Between the footprints of natural climate variability modes

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Hawaii-based Longline Fishery

- 142 vessels
- 49 million hooks
- 13 million km²

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

NOAA National Marine Fisheries Service
Hawaii-based Longline Fishery

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CPUE: Catch Per Unit Effort

# Fish caught per 1,000 hooks set

NOAA National Marine Fisheries Service
Hawaii-based Longline Fishing Ground
Hawaii-based Longline Fishing Ground

Footprints of Variability
Hawaii-based Longline Fishing Ground

Footprints of Variability
• 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
Hawaii-based Longline Fishing Ground

Footprints of Variability
- 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
Hawaii-based Longline Catch

El Niño – Southern Oscillation

Pacific Decadal Oscillation

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
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
Median phytoplankton cell size

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

SeaWiFS & MODIS chlorophyll-a + GODAS 5 m temperature

Interannual variability in bigeye tuna catch
Median phytoplankton cell size

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Median phytoplankton cell size

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SeaWiFS & MODIS chlorophyll-a + GODAS 5 m temperature

SeaWiFS correction: + 0.015 pg C

Saha et al. 2006 *J Climate*, Barnes et al. 2011 *J Plankton Research*
Median phytoplankton cell size

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

SeaWiFS correction: + 0.015 pg C
Interannual variability in bigeye tuna catch

Bigeye CPUE & Biomass CPUE

Median phytoplankton cell size

Wren and Polovina In Prep
Interannual variability in bigeye tuna catch

Bigeye CPUE & Biomass CPUE

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

Correlation with $M_{B50}$

$r = 0.75 \quad p = 0.002$

$r = 0.80 \quad p < 0.001$
Multi-decadal change in bigeye size structure
Multi-decadal change in bigeye size structure

Kume 1969 Far Seas Fisheries Research Laboratory Bulletin
Japanese to English translation by Andrew Tokuda
NOAA National Marine Fisheries Service - Updated figure courtesy of Johanna Wren

Kume 1969 1956 – 1964
Hawaii Observers 2006 – 2016

16 – 28 °N
> 28 °N
Multi-decadal change in bigeye size structure

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
Multi-decadal change in bigeye size structure

Kume 1969
1956 – 1964
Hawaii Observers
2006 – 2016

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Kume 1969
1956 – 1964

Hawaii Observers
2006 – 2016

Kume 1969 *Far Seas Fisheries Research Laboratory Bulletin*
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Multi-decadal change in bigeye size structure

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
Multi-decadal change in bigeye size structure

**COBALT:** Carbon, Ocean Biogeochemistry, and Lower Trophics

Multi-decadal change in bigeye size structure

COBALT: Carbon, Ocean Biogeochemistry, and Lower Trophics

Shallow 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
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)

Multi-decadal change in bigeye size structure

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

**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
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
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