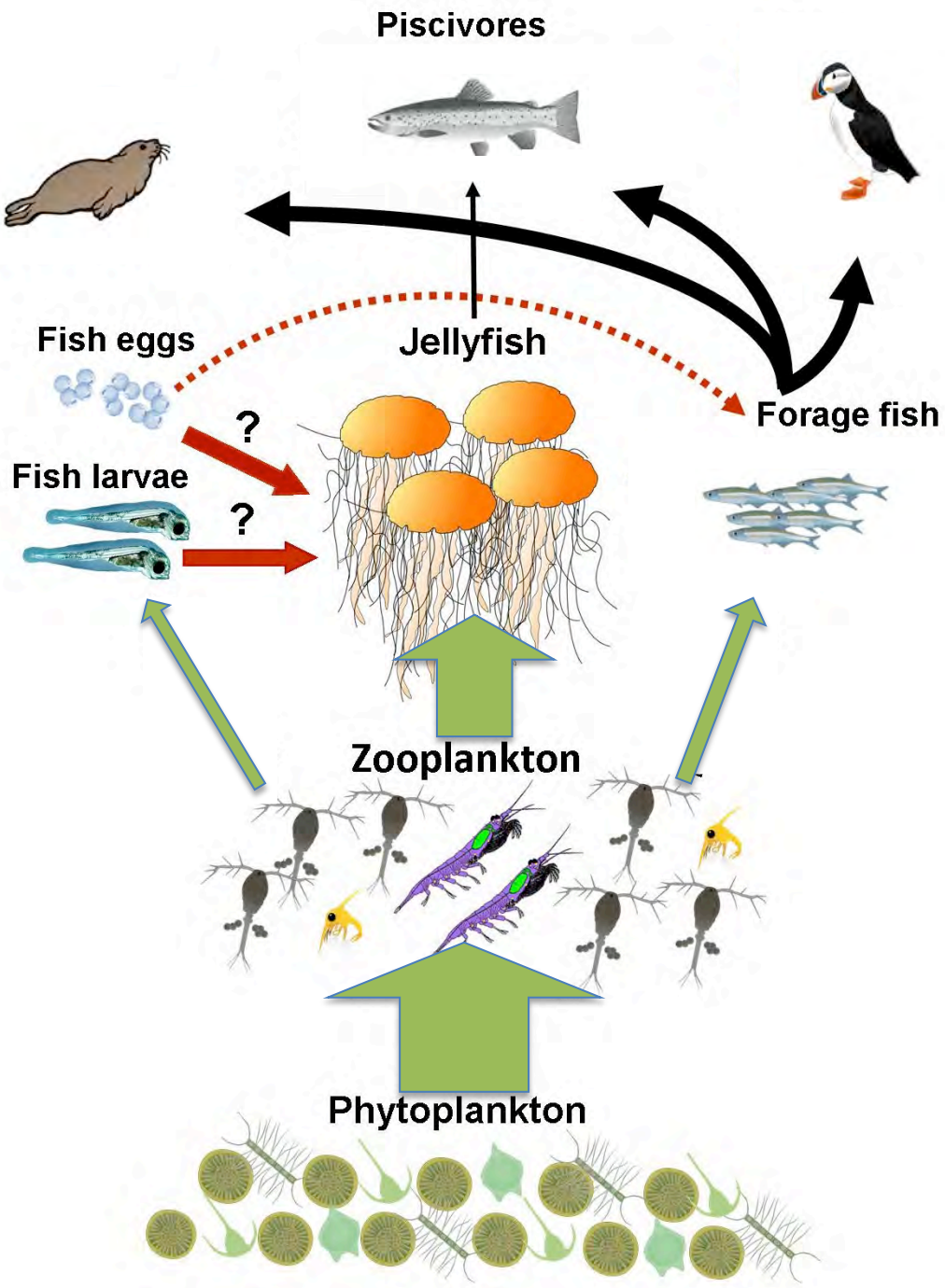
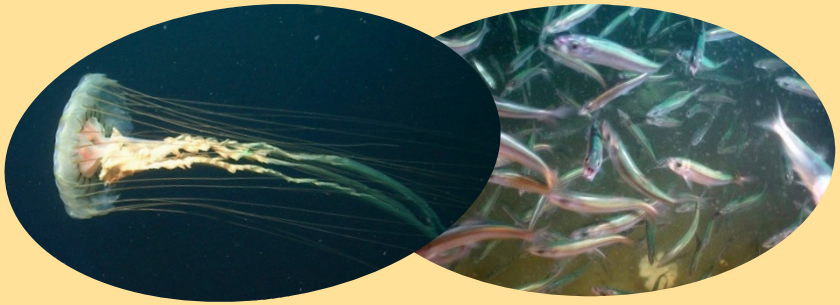


figure: Kelly Robinson

What impacts do jellyfish blooms have on the Bering Sea, Gulf of Alaska, & Northern California Current ecosystems?
What is their impact on small pelagic fishes?

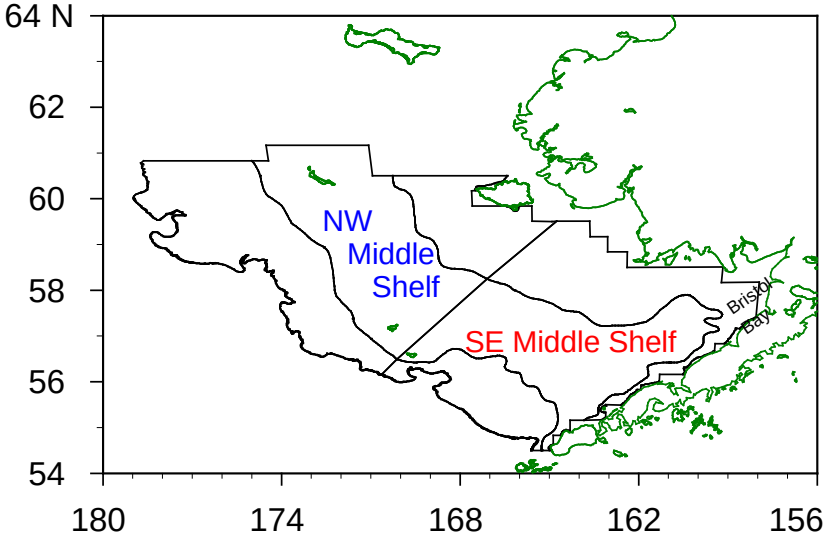


Project Goals

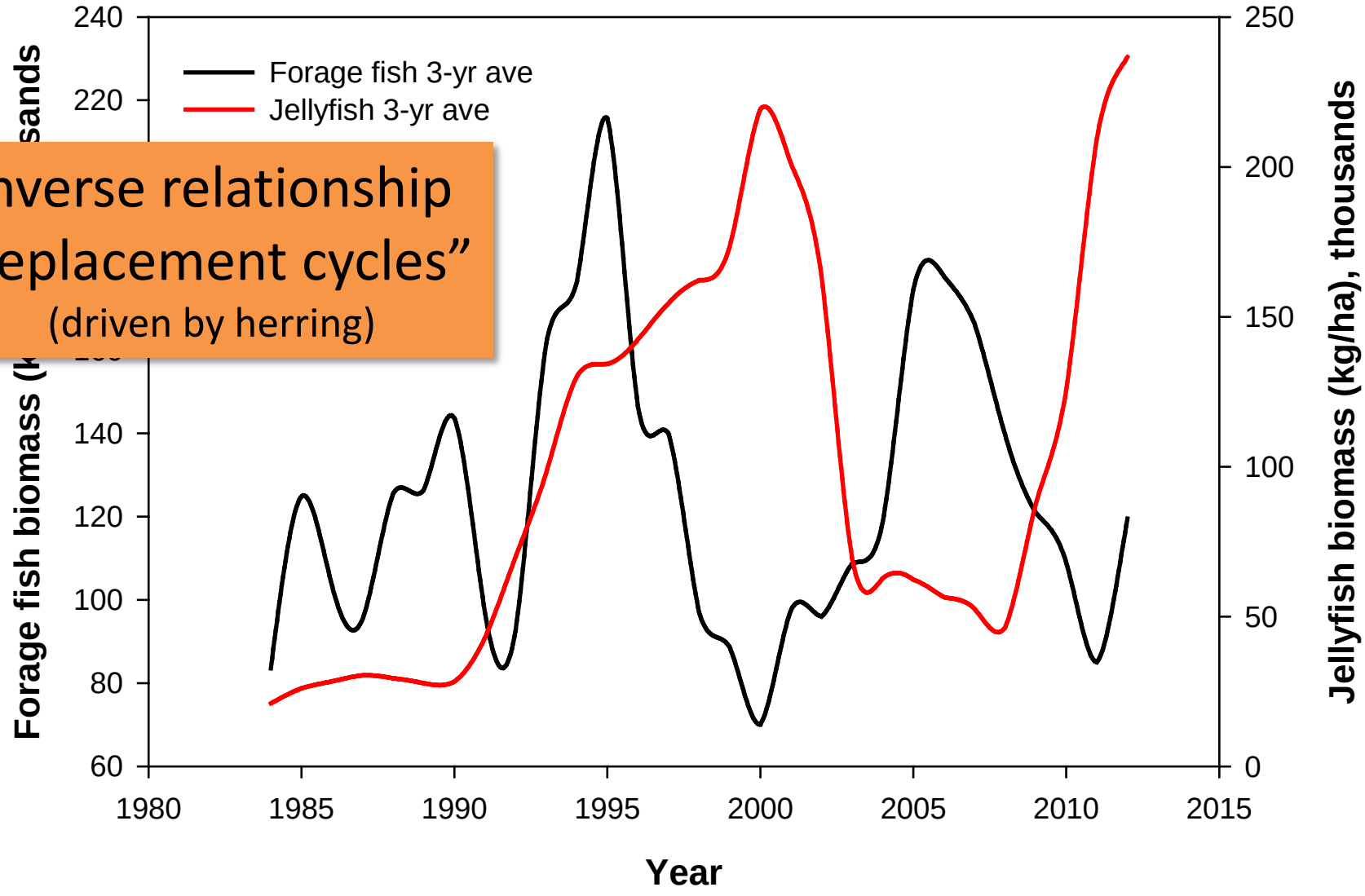
1. Identify the species/years most impacted by jellyfish blooms
2. Determine dietary overlap & spatial overlap of jellyfish & forage fish
3. Determine predatory impacts on fish larvae and zooplankton
4. Use ecosystem modeling to estimate impact of jellyfish on other components of the ecosystem

Eastern Bering Sea Bottom Trawl Jellyfish Biomass

(>95% *Chrysaora melanaster*)



3-year running means of forage fish & jellyfish in Bottom Trawl Survey

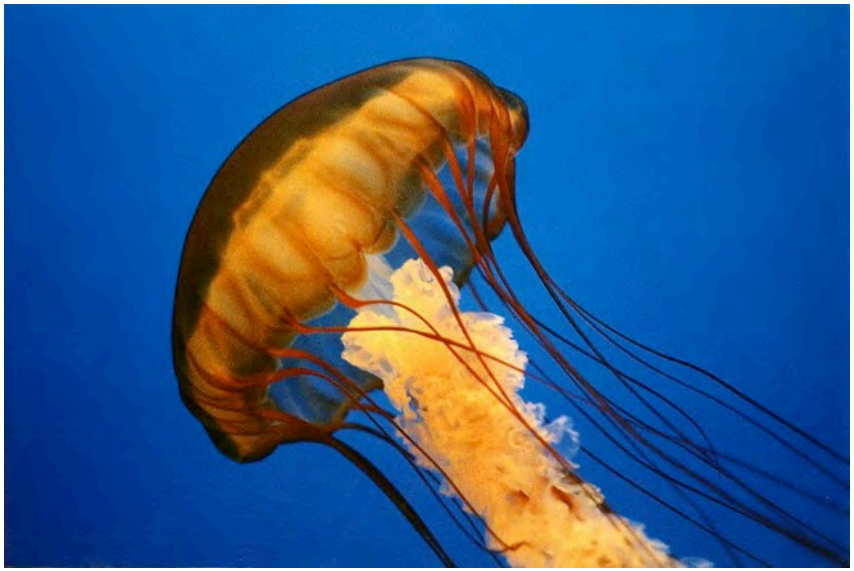


inverse relationship
"replacement cycles"
(driven by herring)

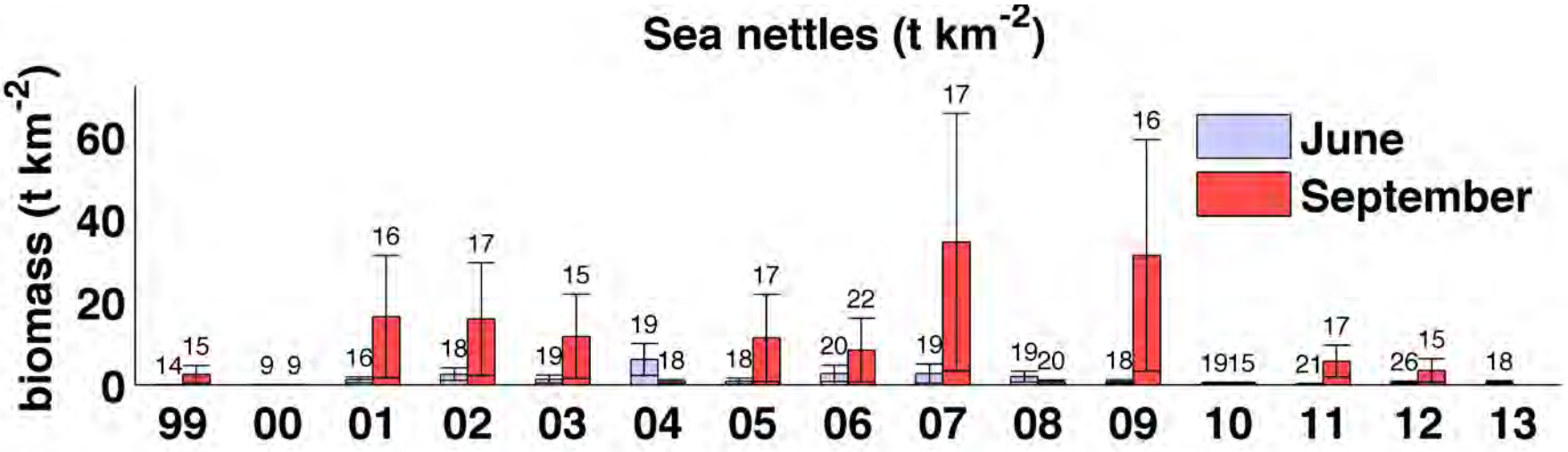
Robinson et al. (2014)

Northern California Current

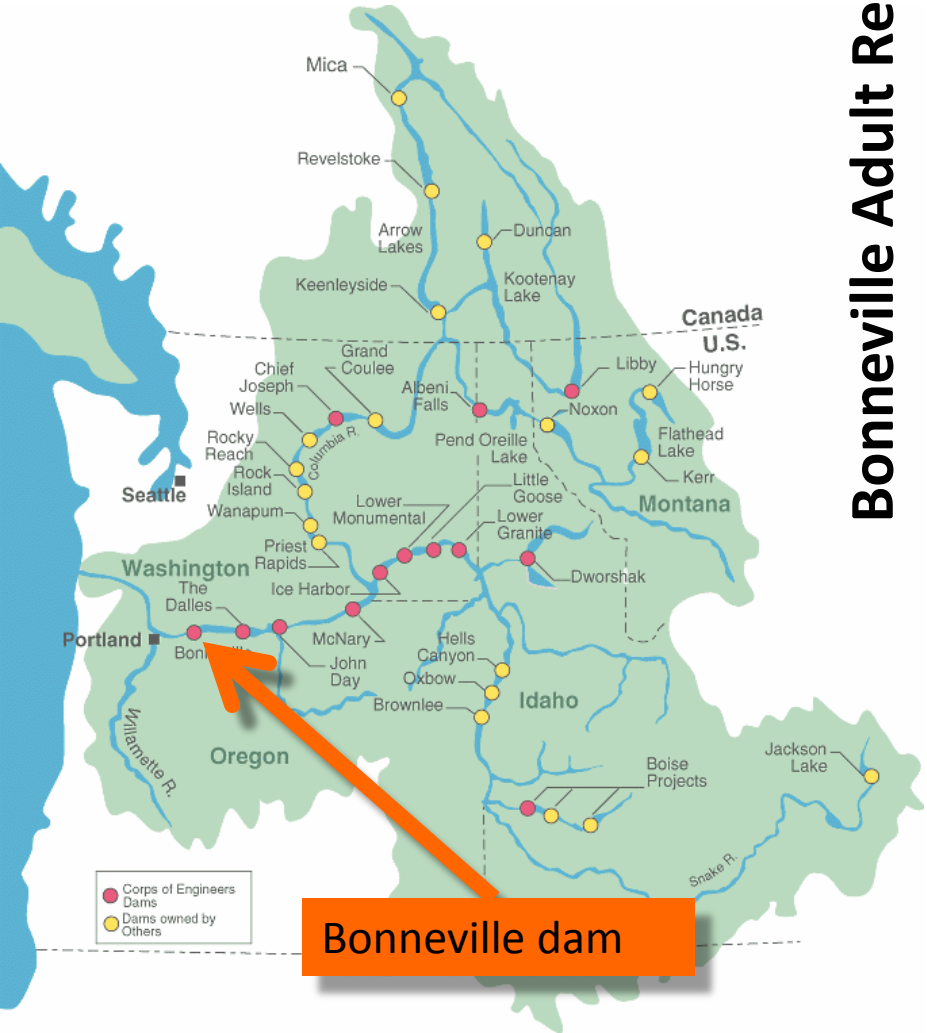
The sea nettle, *Chrysaora fuscescens*

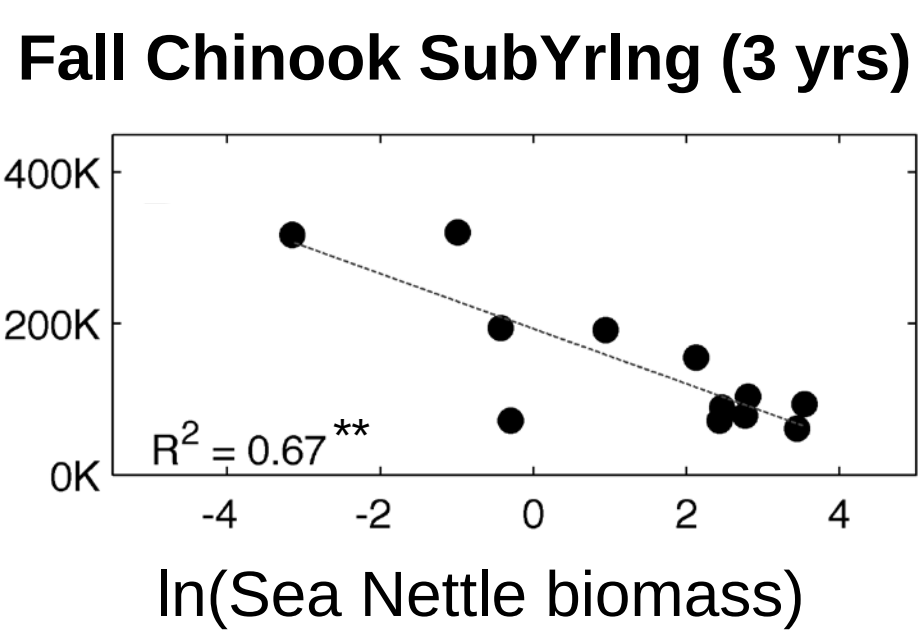


photos: R. Brodeur



Bonneville Adult Returns vs September Sea Nettles (in ocean entry year)

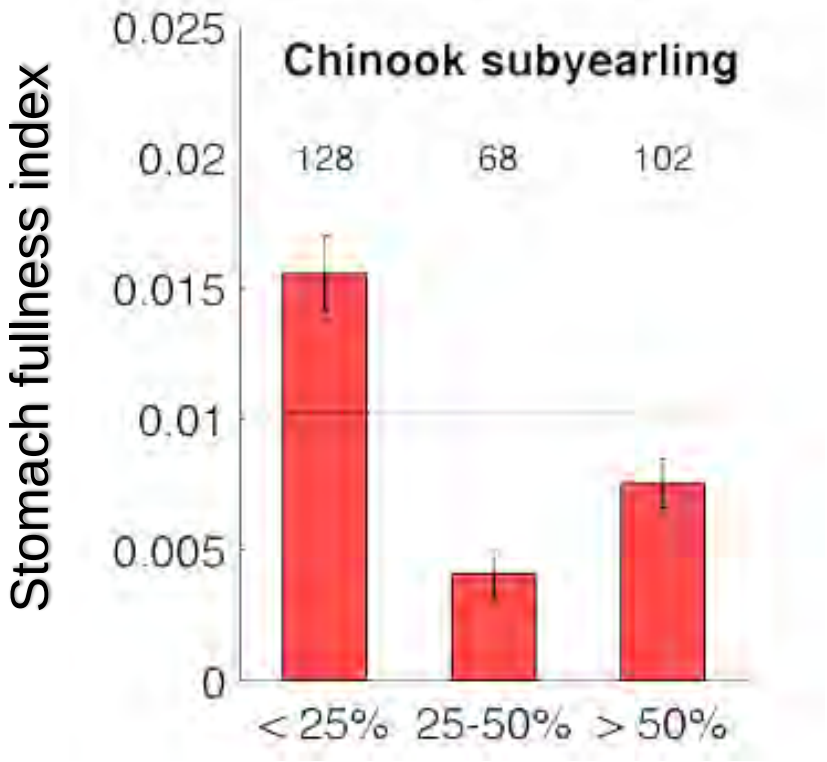




Chinook subyearling

Fall-run Chinook

Index of Feeding Intensity



fewer jellyfish

more jellyfish

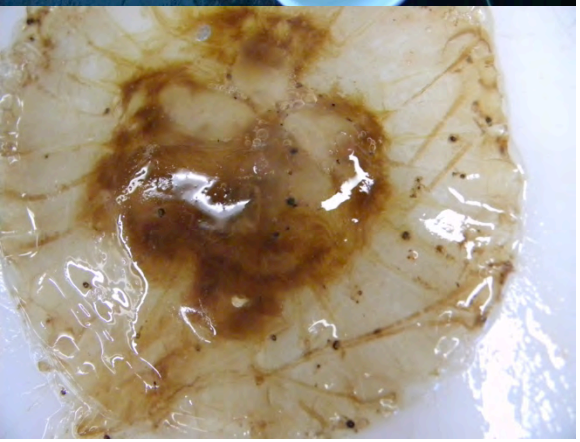
Feeding analysis by E. Daly (OSU)

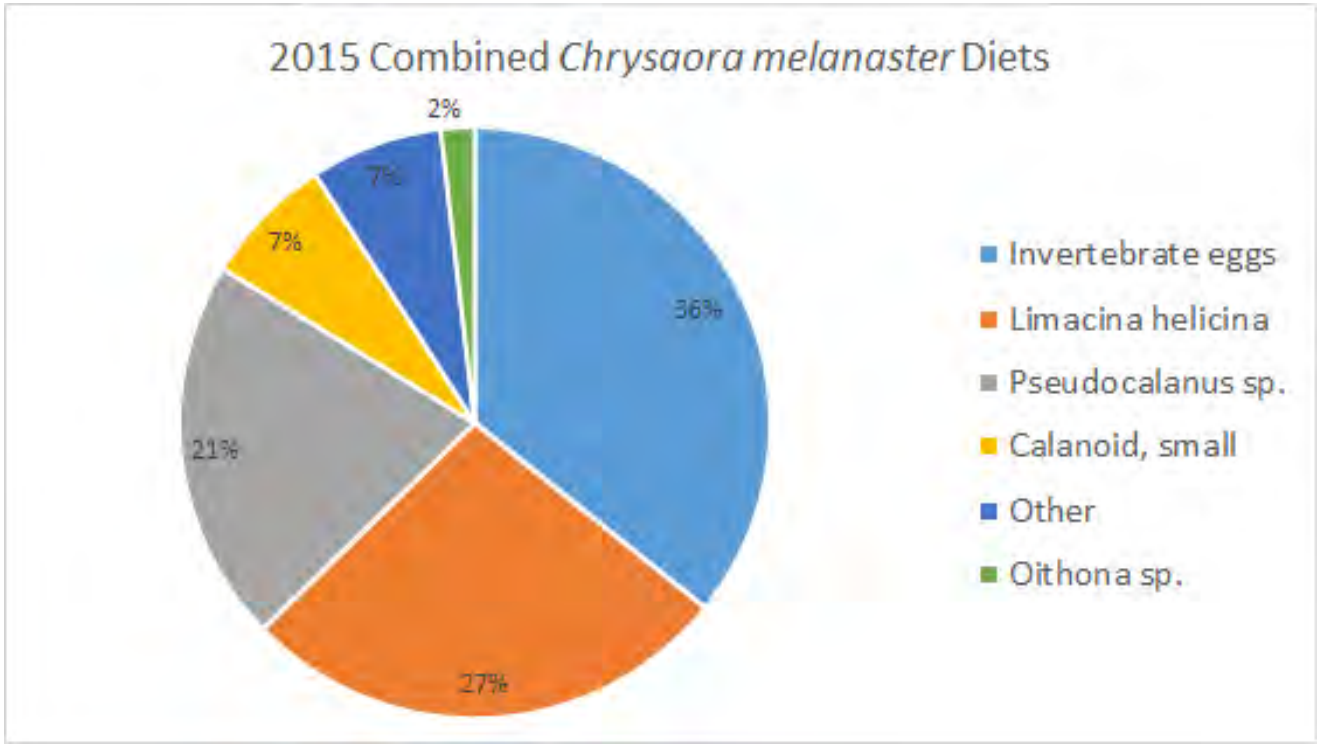
EBS: Spatial & diet overlap between jellyfish & forage fishes

Fishery surveys monitor large jellyfish & forage fish

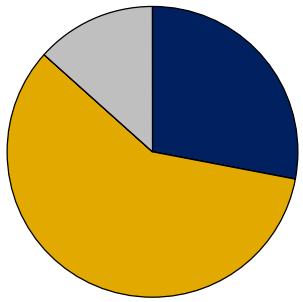
Bering Arctic Subarctic Integrated Surveys
BASIS
Surface Trawls (upper 15 m)
August-September 2004 – 2016

Feeding rates & diet composition

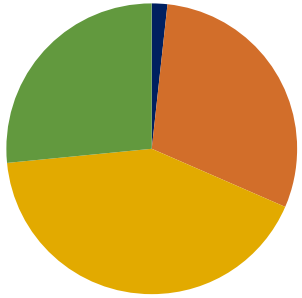




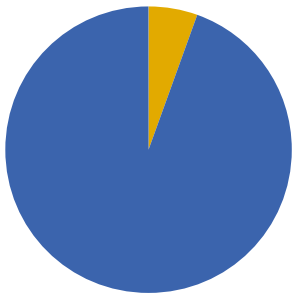
Alaskan Pollock



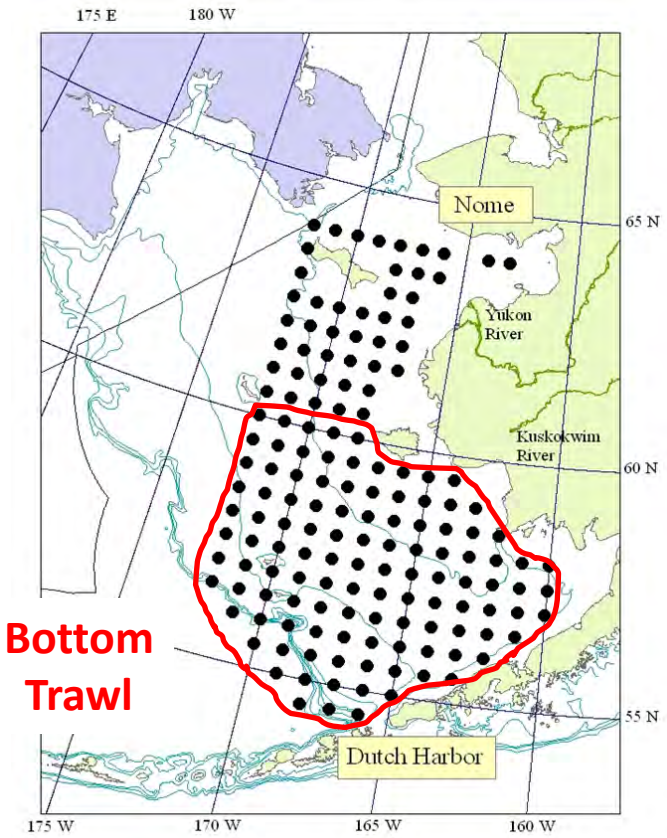
Pacific Cod



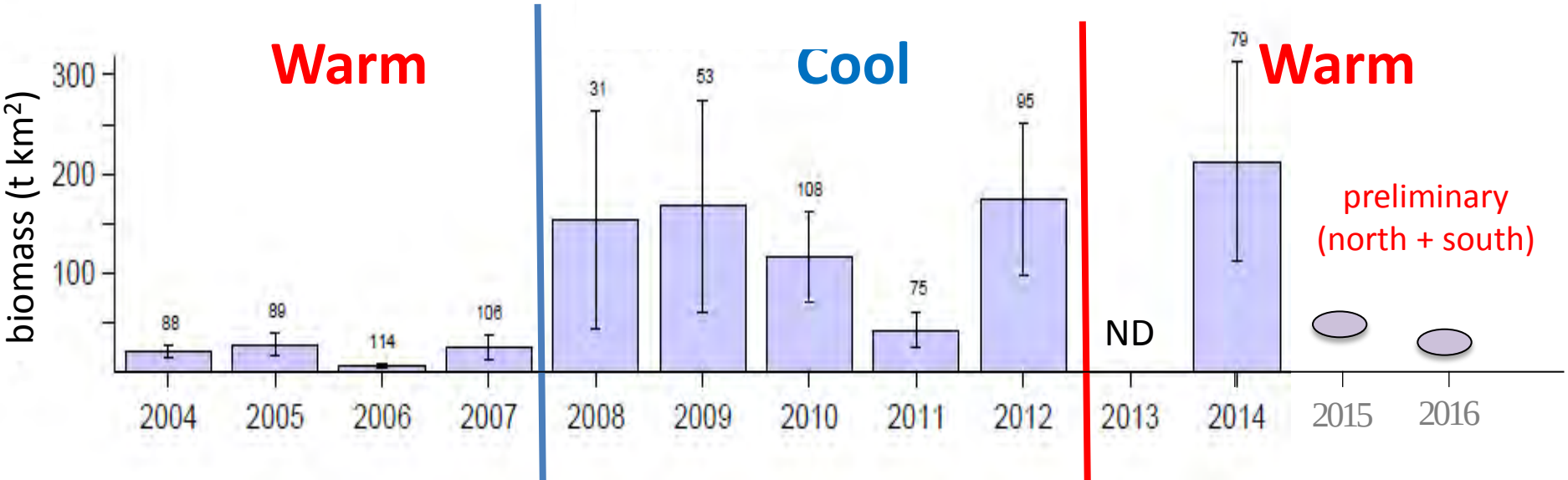
Pacific Herring



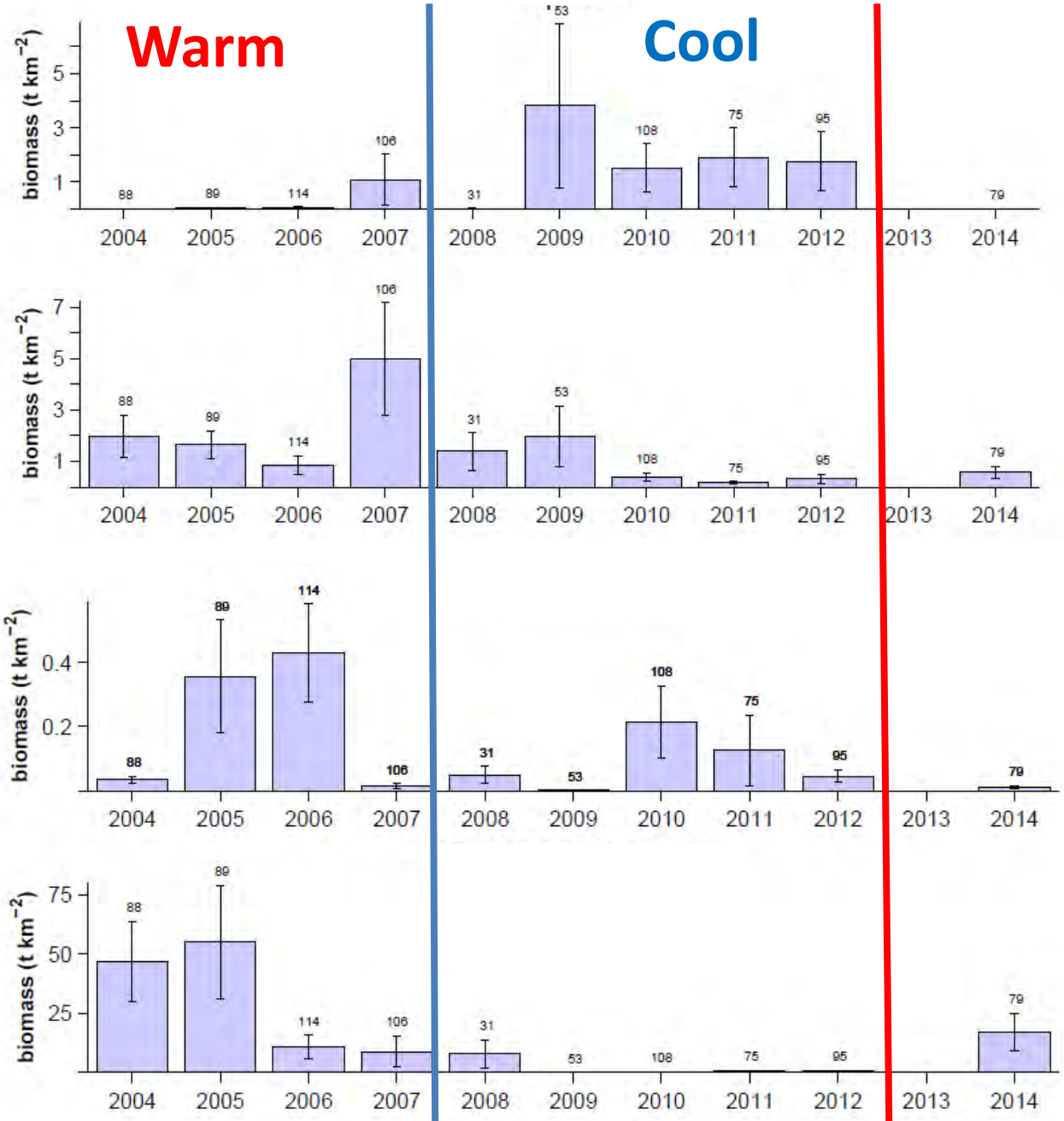
Surface Trawl Jellyfish Biomass



Chrysaora melanaster



Surface Trawl Forage Fish Biomass



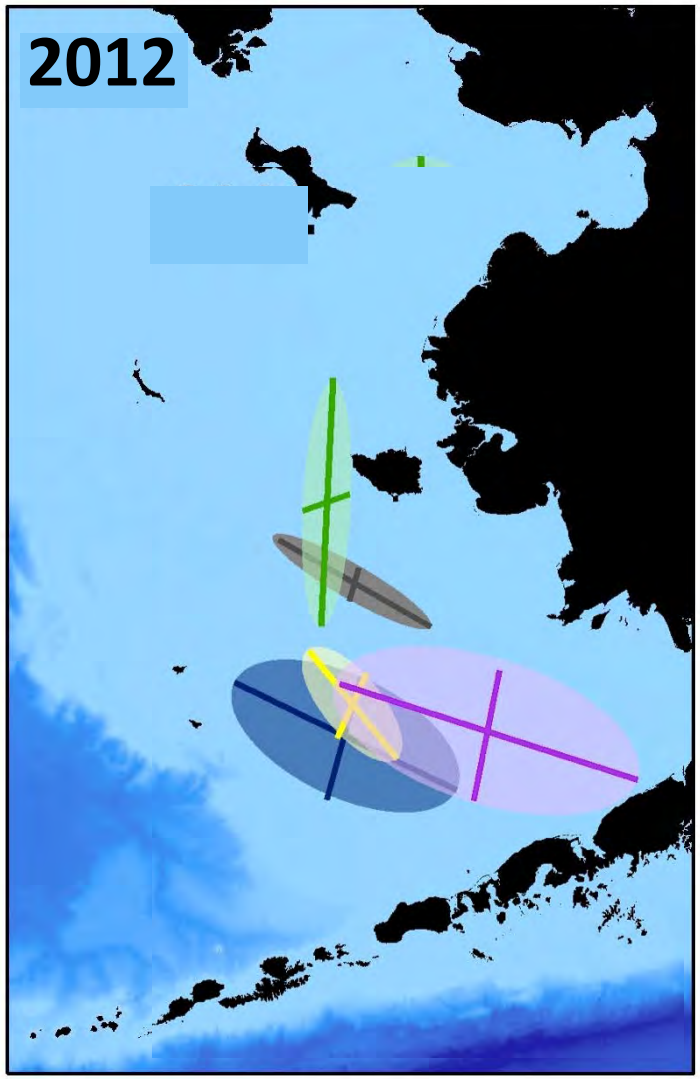
Adult Capelin

Sub-adult Herring

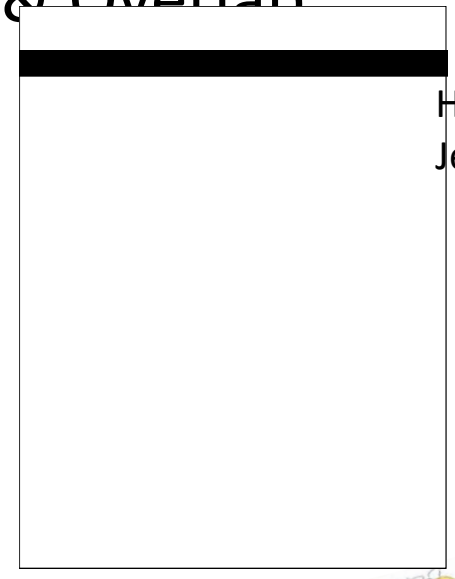
Age- 0 Pacific Cod

Age- 0 Pollock

Geostatistical Analyses



Centroids & Overlap



Herring x
Jellyfish 2006

Chrysaora melanaster

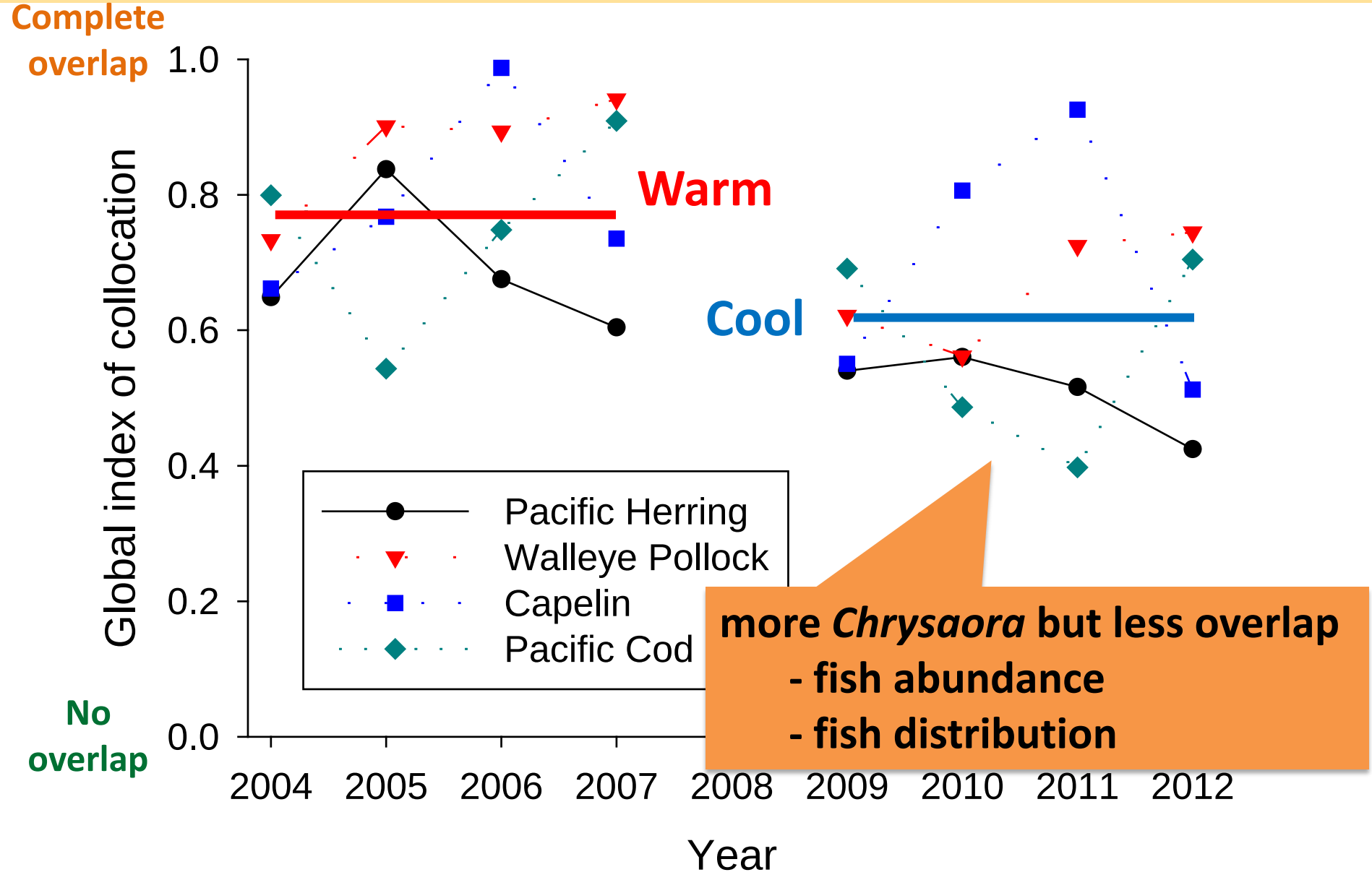
herring

age-0 Pacific cod

age-0 pollock

capelin

Comparison of Global Index of Collocation between *Chrysaora* & forage fishes in the Bering Sea

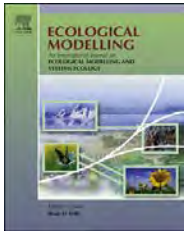


E2E Ecosystem modeling approach

1. Synthesize diet, consumption rate, and community biomass data within a trophic framework to **estimate grazing pressure** of jellyfish upon zooplankton production
2. **Estimate predation pressure** upon fish eggs and larvae
3. Identify important **energy transfer nodes** and compare alternate **ecosystem states** (warm vs cool years, high vs low jelly years)
4. Simulation analyses to estimate **impact of jellyfish blooms** upon other components of the ecosystem
5. Evaluate roles of **food web structure vs physical context** in ecosystem dynamics

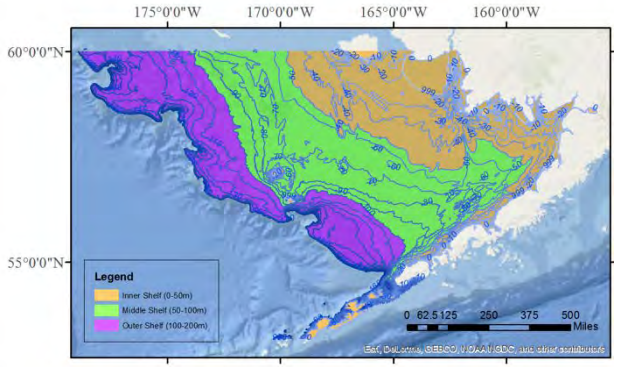
ECOTRAN end-to-end ecosystem modeling platform

Ruzicka, Brink, Bahr, & Gifford (2016) *Ecological Modelling* 331:86-99

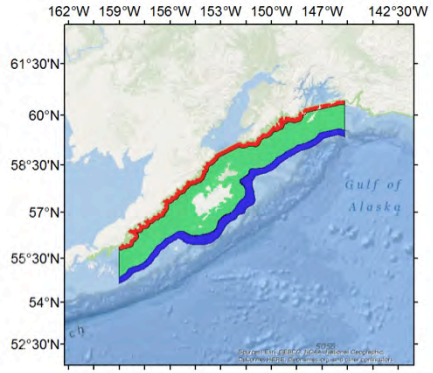


Model analysis: similarly configured models

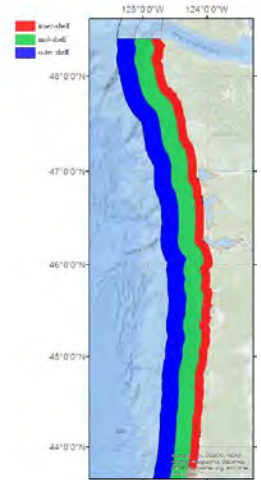
Eastern Bering Sea



western Coastal Gulf of Alaska

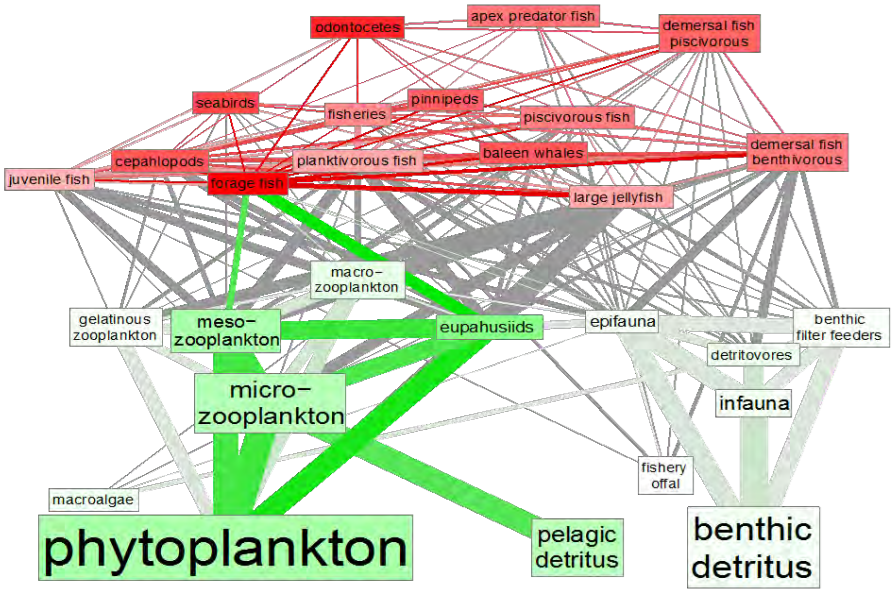


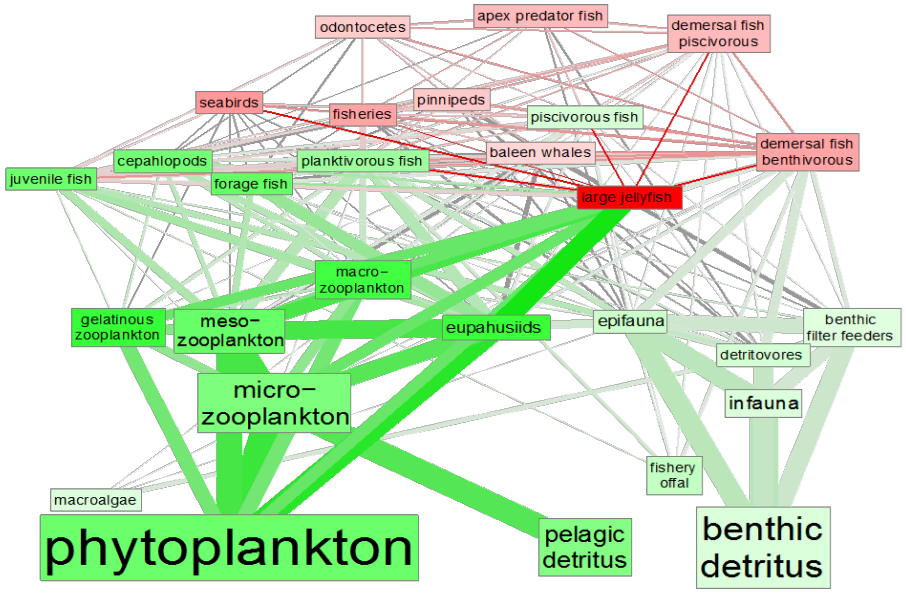
Northern California Current

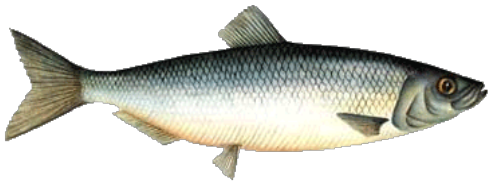


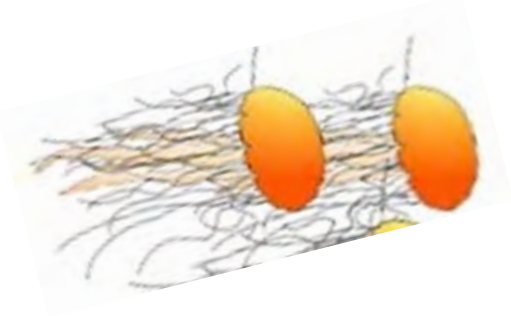
Model analysis: ecosystem state metrics

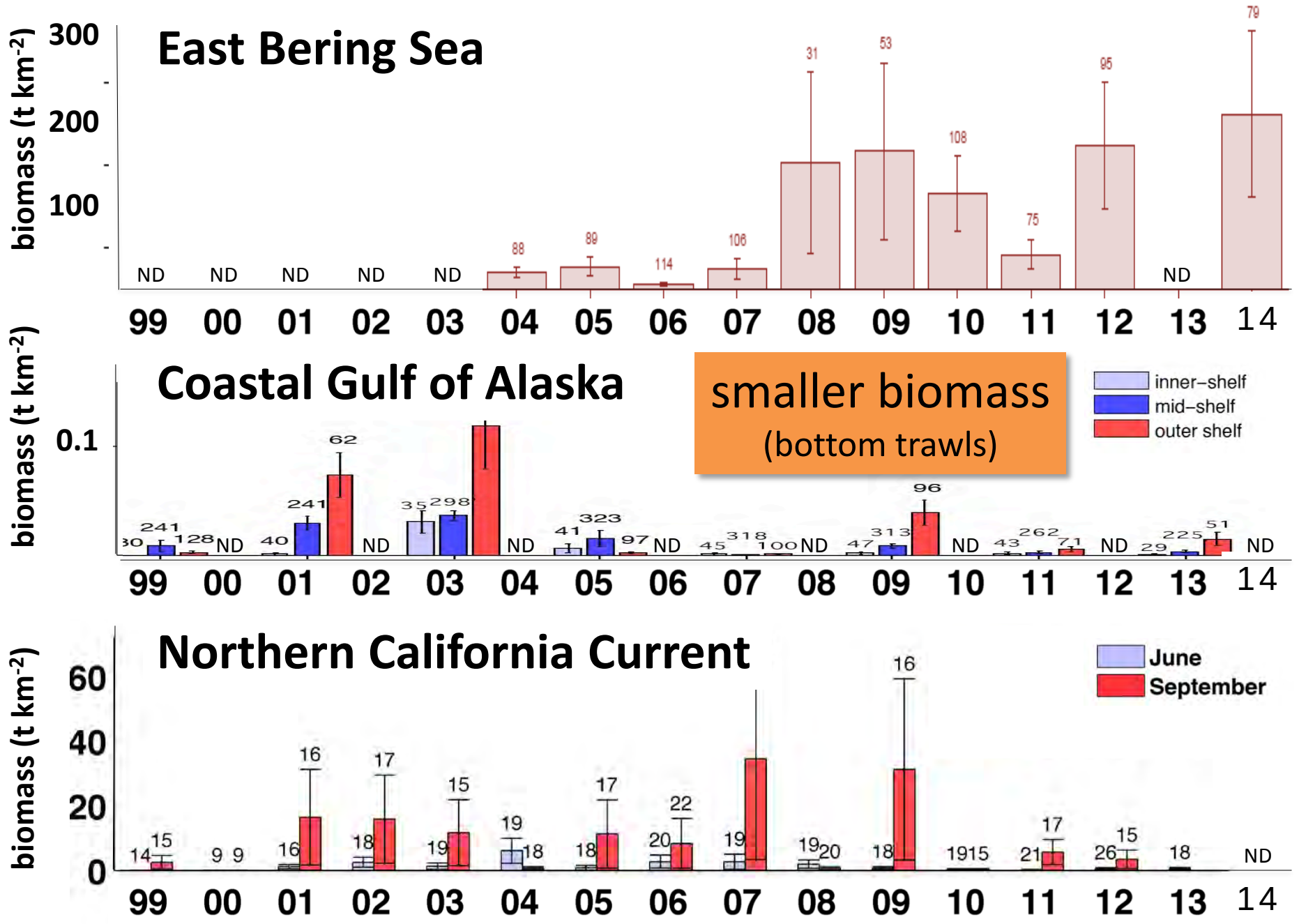
- **Quantify the importance of jellyfish & forage fish groups as energy transfer nodes**





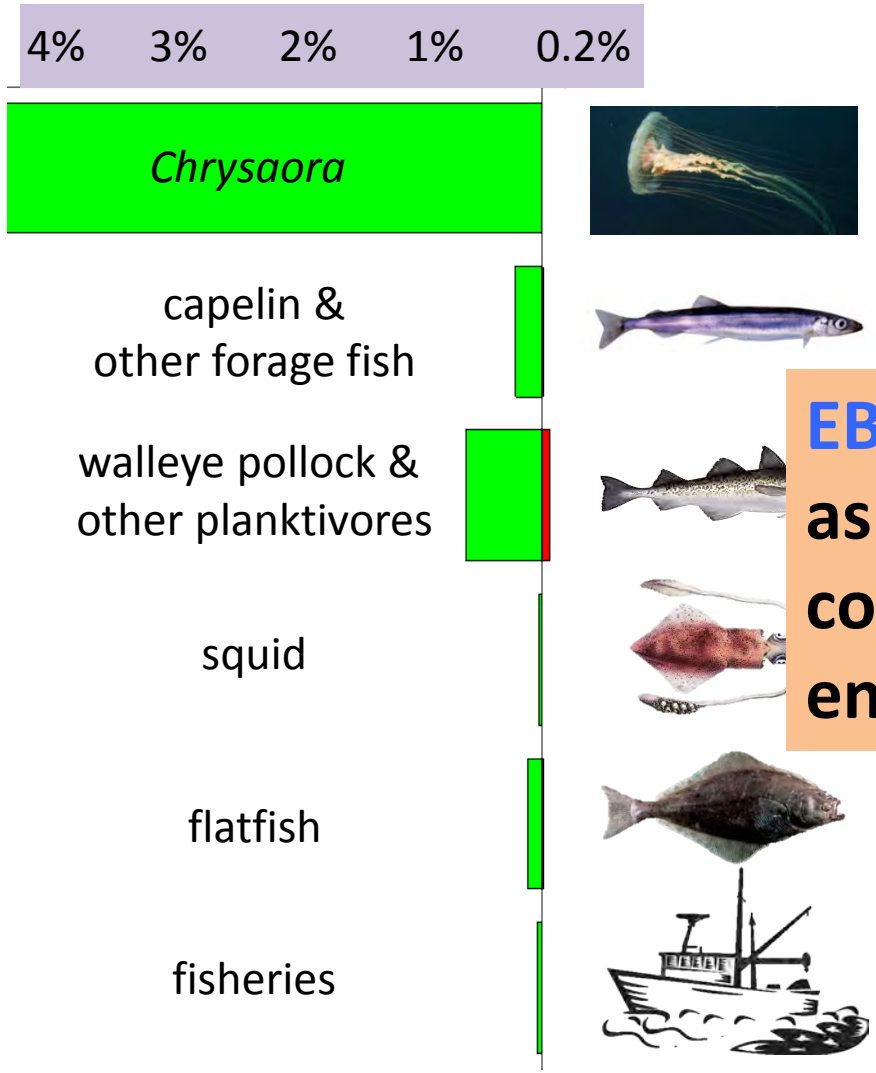





East Bering Sea
biomass (t km-2)
300
200
100
ND ND ND ND ND 88 89 114 106 31 53 108 75 95 ND 79
99 00 01 02 03 04 05 06 07 08 09 10 11 12 13 14
Coastal Gulf of Alaska
biomass (t km-2)
0.1
smaller biomass
(bottom trawls)
inner–shelf
mid–shelf
outer shelf
30 241 128 ND 40 241 62 ND 35 298 ND 41 323 97 ND 45 318 100 ND 47 313 96 ND 43 262 71 ND 29 225 51 ND
99 00 01 02 03 04 05 06 07 08 09 10 11 12 13 14
Northern California Current
biomass (t km-2)
60
40
20
0
June
September
14 15 9 9 16 16 18 17 19 15 19 18 18 17 20 22 19 16 19 20 18 16 19 15 21 17 26 15 18 ND
99 00 01 02 03 04 05 06 07 08 09 10 11 12 13 14

←footprint reach→

(% of all ecosystem production used) (% of all consumer production contributed)



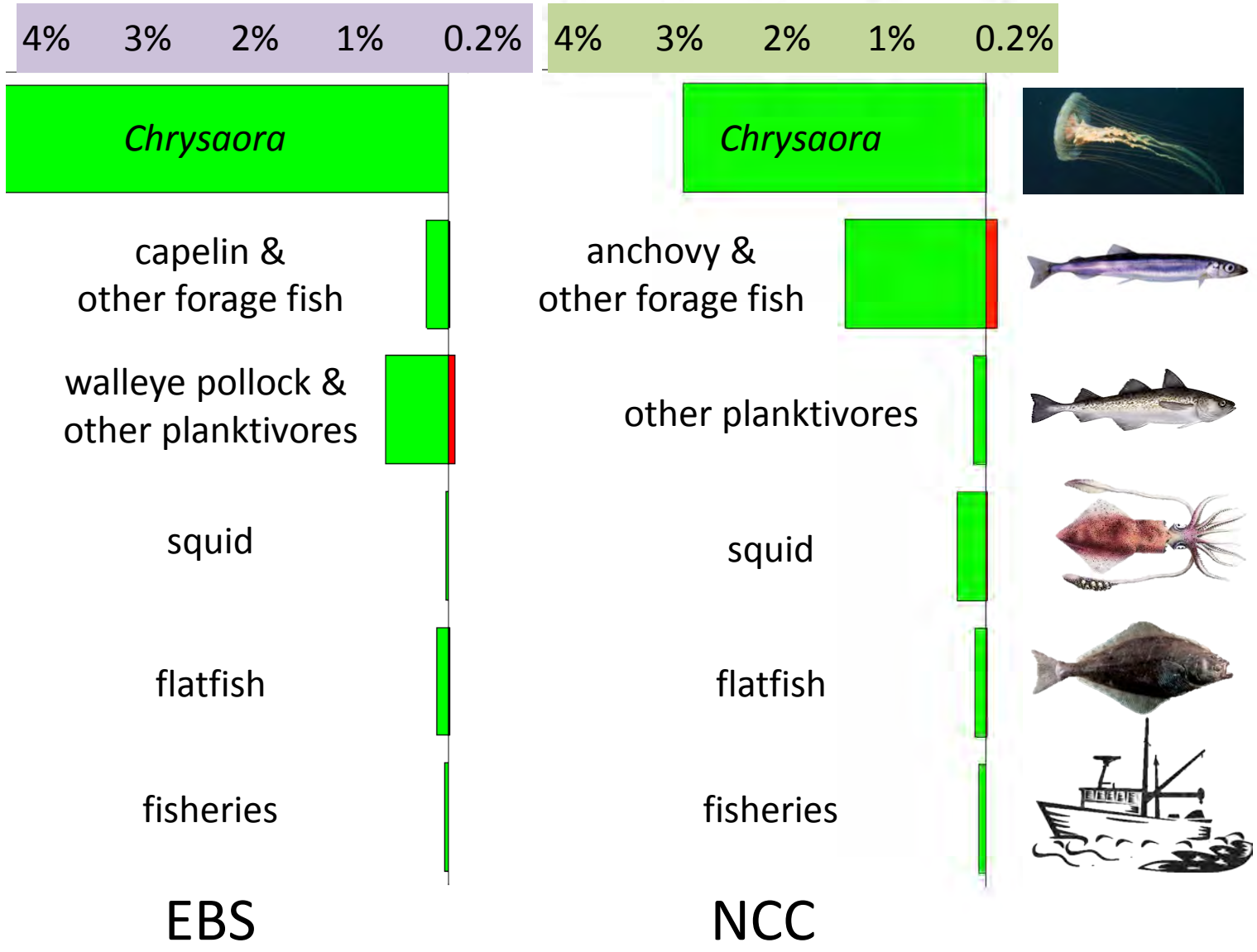
EBS: Jellyfish consume about 20x as much food as forage fish, but contribute only 1/10th as much energy to upper trophic levels

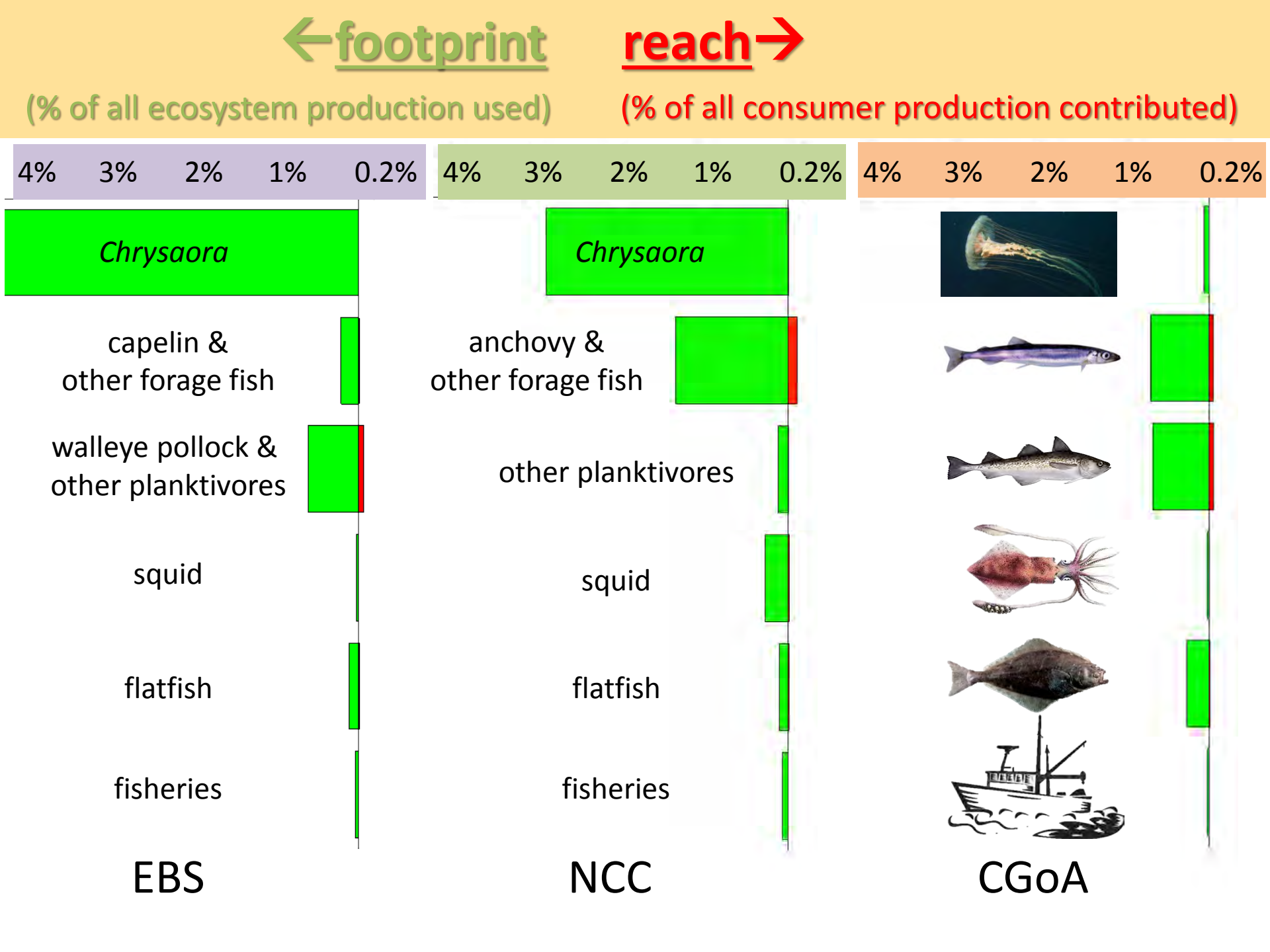
←footprint

(% of all ecosystem production used)

reach→

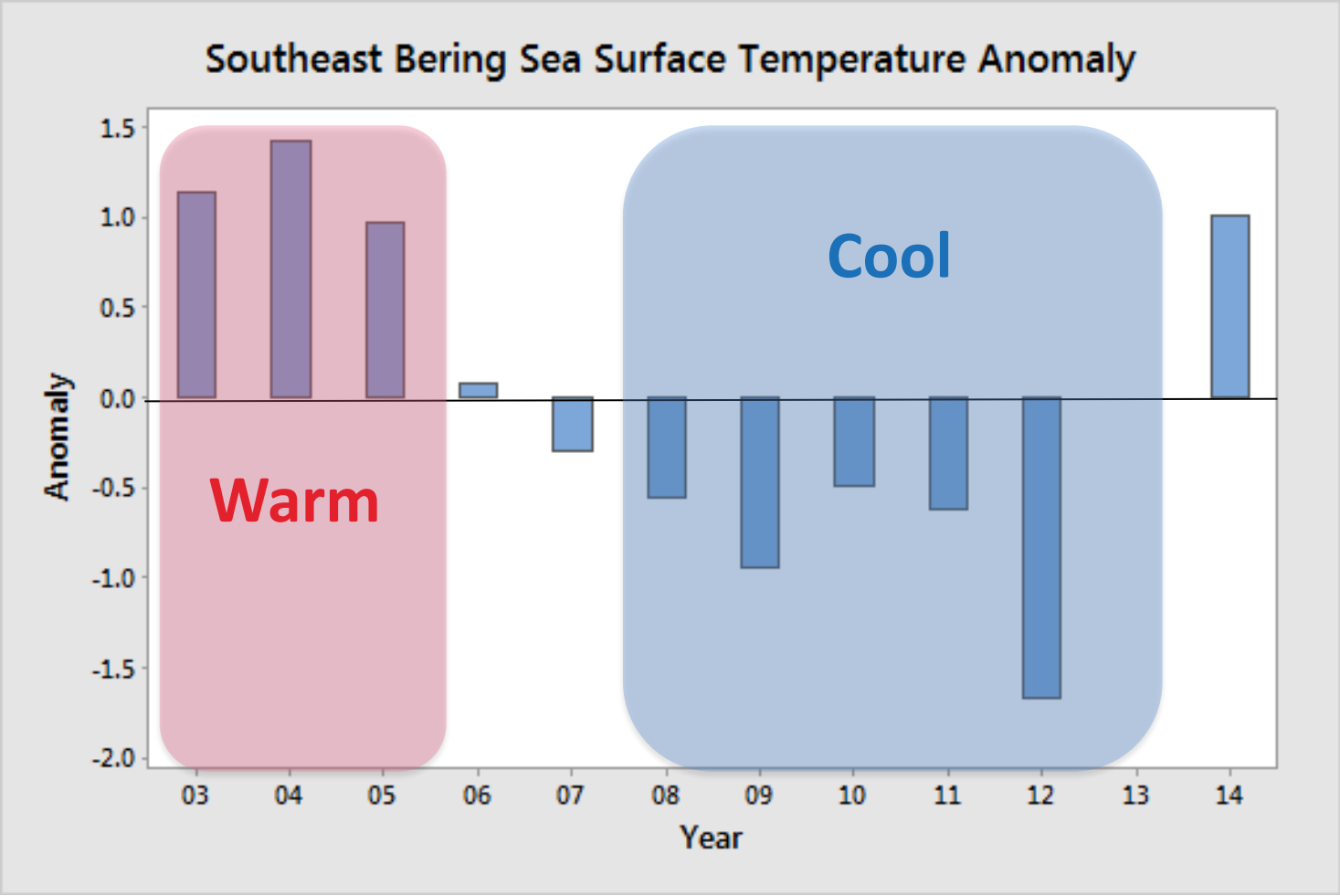
(% of all consumer production contributed)




←footprint
reach→
(% of all ecosystem production used)
(% of all consumer production contributed)
4%
3%
2%
1%
0.2%
Chrysaora
capelin &
other forage fish
walleye pollock &
other planktivores
squid
flatfish
fisheries
EBS
4%
3%
2%
1%
0.2%
Chrysaora
anchovy &
other forage fish
other planktivores
squid
flatfish
fisheries
NCC
4%
3%
2%
1%
0.2%
CGoA

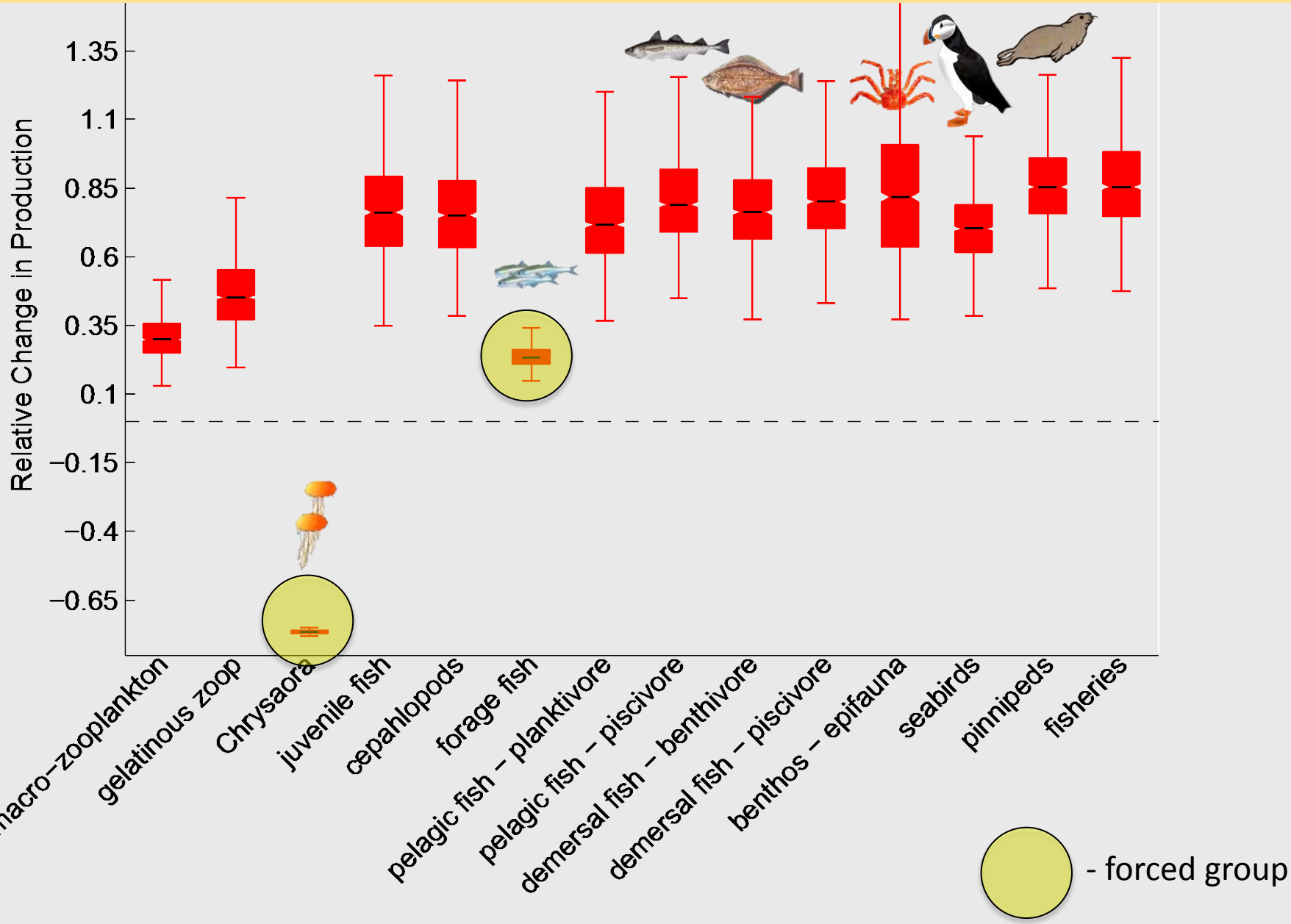
Model analysis: simulations

- **Estimating the effects of a changing pelagic community in different environmental regimes**



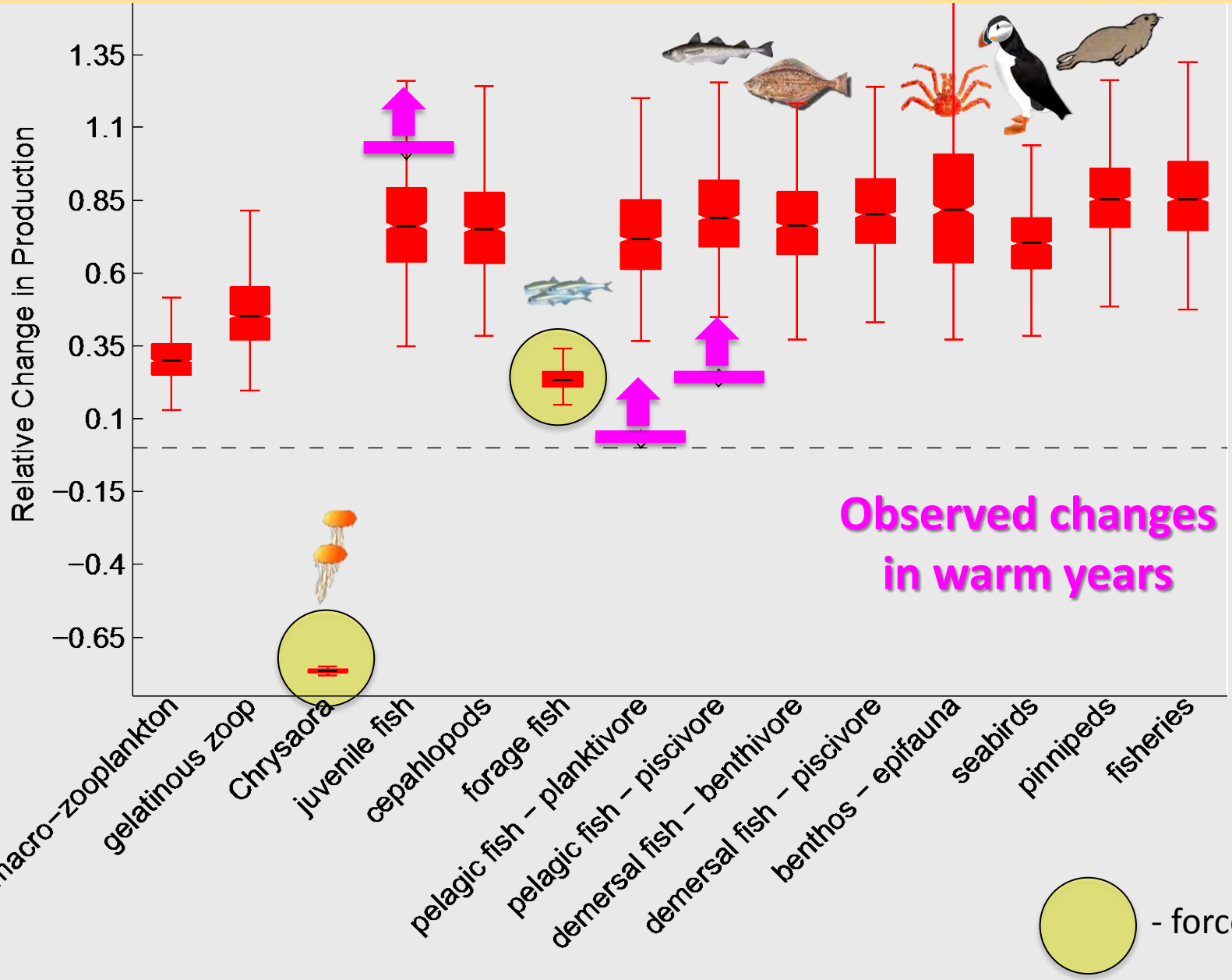
Effects of high Jellyfish abundance in EBS

(simulation of **WARM** period jelly & forage fish abundance over 2004 – 2012 mean)



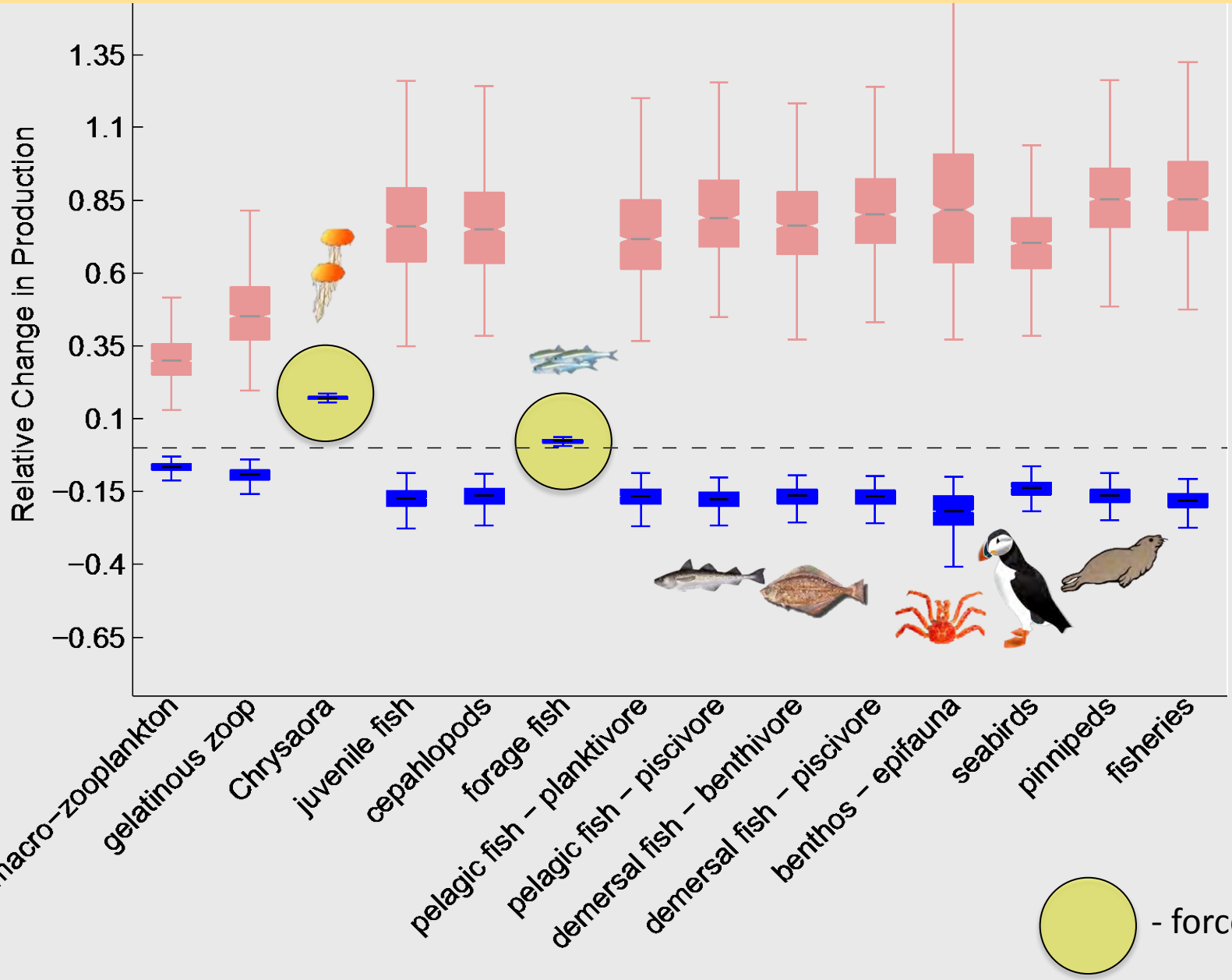
Effects of high Jellyfish abundance in EBS

(simulation of **WARM** period jelly & forage fish abundance over 2004 – 2012 mean)



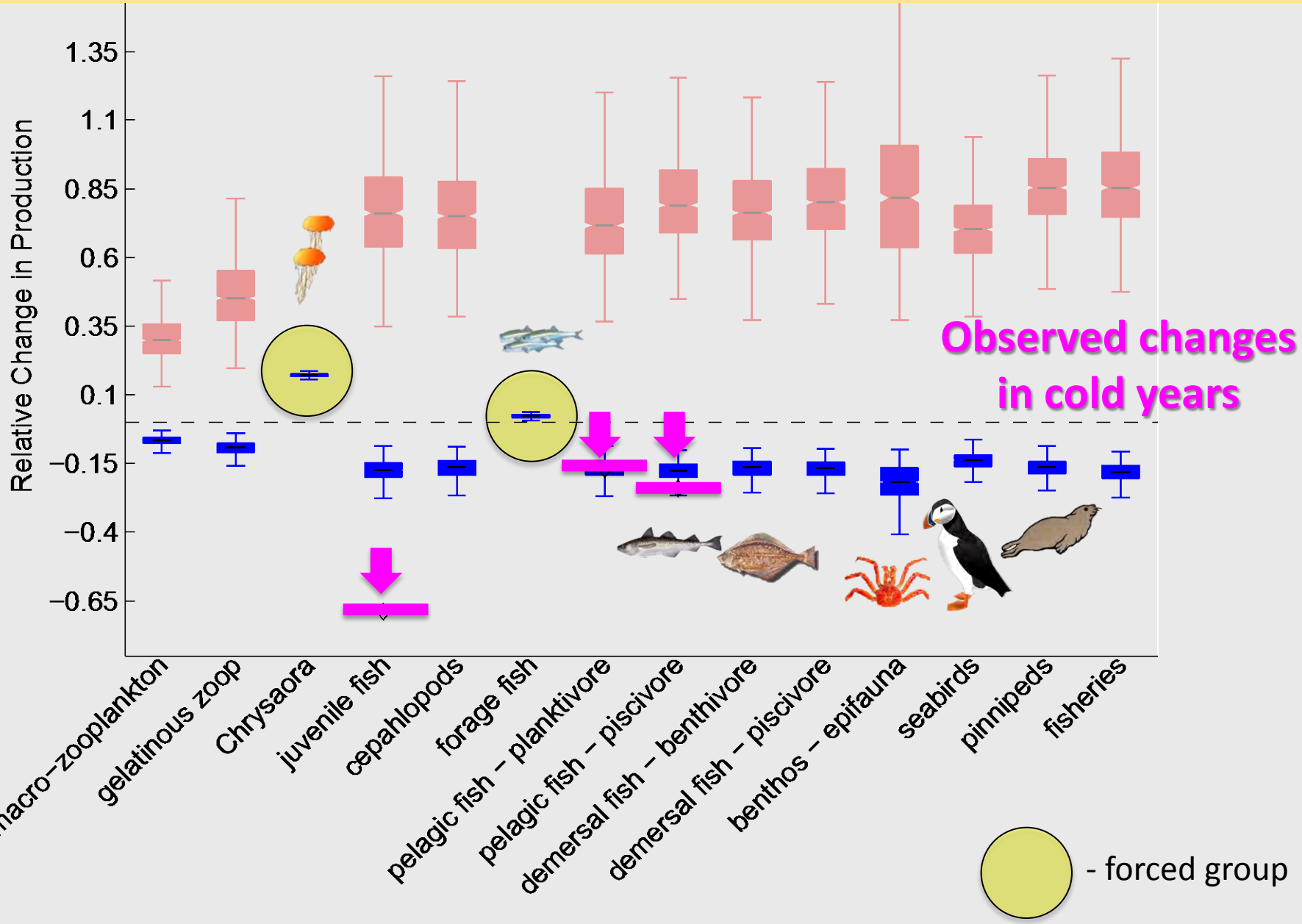
Effects of high Jellyfish abundance in EBS

(simulation of COLD period jelly & forage fish abundance over 2004 – 2012 mean)



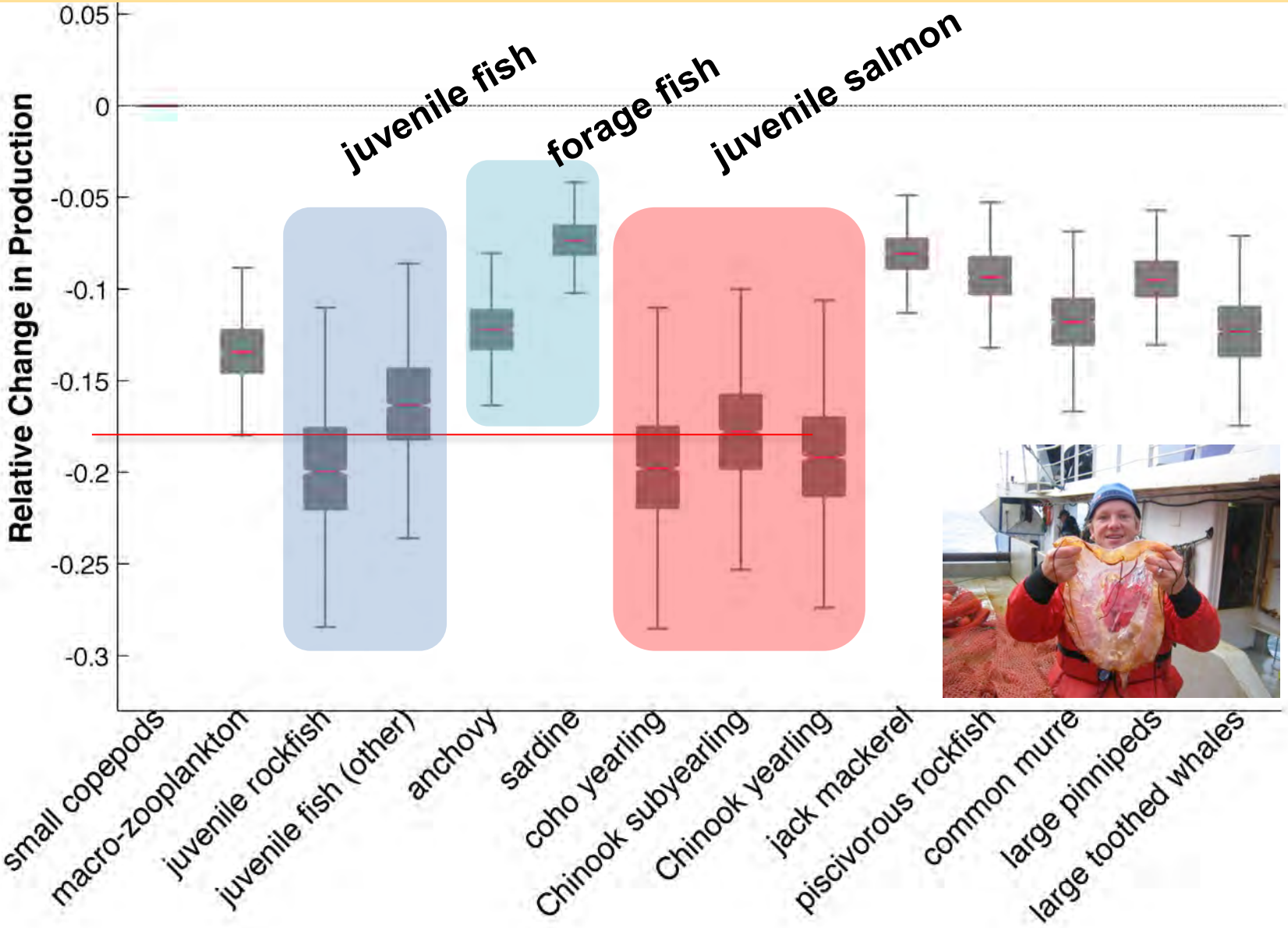
Effects of high Jellyfish abundance in EBS

(simulation of COLD period jelly & forage fish abundance over 2004 – 2012 mean)



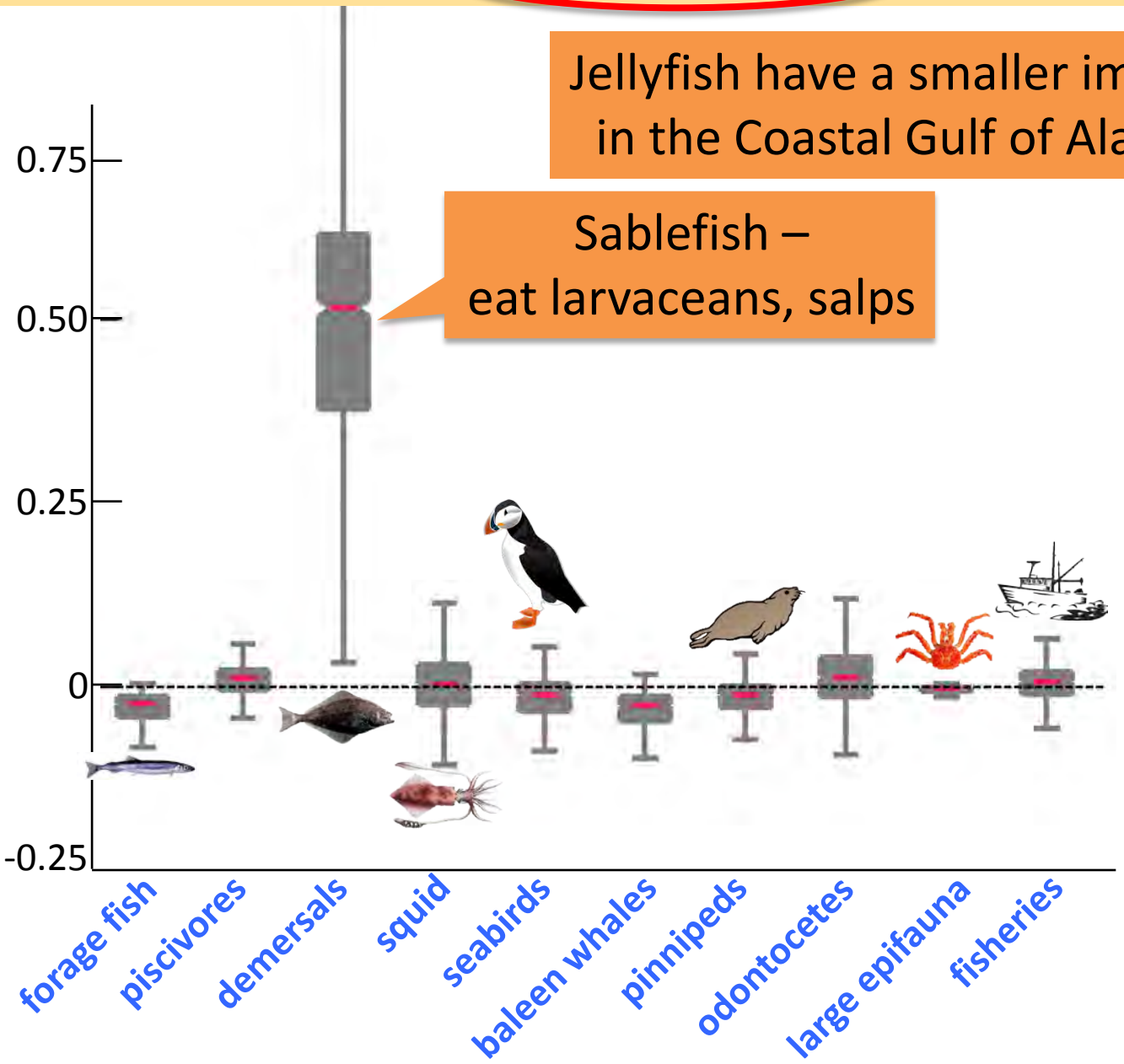
Effects of a Jellyfish bloom in NCC

(simulation of a 1 stdev (≈2x) increase over 1999 – 2012 mean *Chrysaora* biomass)

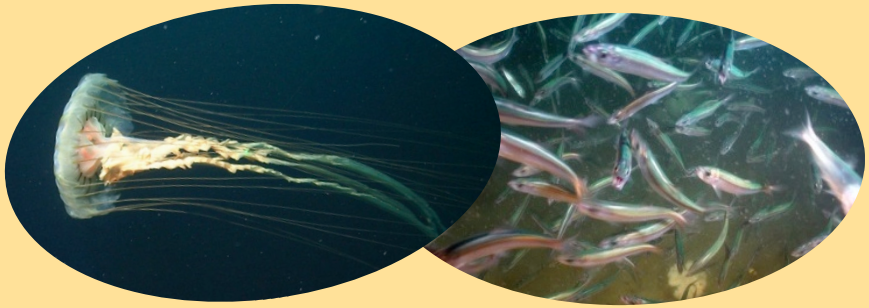


Effects of jellies in western CGoA

(simulation of a 2x increase in gelatinous zooplankton biomass)



Conclusions



- Bottom trawl timeseries suggests **inverse relationship between forage fish and jellyfish in EBS**
- Columbia River salmon return data and juvenile salmon feeding studies suggest **poor foraging environment for young salmon in NCC during high jellyfish years**
- Model analyses infer that ***Chrysaora* consume about 20X as much food as forage fish in the EBS but contribute only 1/10th as much energy to upper trophic levels**. Jellyfish are also important consumers in the NCC but much less so in the CGoA*
- **Model simulations** of changes in **EBS** *Chrysaora* & forage fish abundances in warm (2002-06) & cold (2007-12) years **show large impacts of jellyfish throughout the food web.** Similar impacts in **NCC**, but not in **CGoA**

Thank you!

Kerim Aydin

Bob Lauth

Sea-going scientists at AFSC

NWFSC
NORTHWEST FISHERIES SCIENCE CENTER

NOAA FISHERIES
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

ALASKA FISHERIES SCIENCE CENTER

OREGON STATE UNIVERSITY
Hatfield Marine Science Center
NEWPORT, OREGON

NORTH PACIFIC RESEARCH BOARD