Between the footprints of natural climate variability modes

Phoebe Woodworth-Jefcoats

NOAA Fisheries – Pacific Islands Fisheries Science Center

University of Hawaiʻi at Mānoa

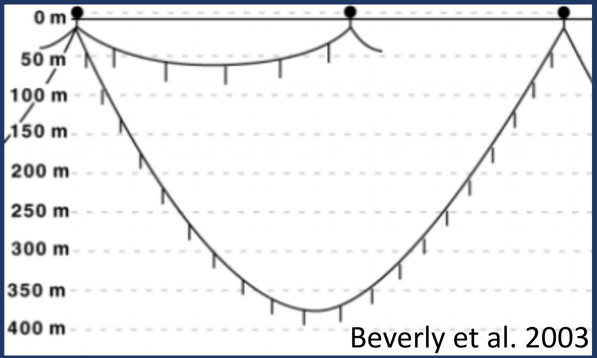
Hawaii-based Longline Fishery

- 142 vessels
- 49 million hooks
- 13 million km^2

- Total landings
  - \$97 million (6th in US)
  - 32 million pounds (27th in the US)

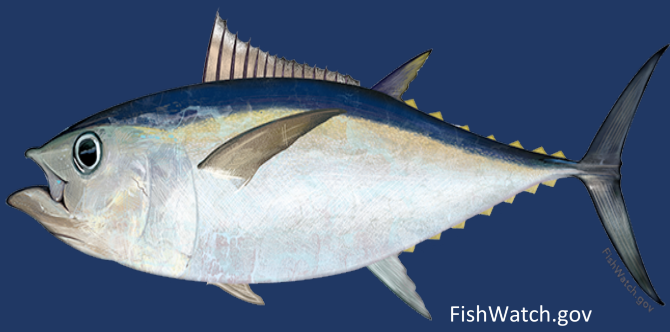
- Larger economic impact
  - 9,546 jobs
  - \$743 million sales impact

- Deep-set fishery for bigeye tuna
  - 229,221 fish
  - 8,483 mt
  - \$70.8 million
- Shallow-set fishery for swordfish
  - 20,381 fish
  - 927 mt
  - \$4.6 million



Beverly et al. 2003

Hawaii-based Longline Fishery



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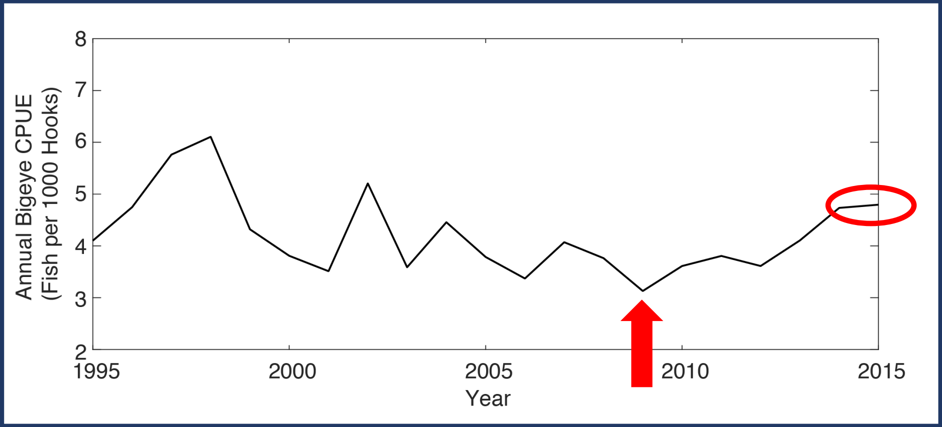
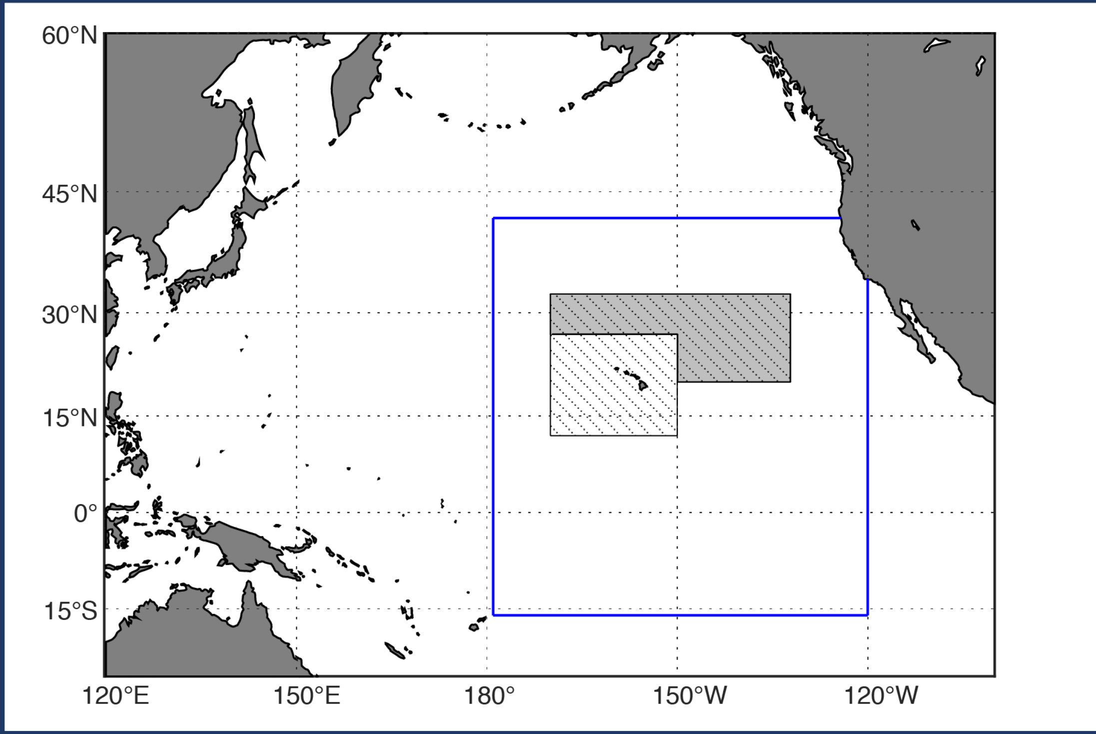


<u>CPUE: Catch Per Unit Effort</u>

Fish caught per 1,000 hooks set

NOAA National Marine Fisheries Service

Hawaii-based Longline Fishing Ground



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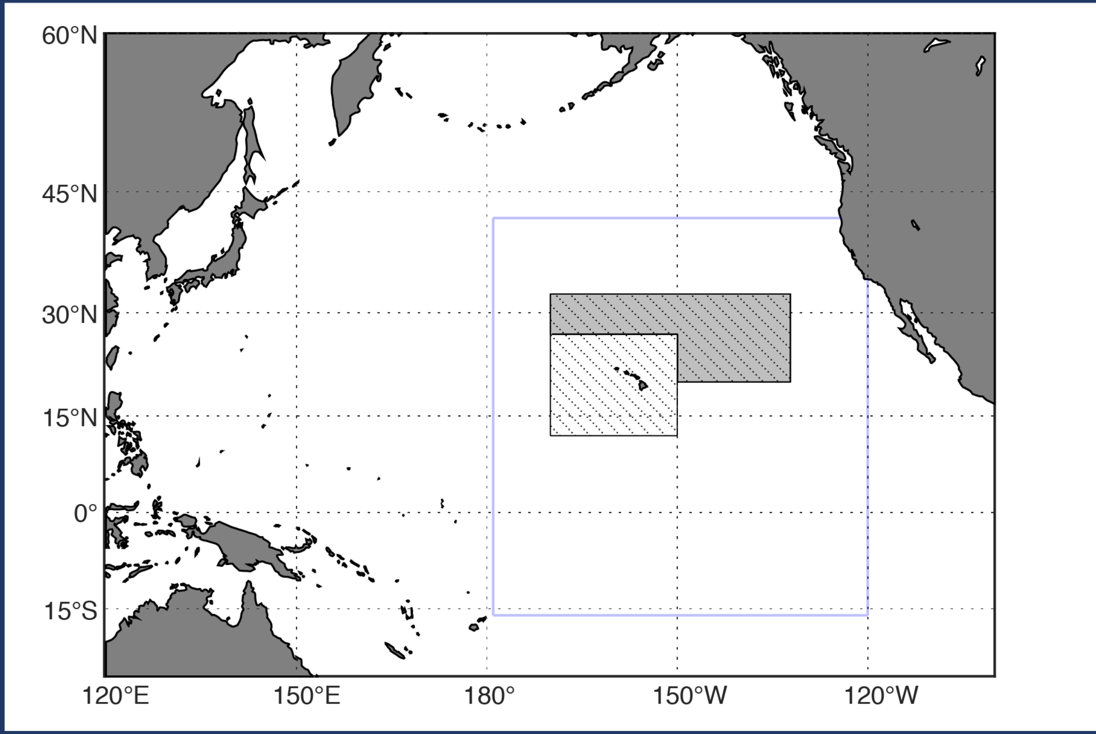
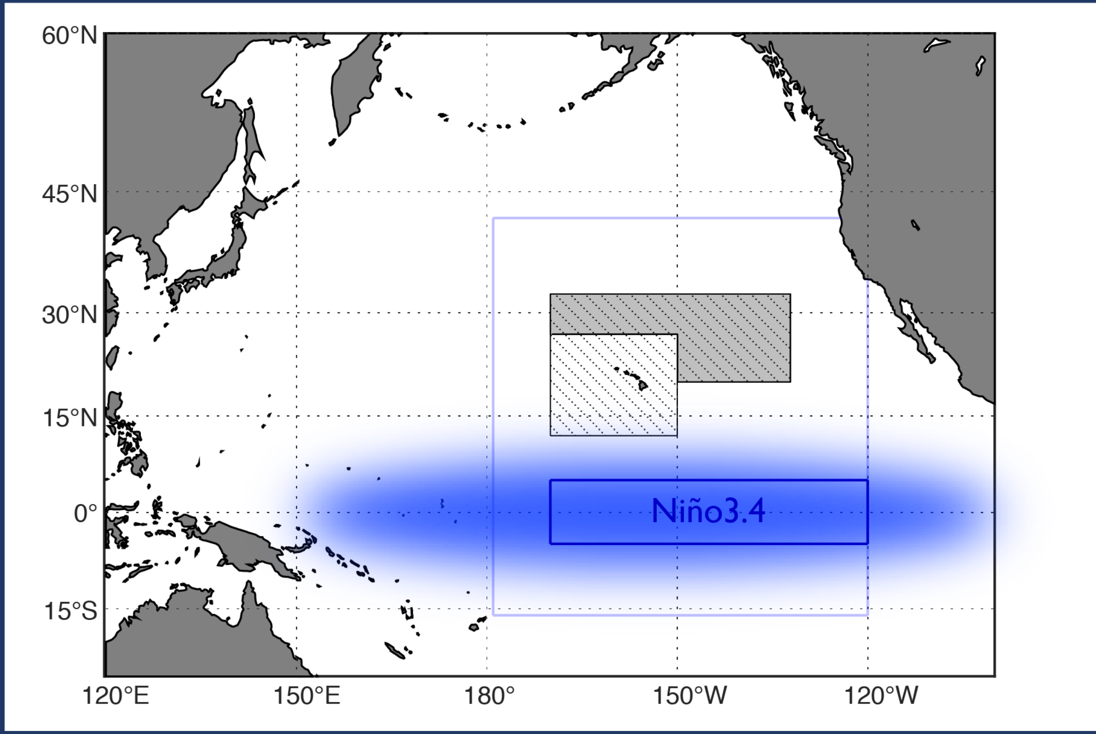


Footprints of Variability

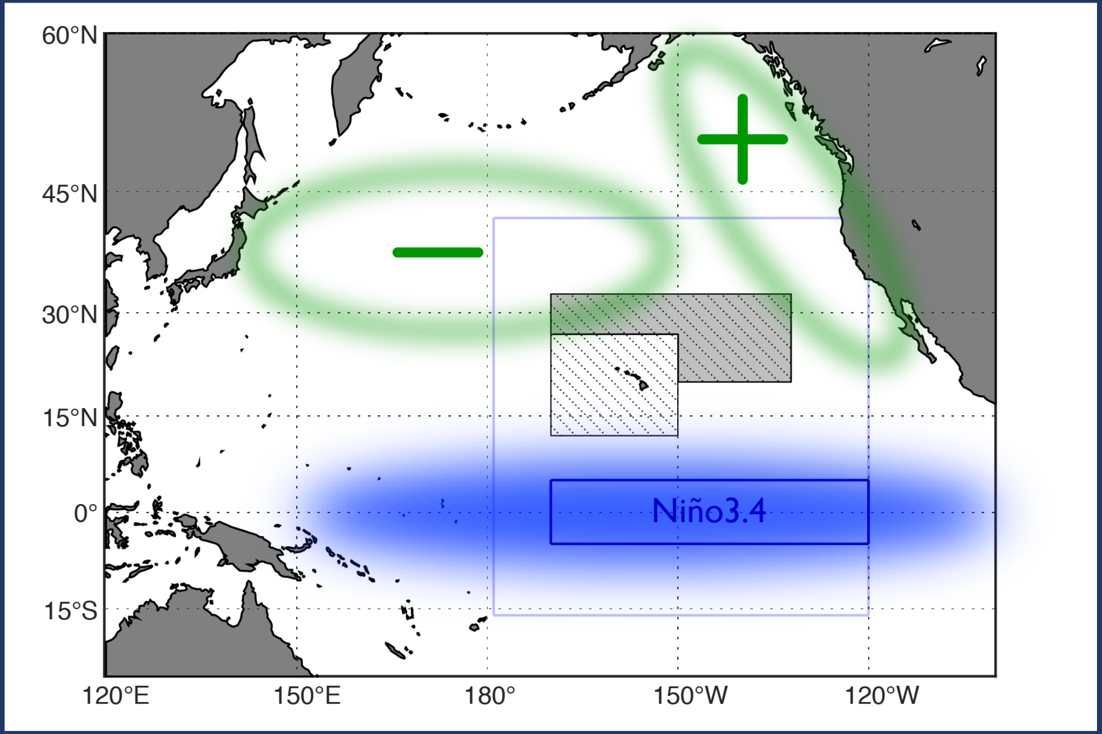
Hawaii-based Longline Fishing Ground



<u>Footprints of Variability</u>

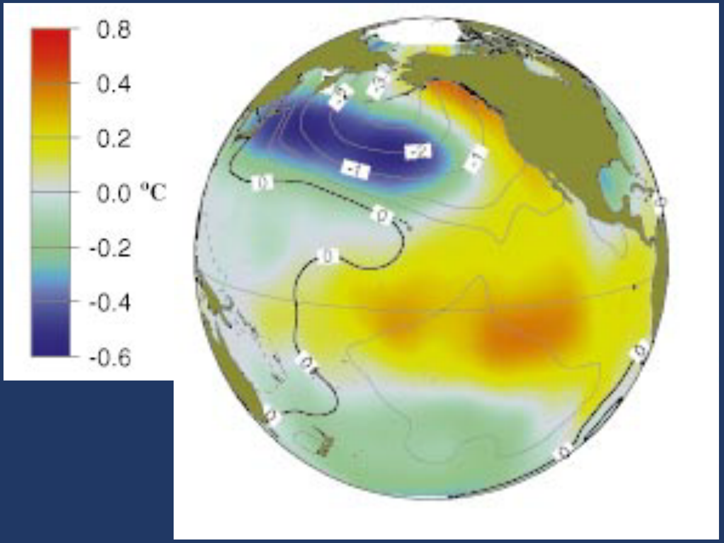
- ENSO

Hawaii-based Longline Fishing Ground



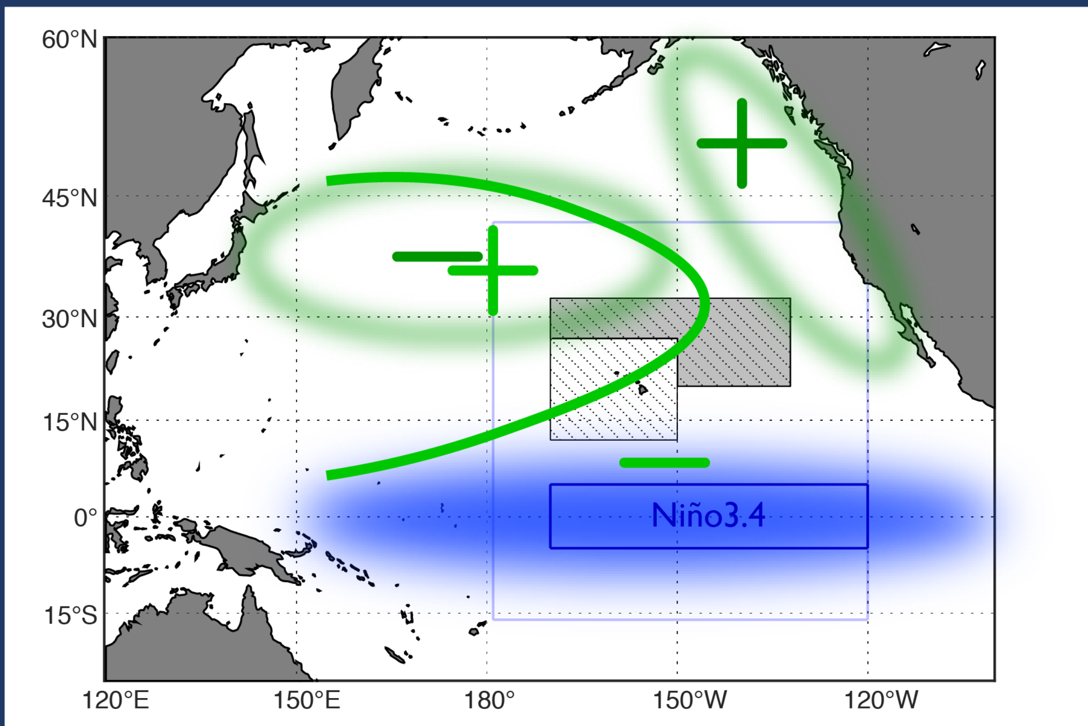
Footprints of Variability

- ENSO
- PDO



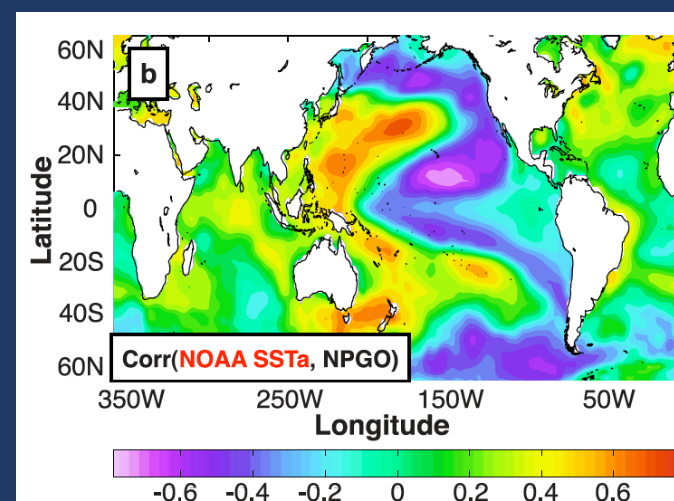
Mantua et al. 1997 *BAMS*

Hawaii-based Longline Fishing Ground



Footprints of Variability

- ENSO
- PDO
- NPGO



Mantua et al. 1997 *BAMS*, Di Lorenzo et al. 2008 *GRL*

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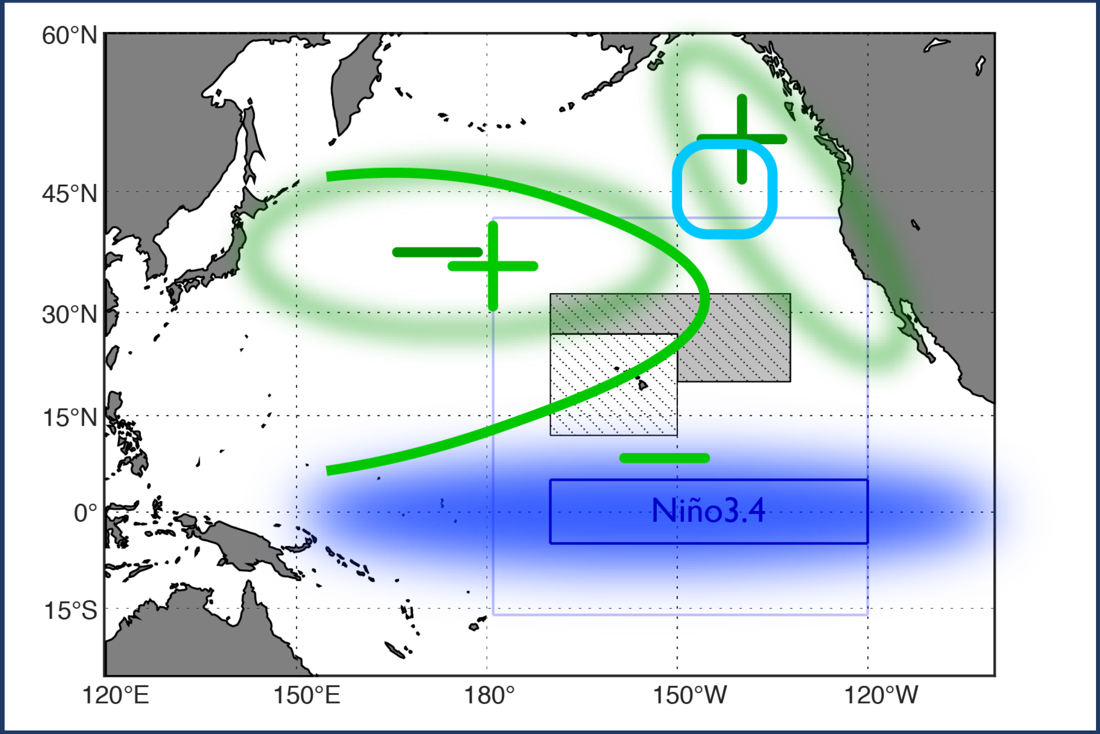
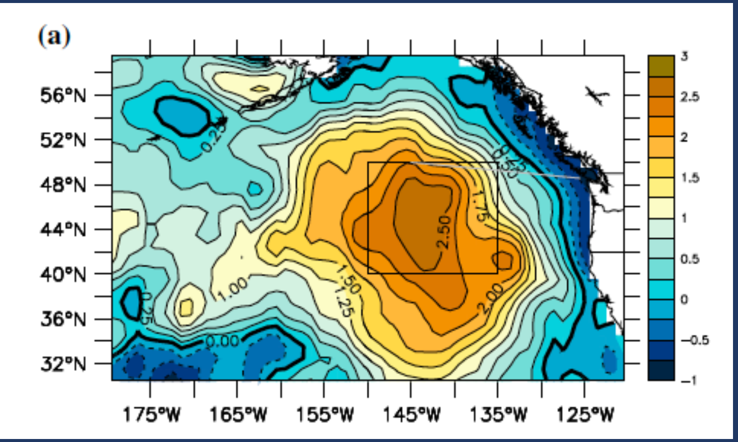


<u>Footprints of Variability</u>

- ENSO
- PDO
- NPGO
- Warm Blob

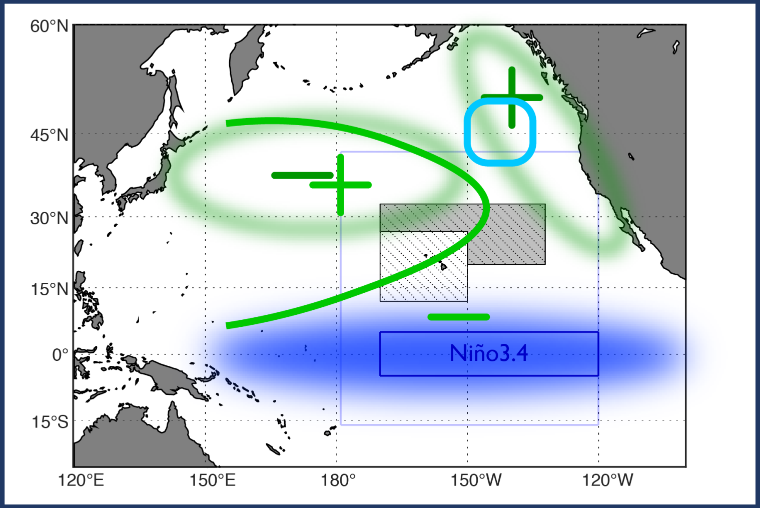


Mantua et al. 1997 *BAMS*, Di Lorenzo et al. 2008 *GRL*, Bond et al. 2015 *GRL*, Whitney 2015 *GRL*

Between Spatial Footprints

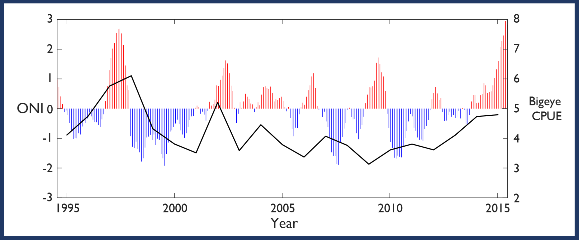
The Hawaii-based longline fishing grounds

- Sit between the footprints of climate modes (ENSO, PDO)
- Are bisected by the footprints of climate modes (NPGO)

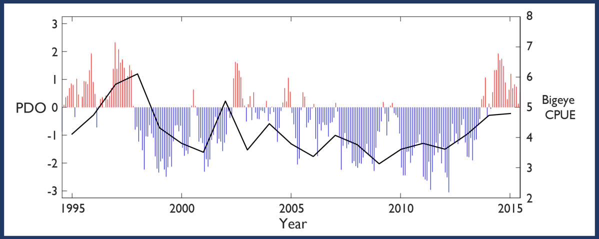


Hawaii-based Longline Catch

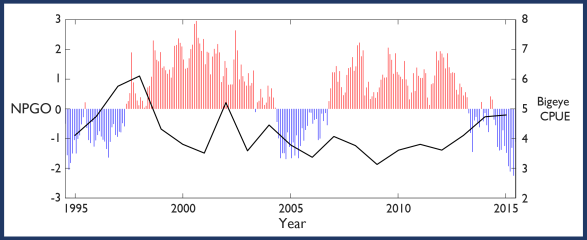
El Niño – Southern Oscillation



Pacific Decadal Oscillation



North Pacific Gyre Oscillation



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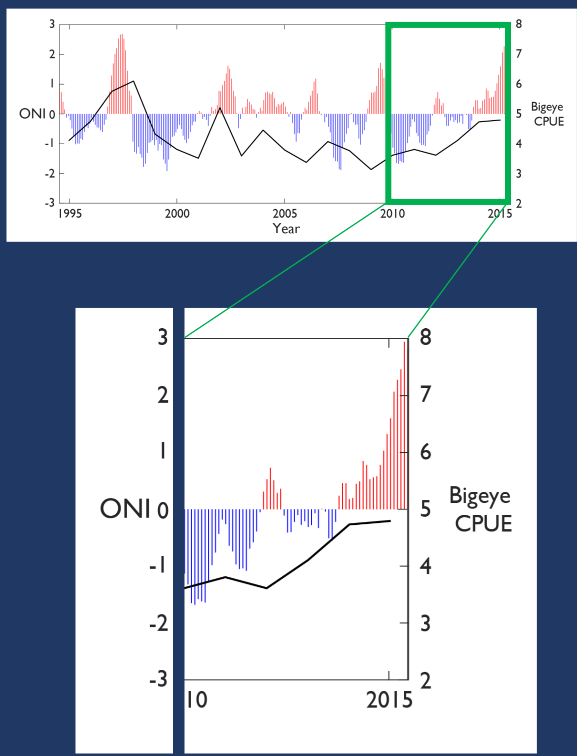

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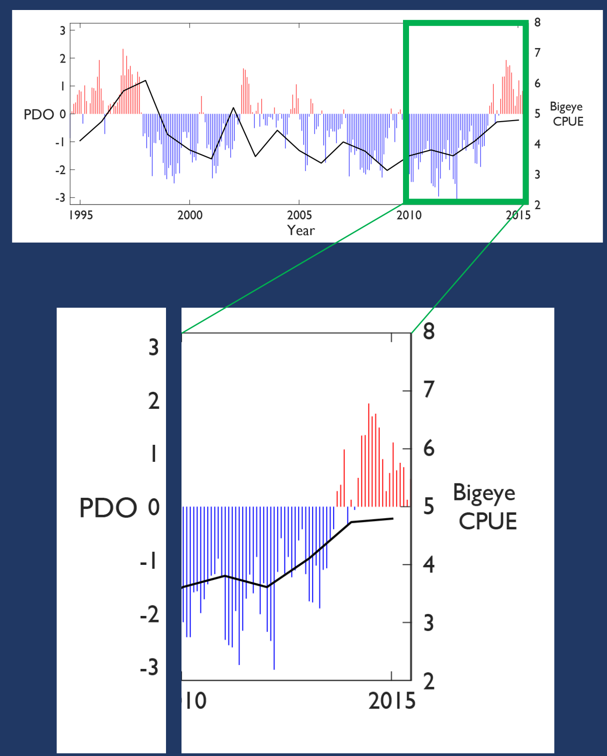
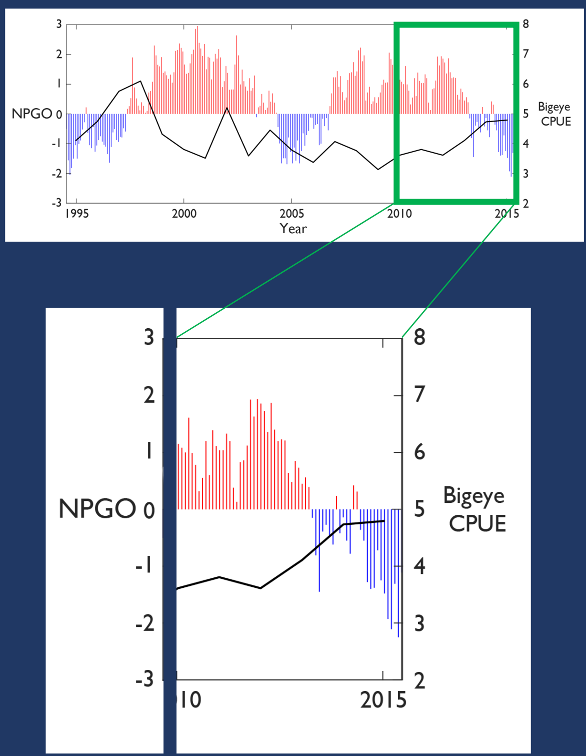


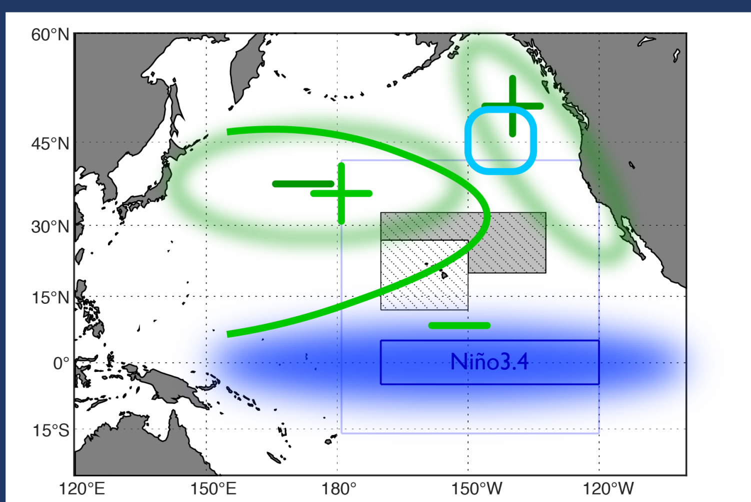
North Pacific Gyre Oscillation



Between Spatial & Temporal Footprints

The Hawaii-based longline fishing grounds

- Sit between the footprints of climate modes (ENSO, PDO)
- Are bisected by the footprints of climate modes (NPGO)

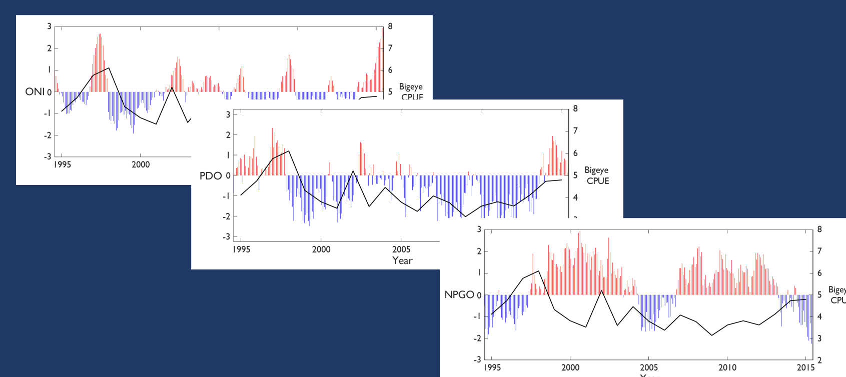


The Hawaii-based longline fishery

- Is managed at annual scale
- Catches fish that live for several years

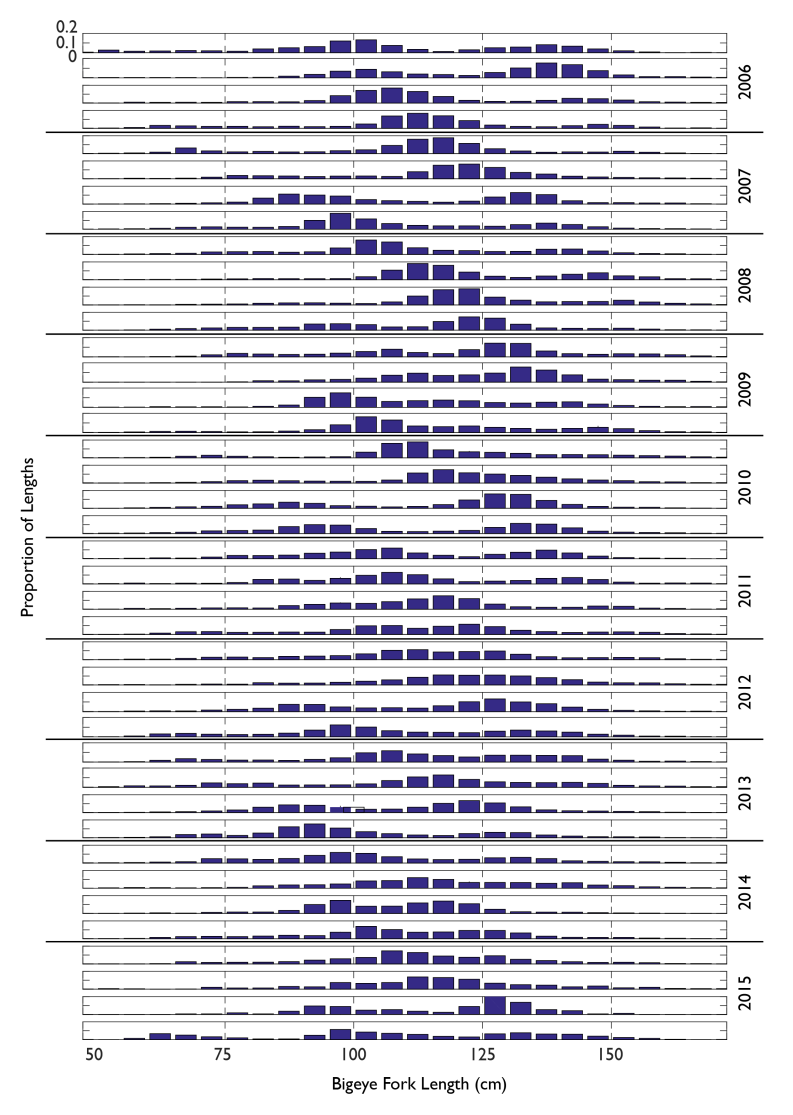
Whereas modes of variability are relevant on scales of

- Months (ENSO)
- Decades (PDO, NPGO)



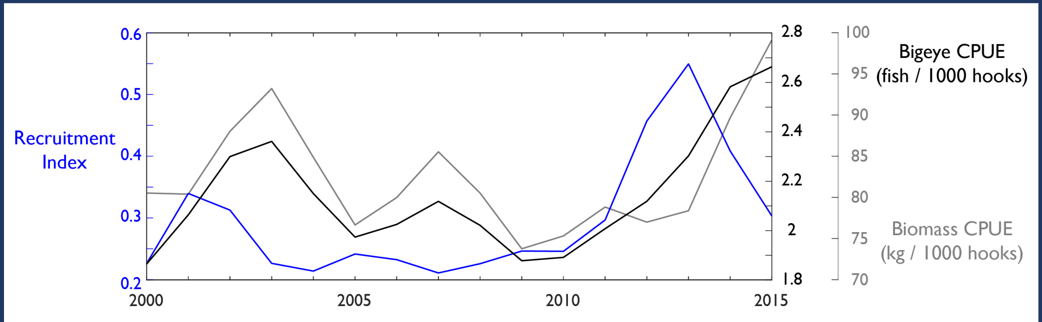
Interannual variability in bigeye tuna catch

Interannual variability in bigeye tuna catch



Bigeye size structure can be tracked through time

Allows for the identification of recruitment pulses



Recruitment Index = CPUE of bigeye ≤ 15 kg

But what drives recruitment pulses?

Wren and Polovina *In Prep*

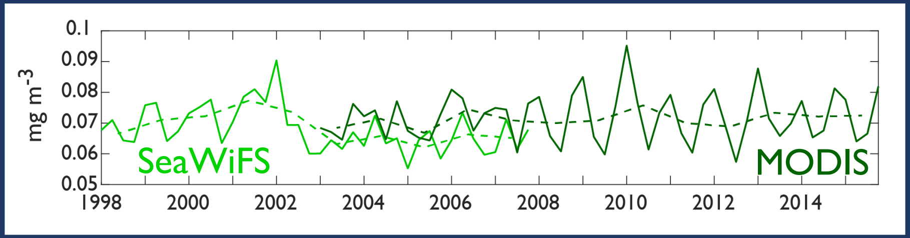
SeaWiFS & MODIS chlorophyll-a + GODAS 5 m temperature

Median phytoplankton cell size

$$\log_{10} M_{B50} = 0.929 \log_{10} chl - 0.043T + 1.340$$

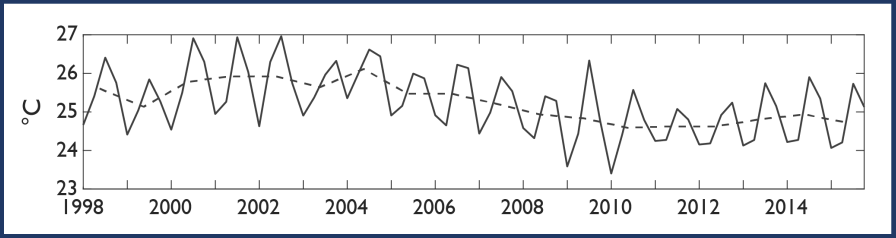
Saha et al. 2006 *J Climate*, Barnes et al. 2011 *J Plankton Research*

SeaWiFS & MODIS chlorophyll-a



\+

GODAS 5 m temperature



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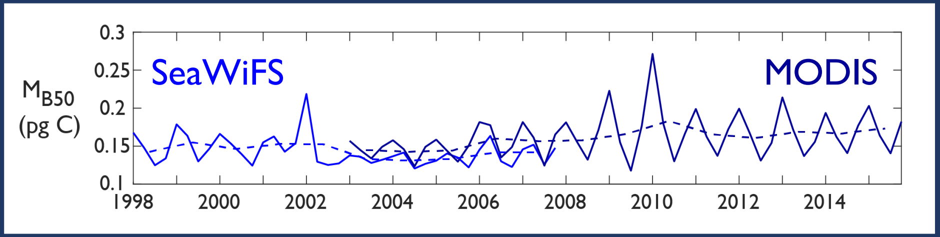

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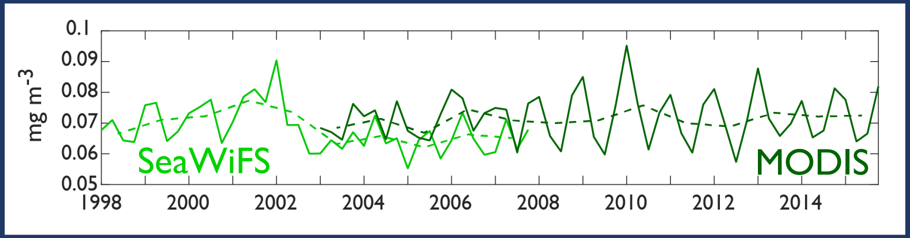

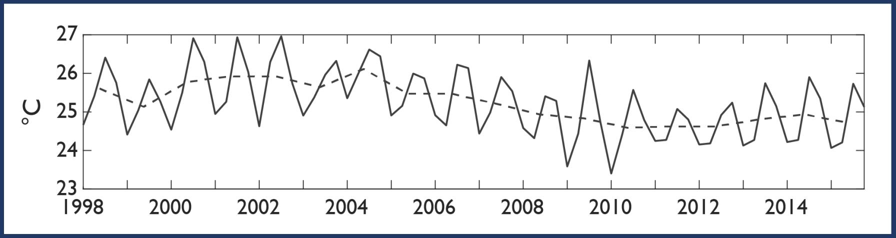

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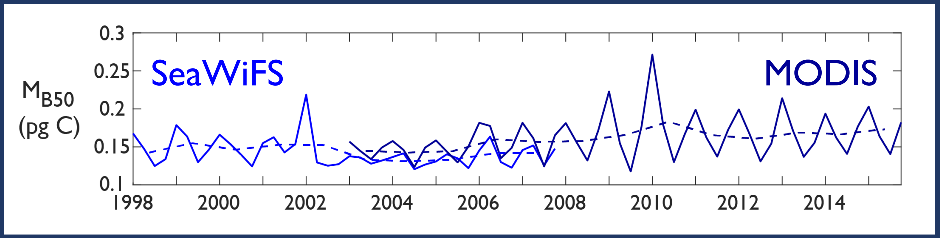
SeaWiFS correction: + 0.015 pg C



Saha et al. 2006 *J Climate*, Barnes et al. 2011 *J Plankton Research*

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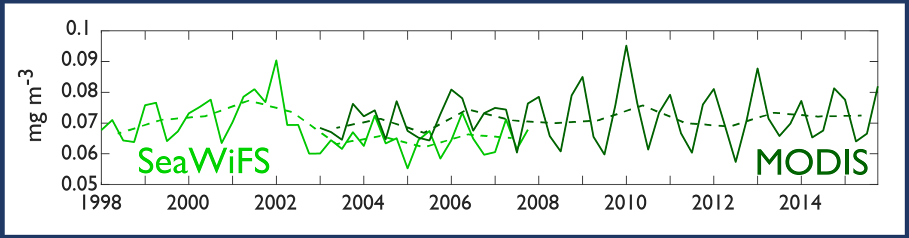

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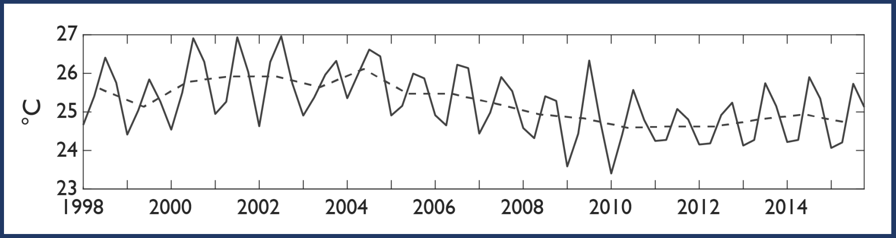

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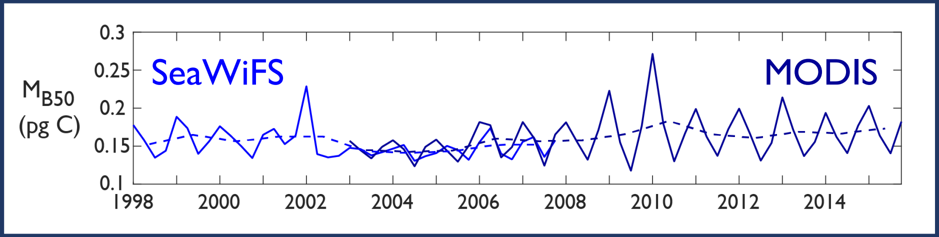

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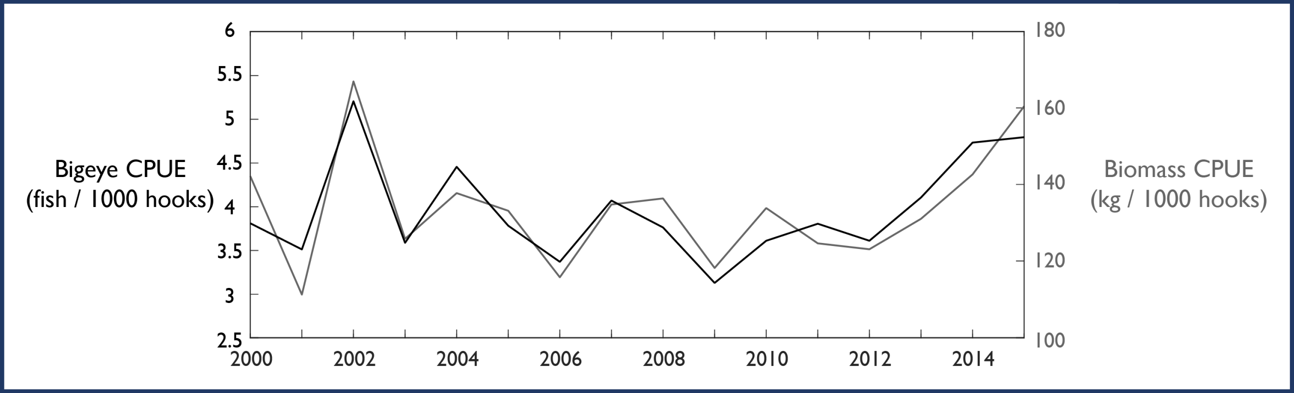
Interannual variability in bigeye tuna catch

Bigeye CPUE
&
Biomass CPUE



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phytoplankton
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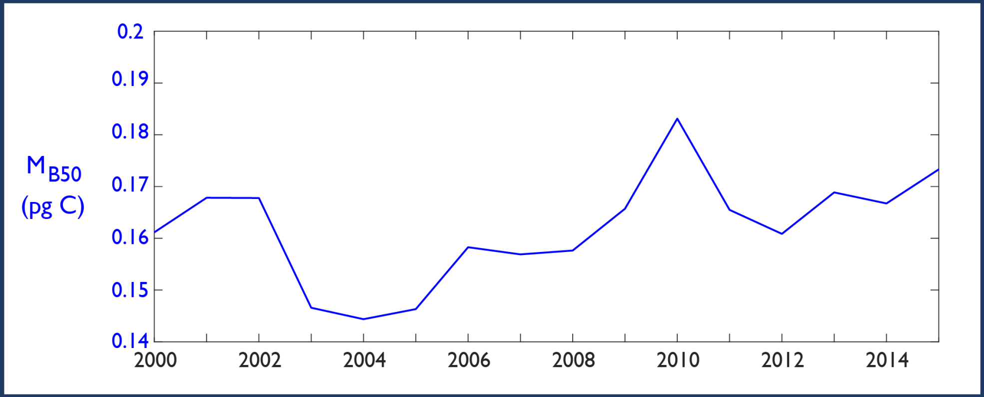

Wren and Polovina *In Prep*

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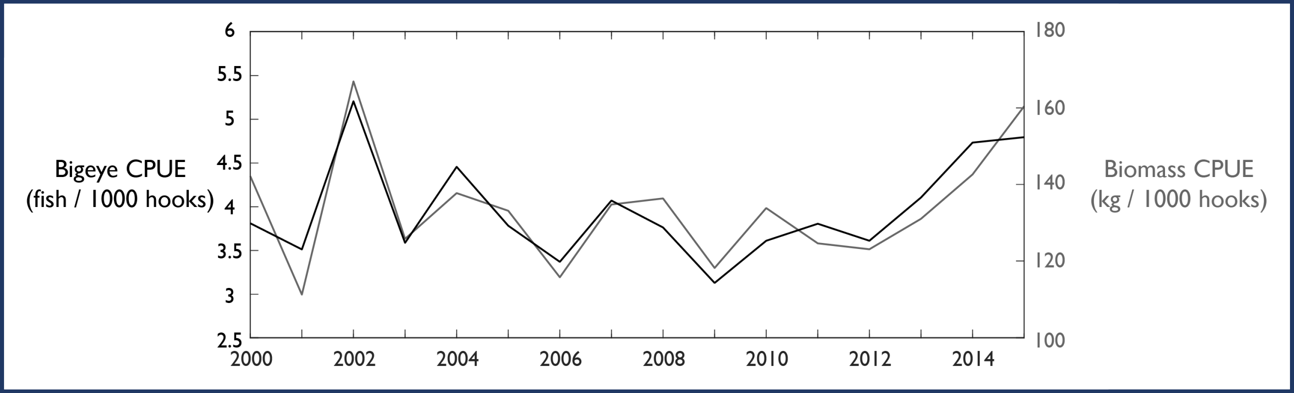
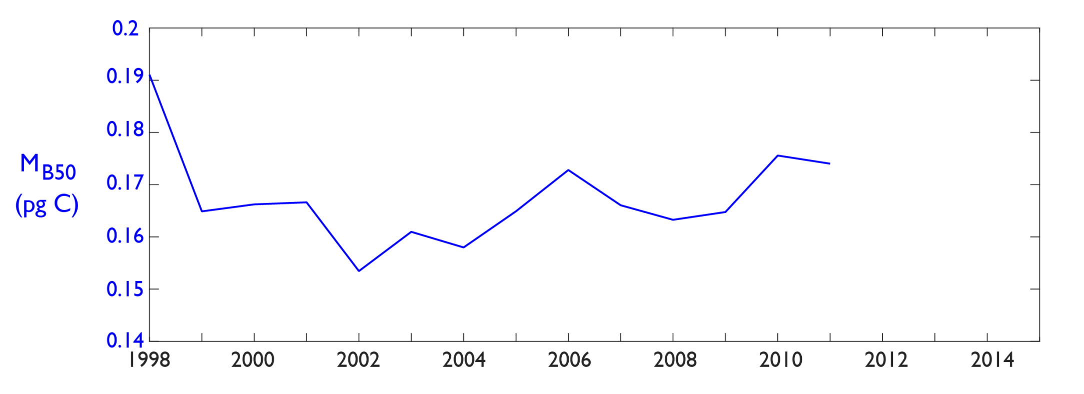


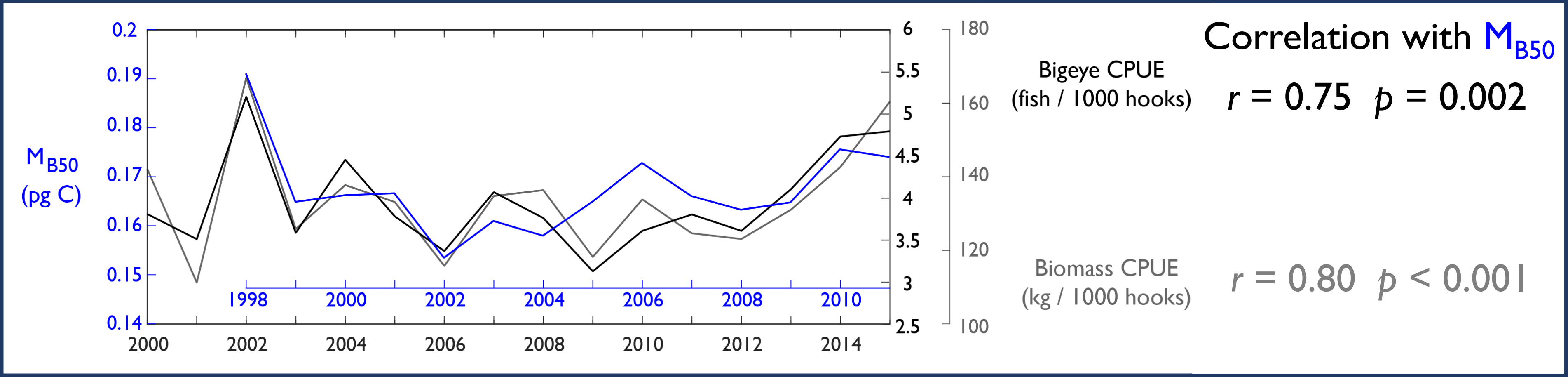
Median
phytoplankton
cell size
4-year lag



Wren and Polovina *In Prep*

When lagged 4 years,
median phytoplankton cell size is well correlated with CPUE

Could indicate food quality, leading to larval and/or juvenile survival



Wren and Polovina *In Prep*, Llopiz and Hobday 2015 *DSR-II*

Multi-decadal change in bigeye size structure

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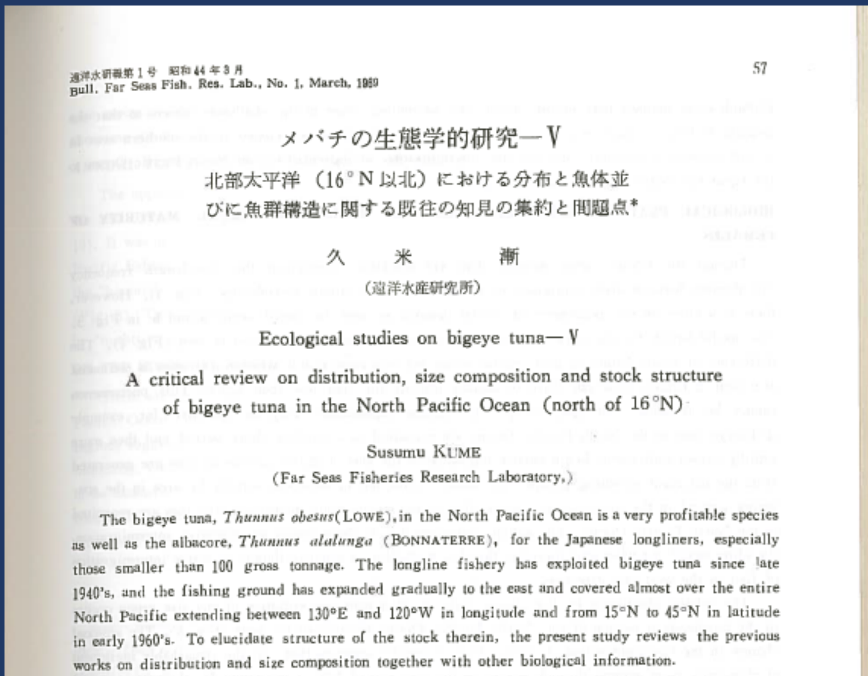
遠洋水研報第1号　昭和44年3月
Bull. Far Seas Fish. Res. Lab., No. 1, March, 1969
57

メバチの生態学的研究—V

北部太平洋（16°N以北）における分布と魚体並びに魚群構造に関する既往の知見の集約と問題点*

久　米　漸

（遠洋水産研究所）

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Susumu KUME

(Far Seas Fisheries Research Laboratory)

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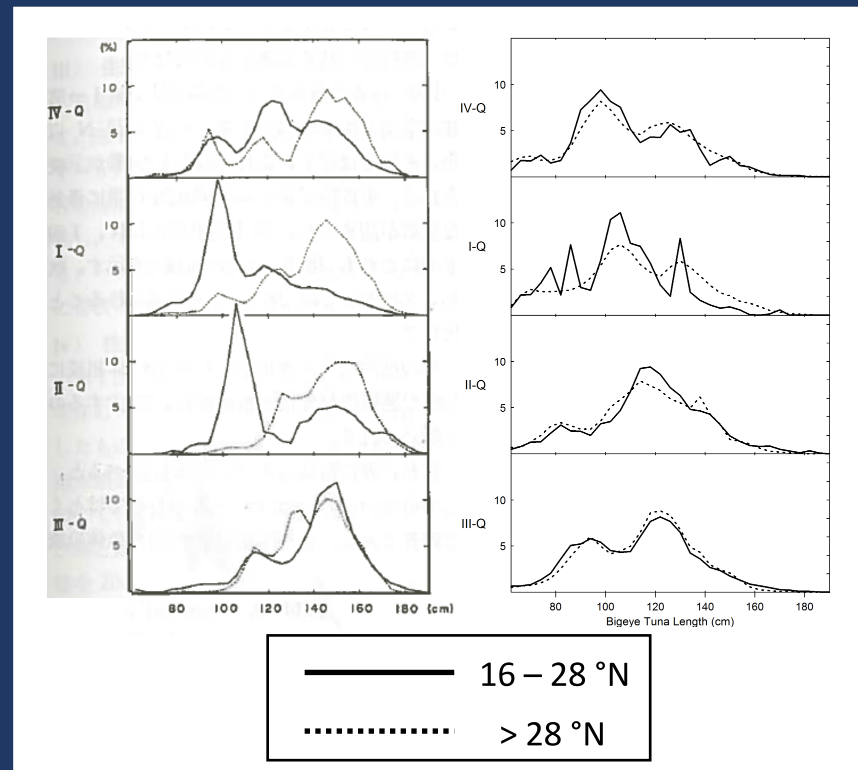
Kume 1969
1956 – 1964

Hawaii
Observers
2006 – 2016



Kume 1969 *Far Seas Fisheries Research Laboratory Bulletin*
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NOAA National Marine Fisheries Service - Updated figure courtesy of Johanna Wren

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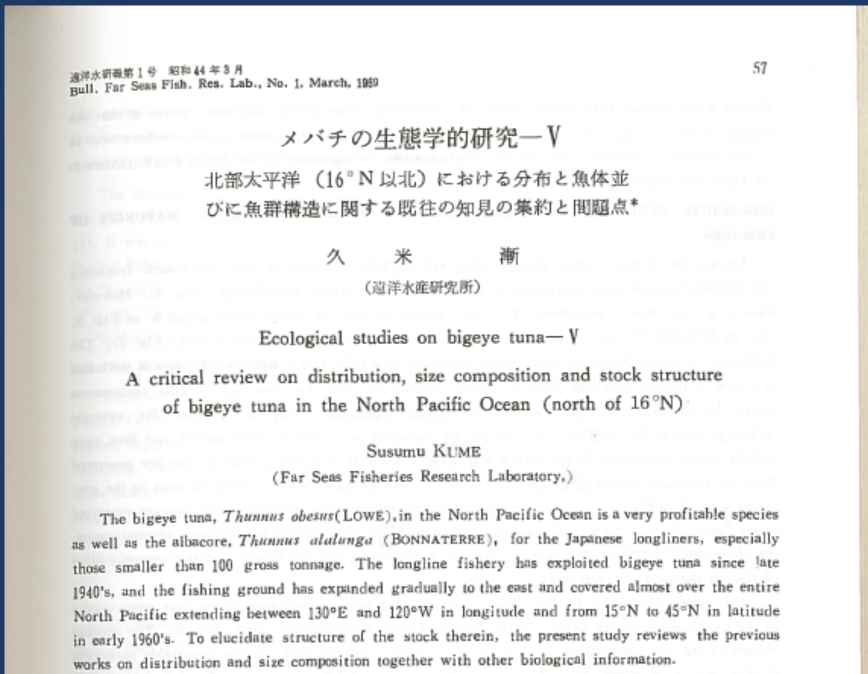

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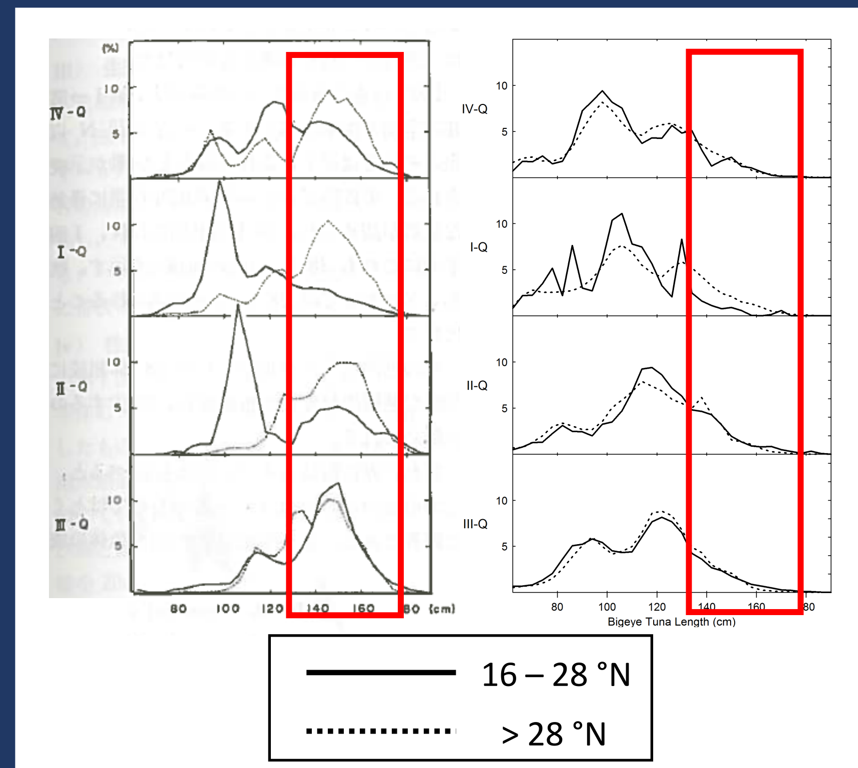

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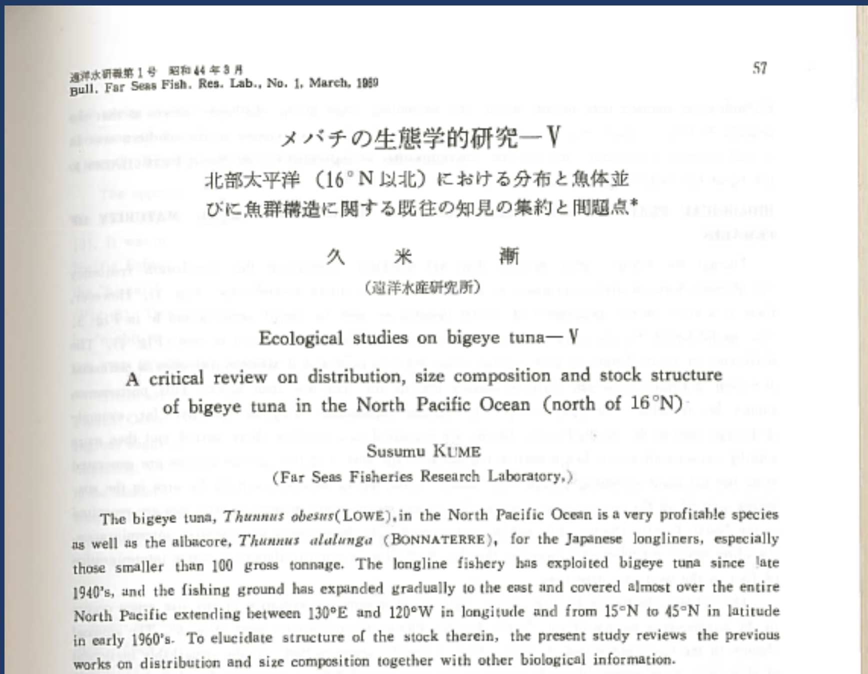

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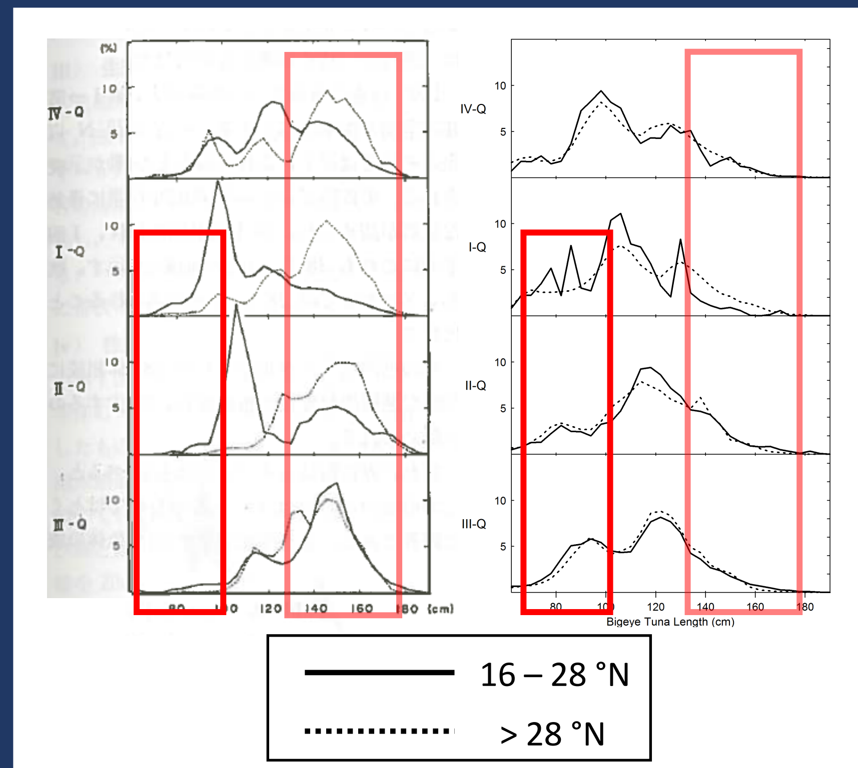

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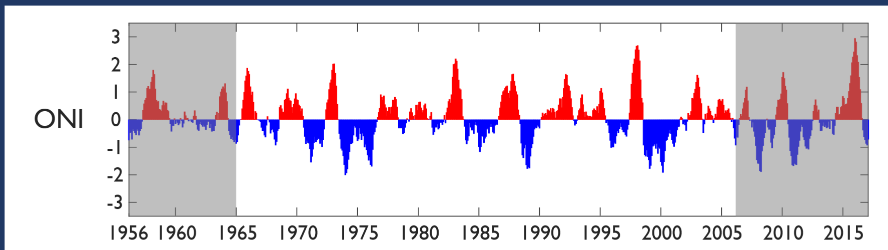

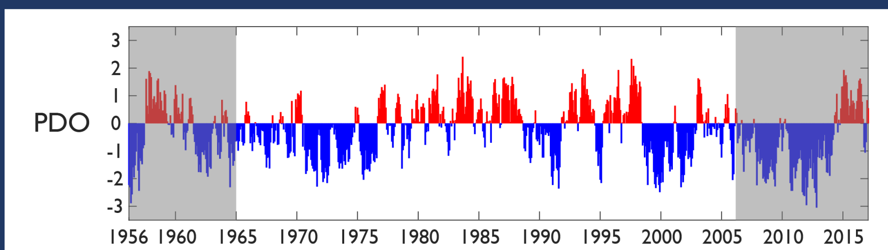

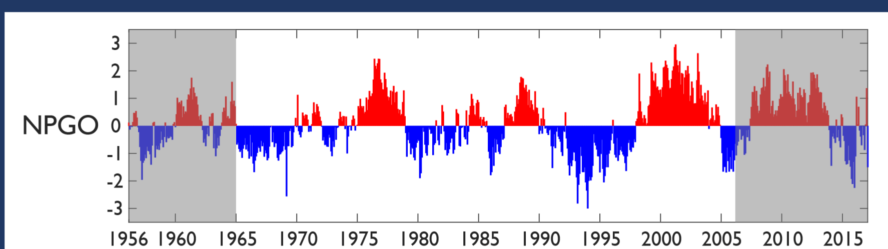

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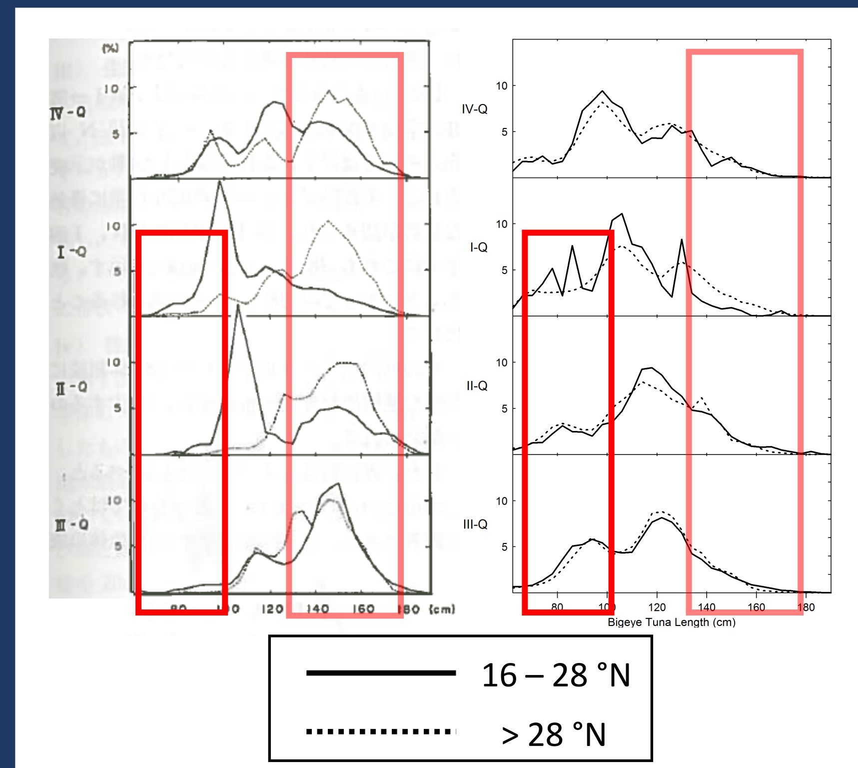

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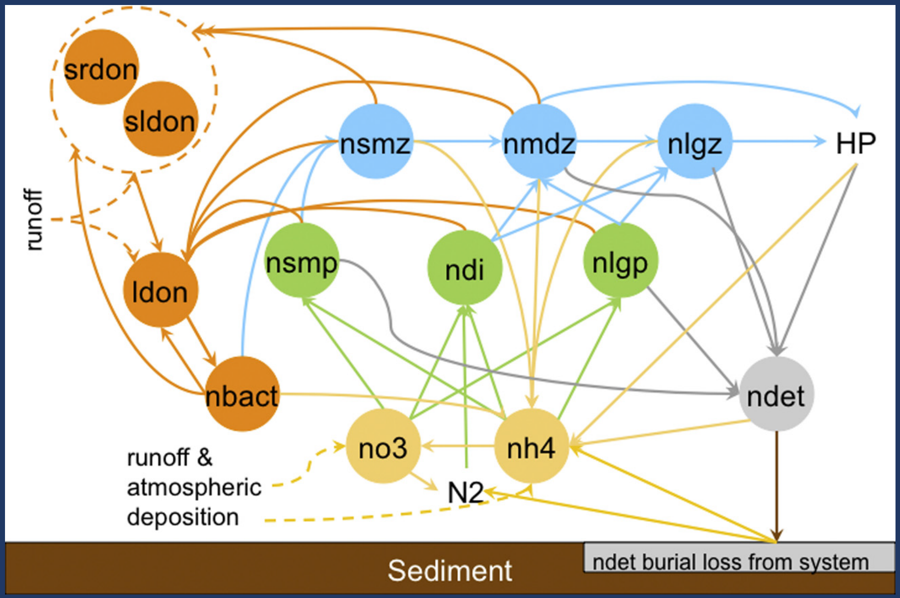
COBALT:
Carbon, Ocean Biogeochemistry, and Lower Trophics

Common Ocean-Ice Reference Experiment (CORE-II)



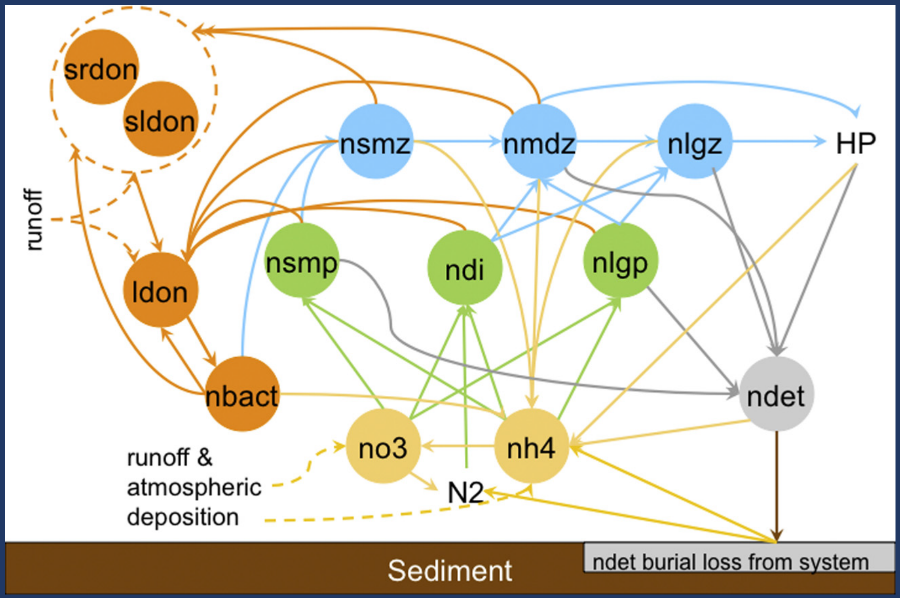
Small, Medium, and Large Zooplankton

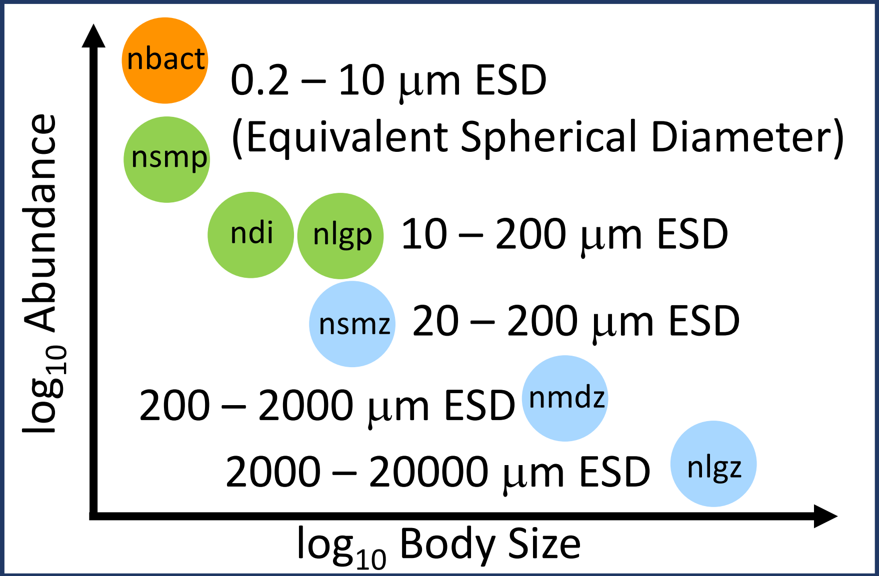
Small, Diazotroph, and Large Phytoplankton

Heterotrophic Bacteria

Stock et al. 2014 *Progress in Oceanography*

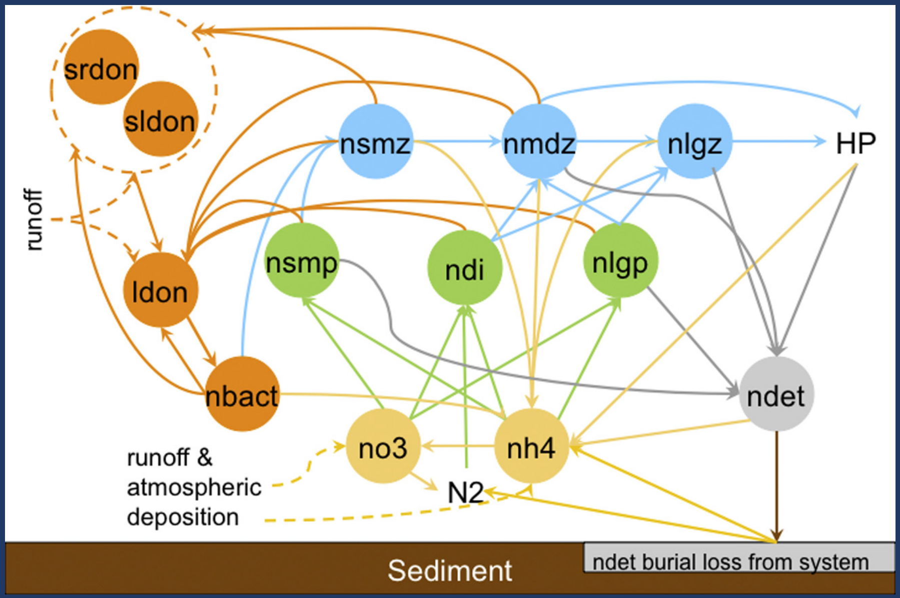
COBALT:
Carbon, Ocean Biogeochemistry, and Lower Trophics

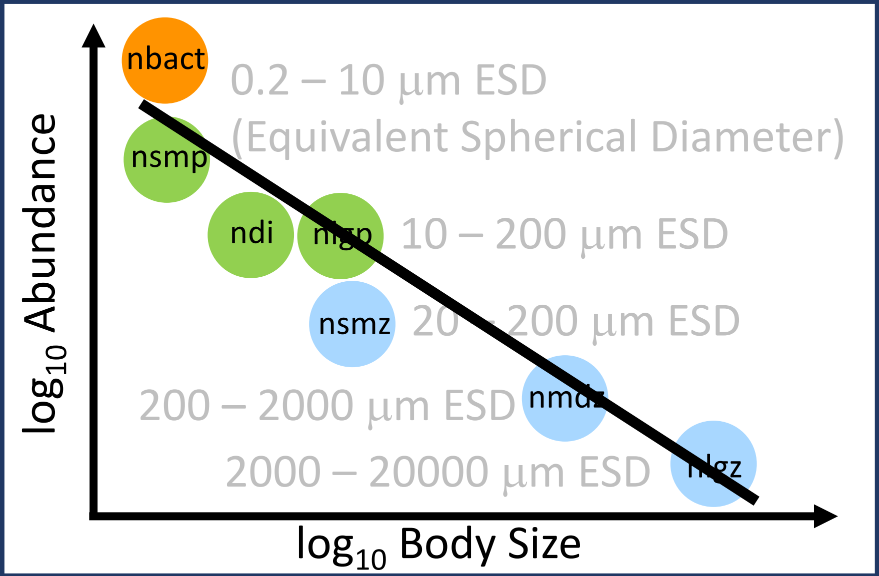




Stock et al. 2014 *Progress in Oceanography*,
Sieburth et al. 1978 *Limnology & Oceanography*, Blanchard et al. 2009 *J. Animal Ecology*

COBALT:
Carbon, Ocean Biogeochemistry, and Lower Trophics





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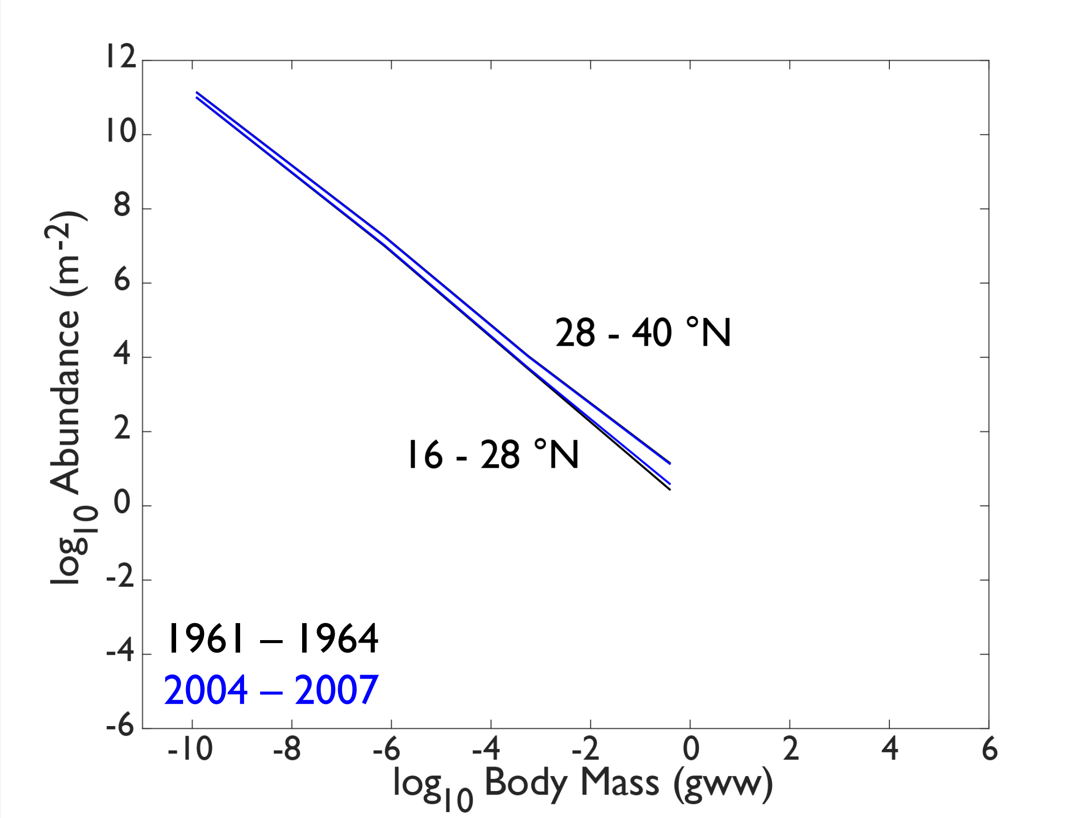
Multi-decadal change in bigeye size structure

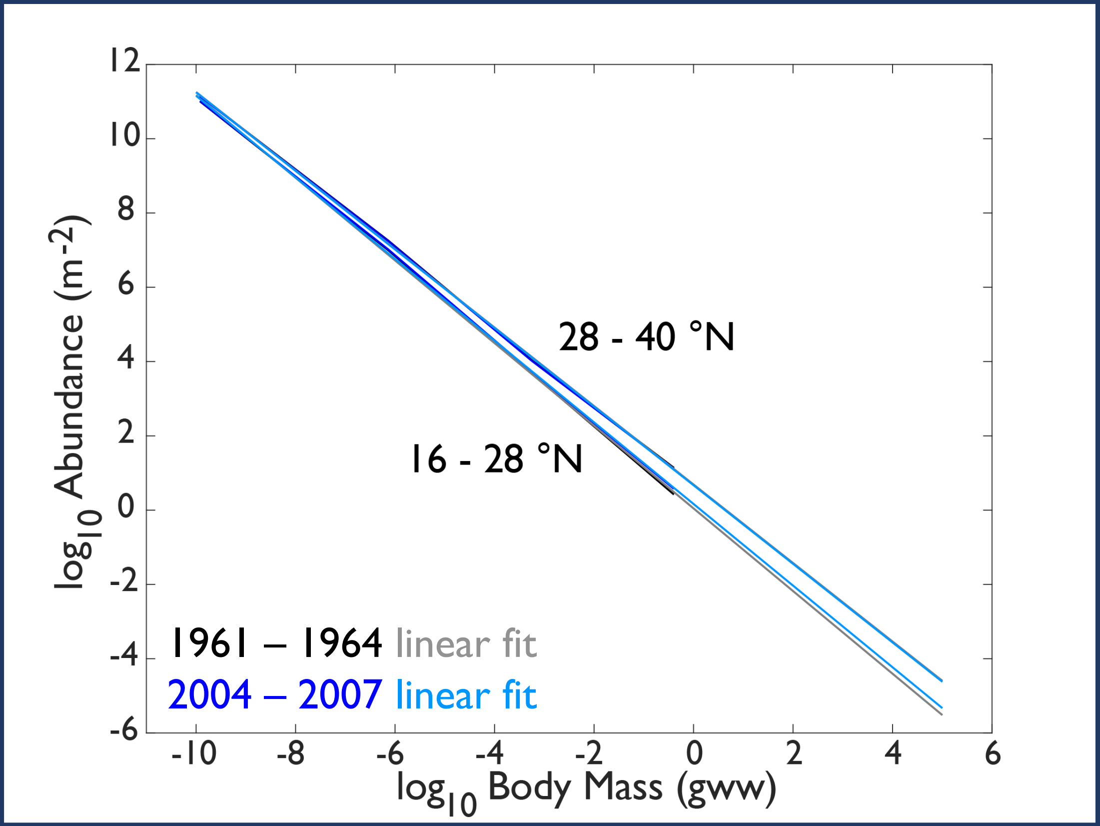


Shallower slope and larger intercept in northern region –
- coincides with more large bigeye in these waters in Kume 1969

Change in plankton community between two time periods:
- Northern region
  - 2 – 5% decline in plankton biomass
- Southern region
  - 2 – 42% increase in plankton biomass

COBALT data courtesy of Charlie Stock, GFDL

Multi-decadal change in bigeye size structure



Initial linear spectra, 1961 – 1964

Northern region:

Slope = -1.06, intercept = 0.69

Southern region:

Slope = -1.11, intercept = 0.05

Very little change in size spectrum between two time periods

Northern region:

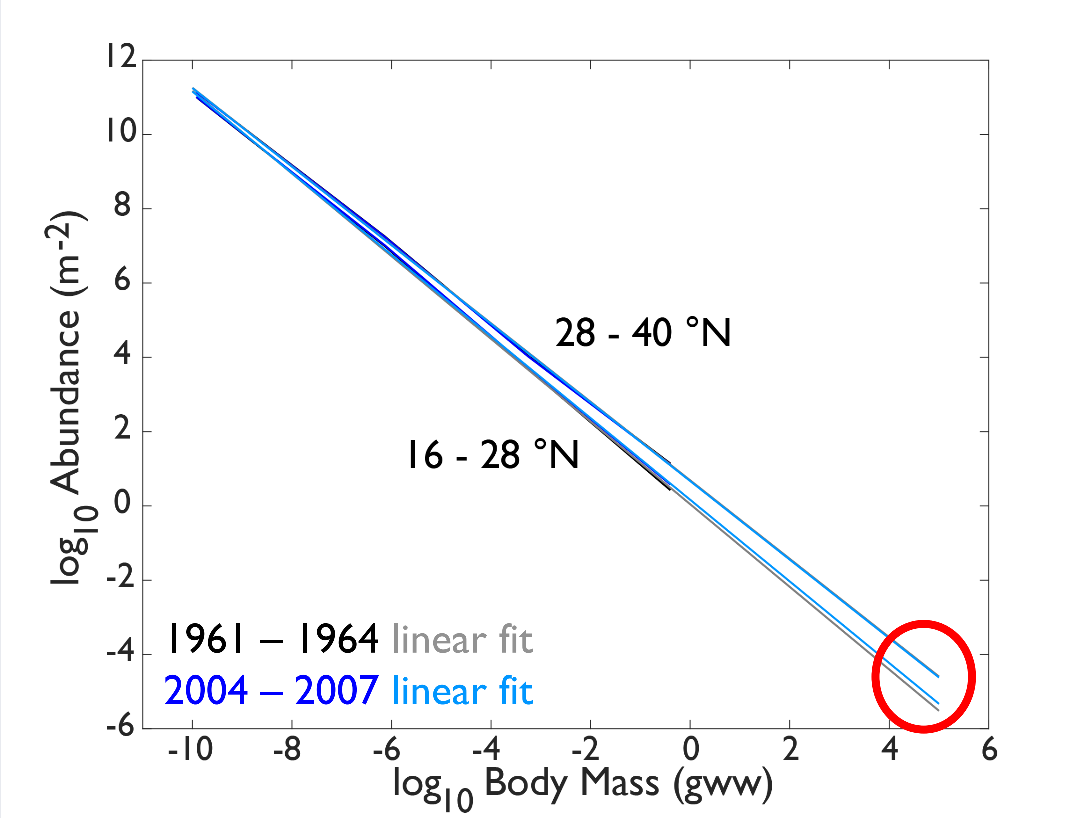
Slope Δ -0.1%, intercept Δ -3%

Southern region:

Slope Δ +1%, intercept Δ +230% (+30% linear abundance)

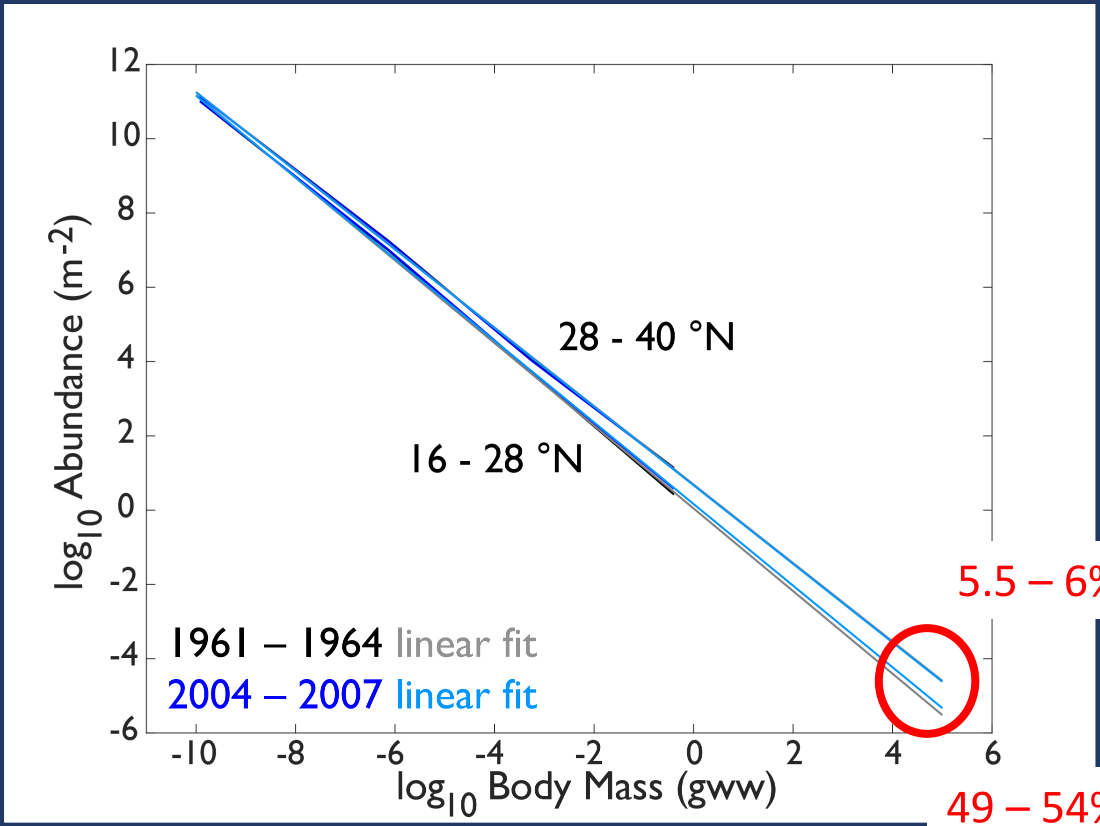
COBALT data courtesy of Charlie Stock, GFDL

Multi-decadal change in bigeye size structure



COBALT data courtesy of Charlie Stock, GFDL

Multi-decadal change in bigeye size structure



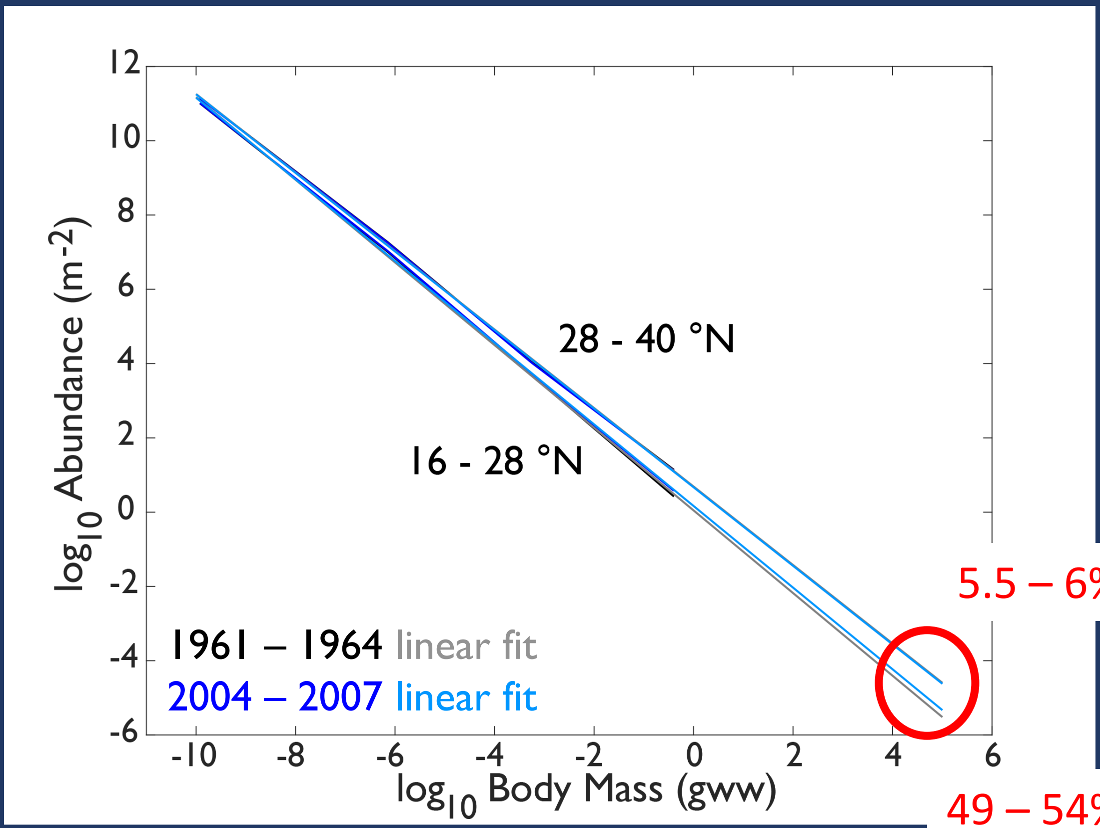
5.5 – 6% decline in abundance

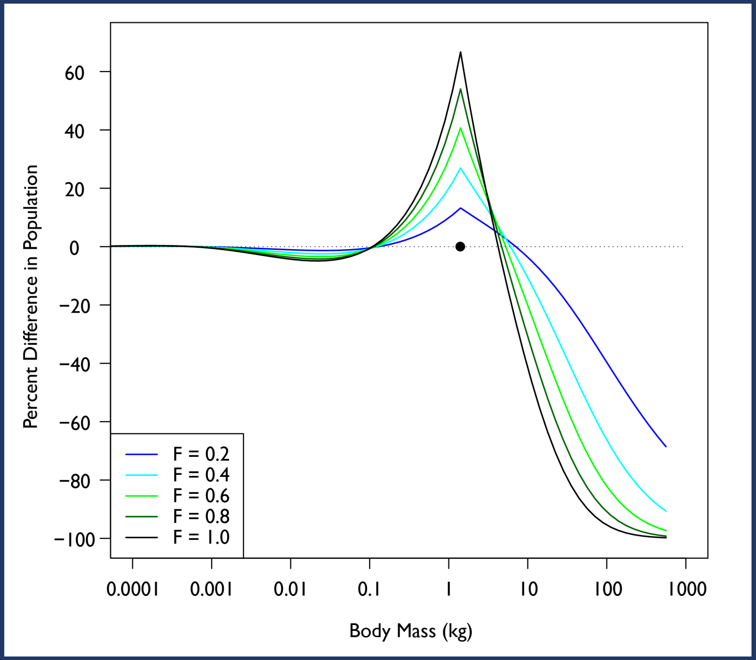
49 – 54% increase in abundance

So what might be driving change in bigeye size structure?

COBALT data courtesy of Charlie Stock, GFDL

Multi-decadal change in bigeye size structure





5.5 – 6% decline in abundance

49 – 54% increase in abundance

COBALT data courtesy of Charlie Stock, GFDL; Polovina and Woodworth-Jefcoats 2013 *PLoS ONE*

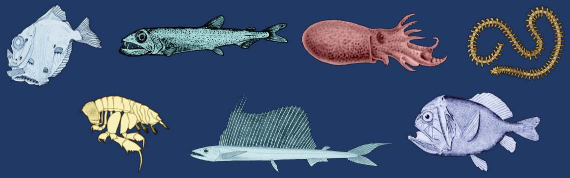
Variability at mid-trophic levels

Lancetfish (*Alepisaurus ferox)*

- Most abundantly caught fish in Hawaii-based longline fishery
- Unique digestive physiology

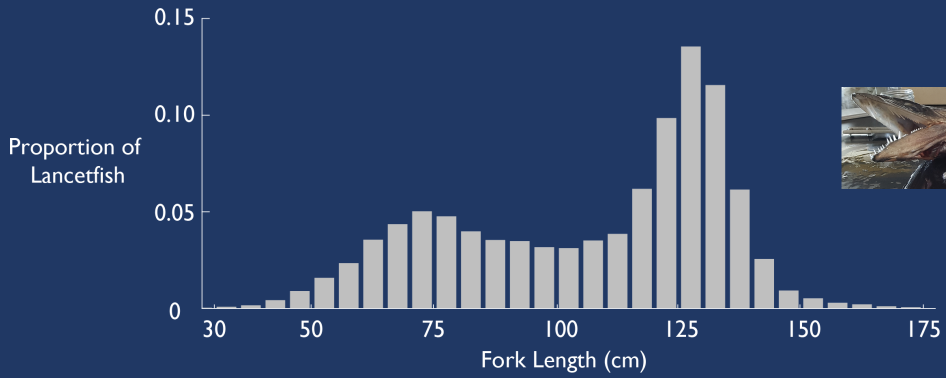
70% of diet from 7 prey families

- Hatchetfishes
- Hammerjaws
- Amphitretidae (pelagic octopods)
- Alciopidae (polychaetes)
- Phrosinidae (hyperiid amphipod)
- Lancetfishes
- Fangtooths



Portner et al. In Press *DSR-I*, Images courtesy of Elan Portner

Lancetfish as mid-water samplers

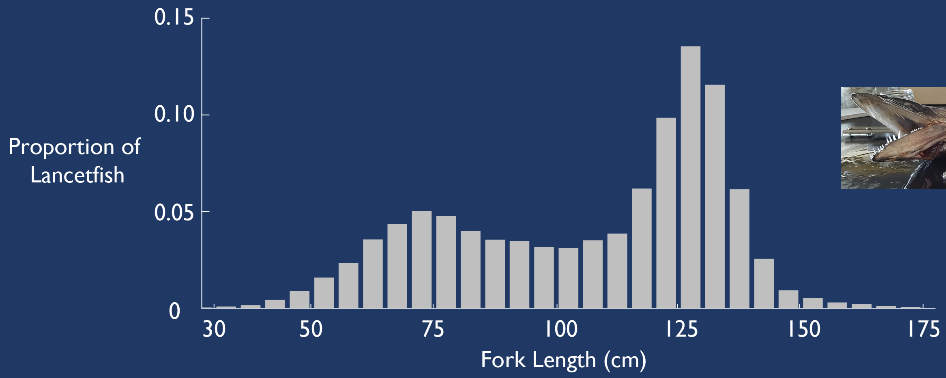


Small Lancetfish (< 1 m)

Large Lancetfish (> 1 m)

Portner et al. In Press *DSR-I*

Lancetfish as mid-water samplers



Small Lancetfish (< 1 m)

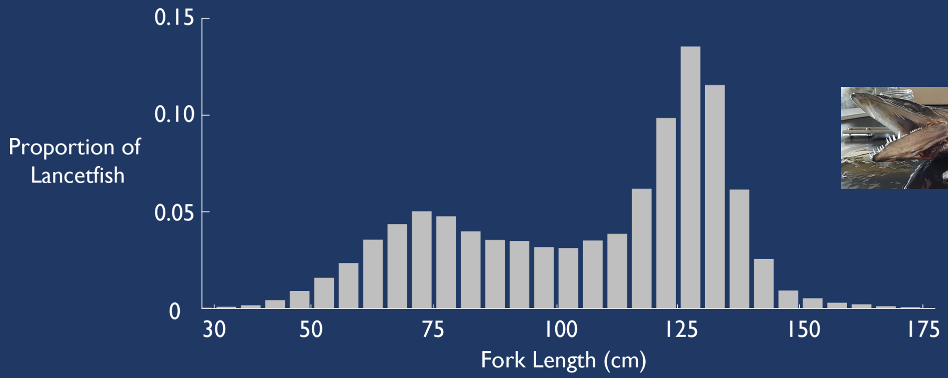
- Smaller, more epipelagic prey

Large Lancetfish (> 1 m)

- Larger, more meso- and bathypelagic prey

Portner et al. In Press *DSR-I*

Lancetfish as mid-water samplers



Small Lancetfish (< 1 m)

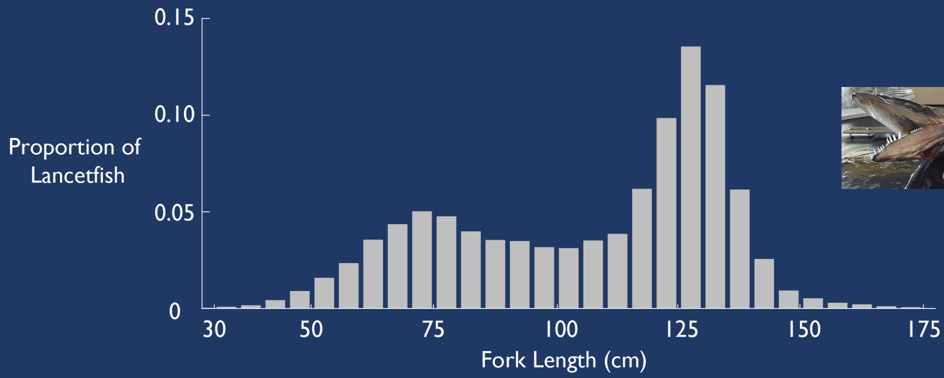
- Smaller, more epipelagic prey

Large Lancetfish (> 1 m)

- Larger, more meso- and bathypelagic prey
- Spatial differences in diet

Portner et al. In Press *DSR-I*

Lancetfish as mid-water samplers



Small Lancetfish (< 1 m)

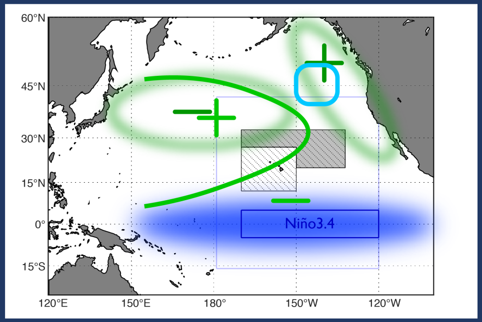
- Smaller, more epipelagic prey
- Winter diet vs. remaining seasons

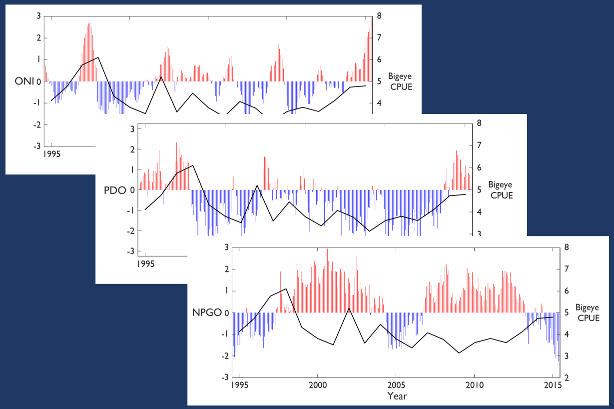
Large Lancetfish (> 1 m)

- Larger, more meso- and bathypelagic prey
- Spatial differences in diet
- Winter diet, spring diet, remaining seasons

Portner et al. In Press *DSR-I*

Between the footprints of natural climate variability modes





Need for understanding additional drivers of bigeye catch, highlighted by:

- Environmental links to recruitment pulses that would enable predictive capacity
- Multi-decadal changes in size structure
- Ability to detect changes at mid-trophic levels

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