Using satellite data to predict fishery performance

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Johanna Wren

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Hawai‘i-based longline bigeye tuna fishery – 2019

- 146 vessels
- 61 million hooks
- > 15 million km^2

- Total landings
  - $90 million (9th in US)
  - 29 million pounds (23rd in the US)
  - 46% of US tuna landings – 2018
  - 63% of US tuna landings revenue – 2018

- Importance of bigeye to the fishery
  - 19% of all fish caught
  - 32% of all fish retained
  - 53% of catch in weight
  - 66% of ex vessel revenue

NOAA National Marine Fisheries Service; WPRFMC 2020: Annual SAFE Report Pacific Island Pelagic FEP 2019

Photos courtesy of NOAA Fisheries/Justin Hospital (top) & ../Katie Davis (bottom)

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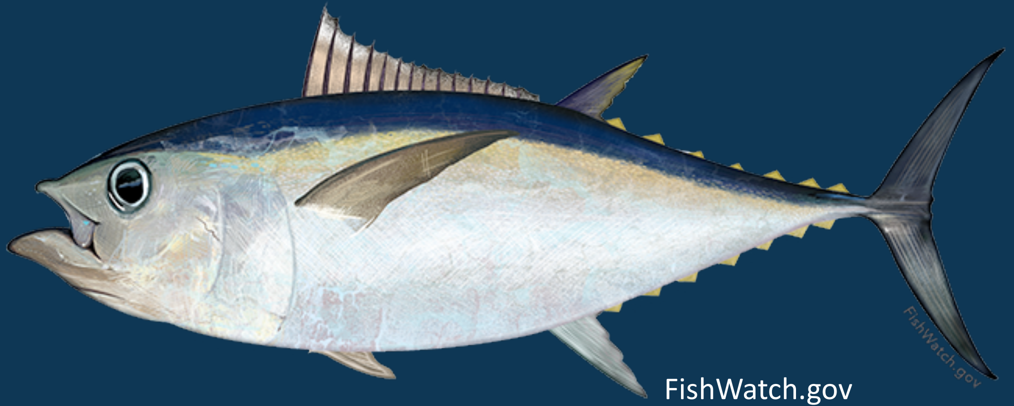
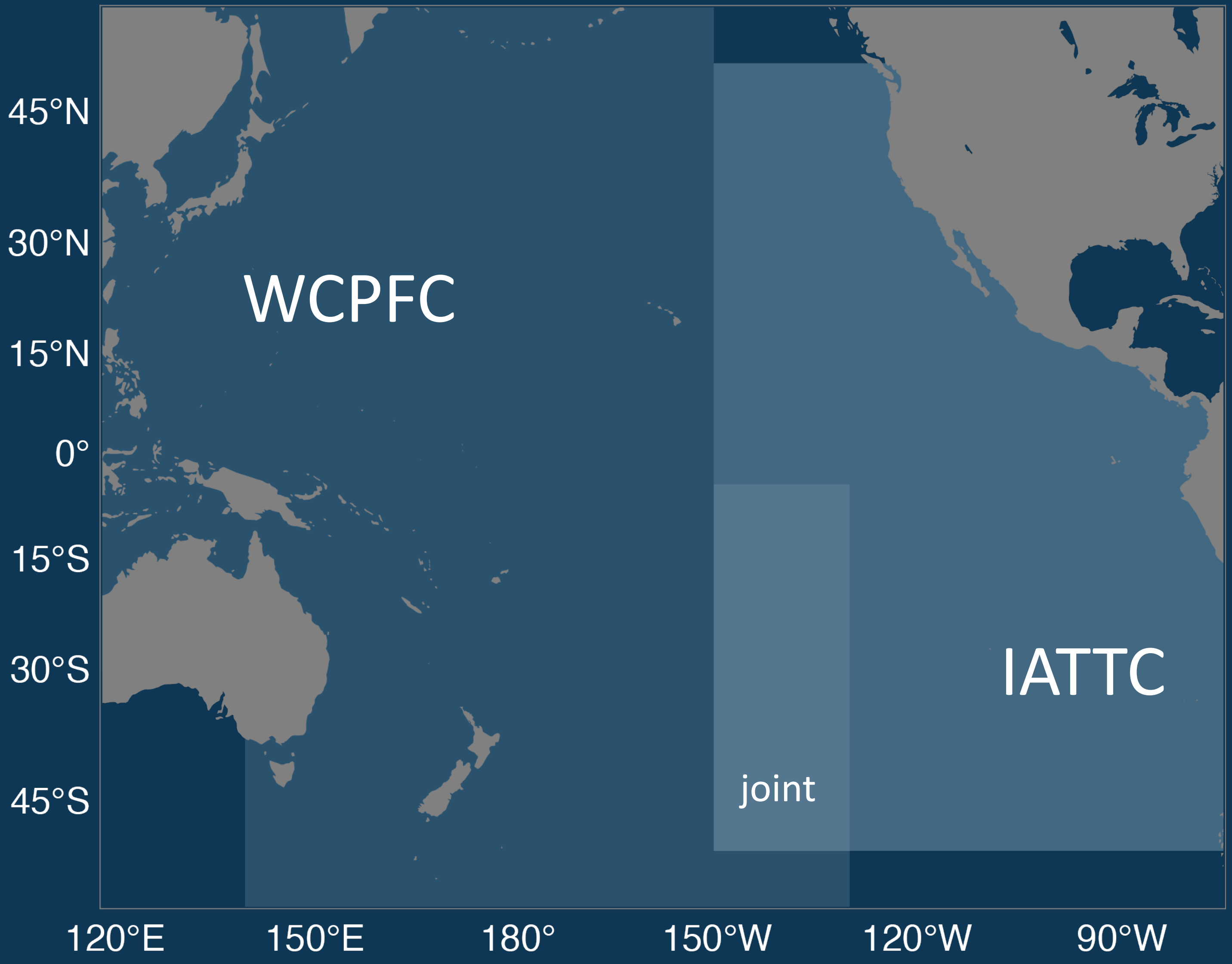


- Bigeye face an uncertain future
  - Intermittently experiencing overfishing
  - Assessments include noted uncertainty

Abascal et al. 2018; Aires-da-Silva and Maunder 2015; Ducharme-Barth et al. 2020; Harley et al. 2014; McKechnie et al 2017; Xu et al. 2018, 2020

NOAA National Marine Fisheries Service; WPRFMC 2020: Annual SAFE Report Pacific Island Pelagic FEP 2019

Uncertainty and challenges surrounding bigeye tuna



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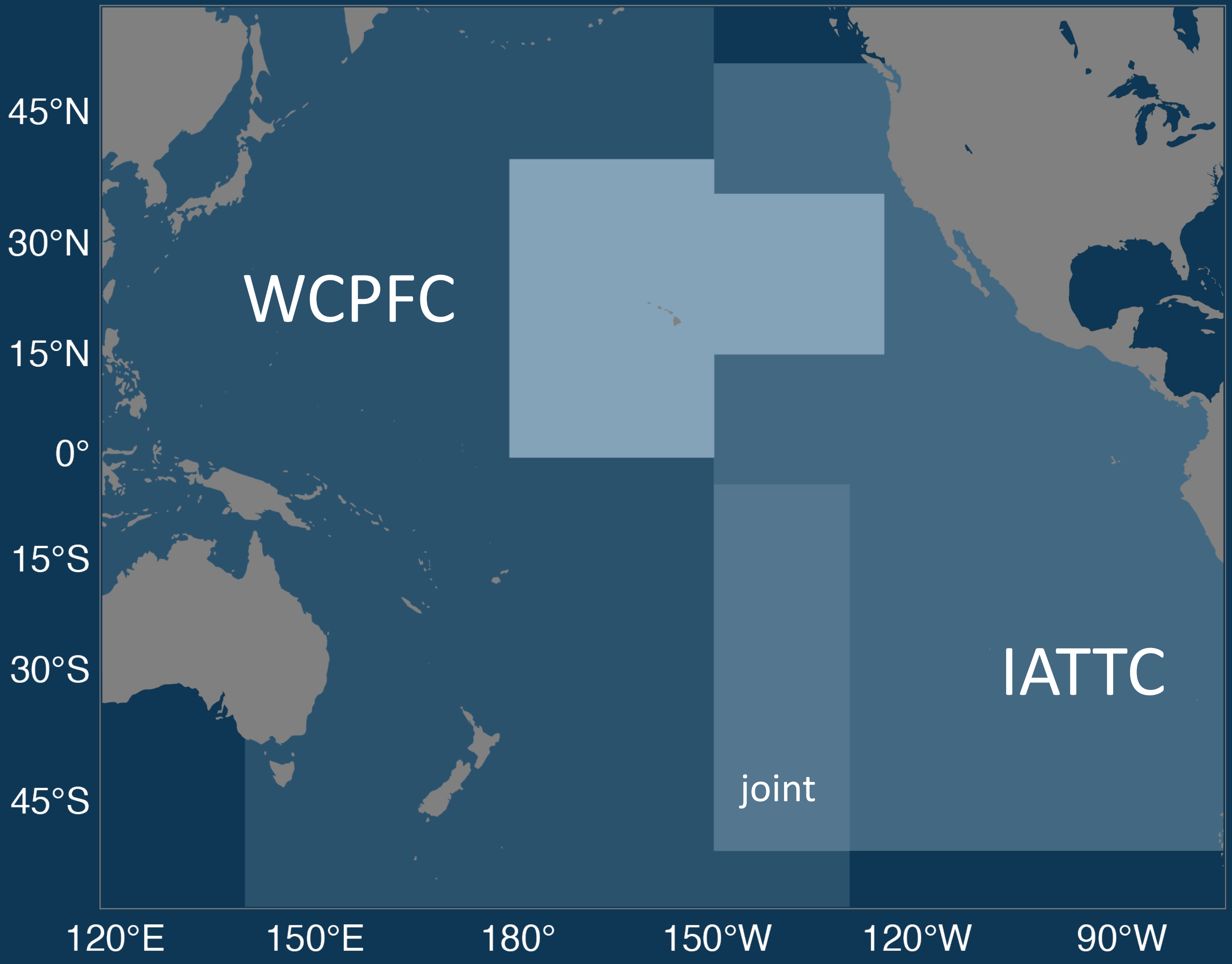
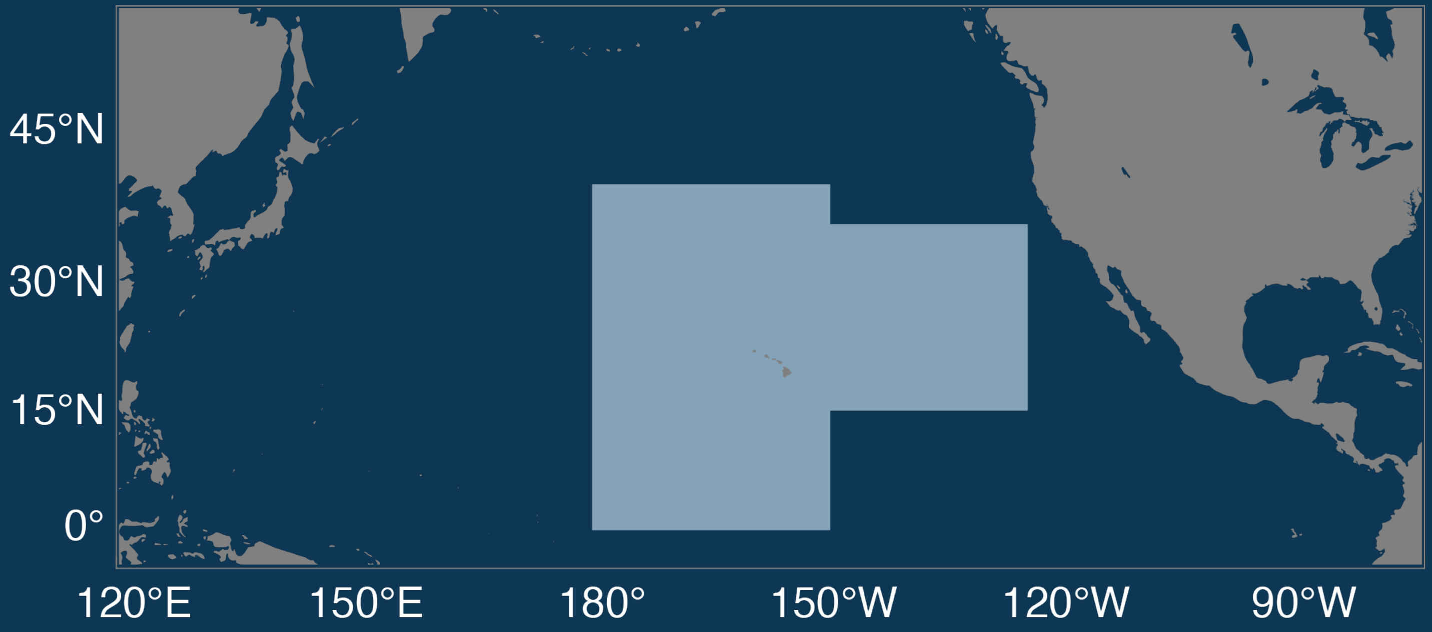


Focusing on the Hawai‘i-based fishing grounds

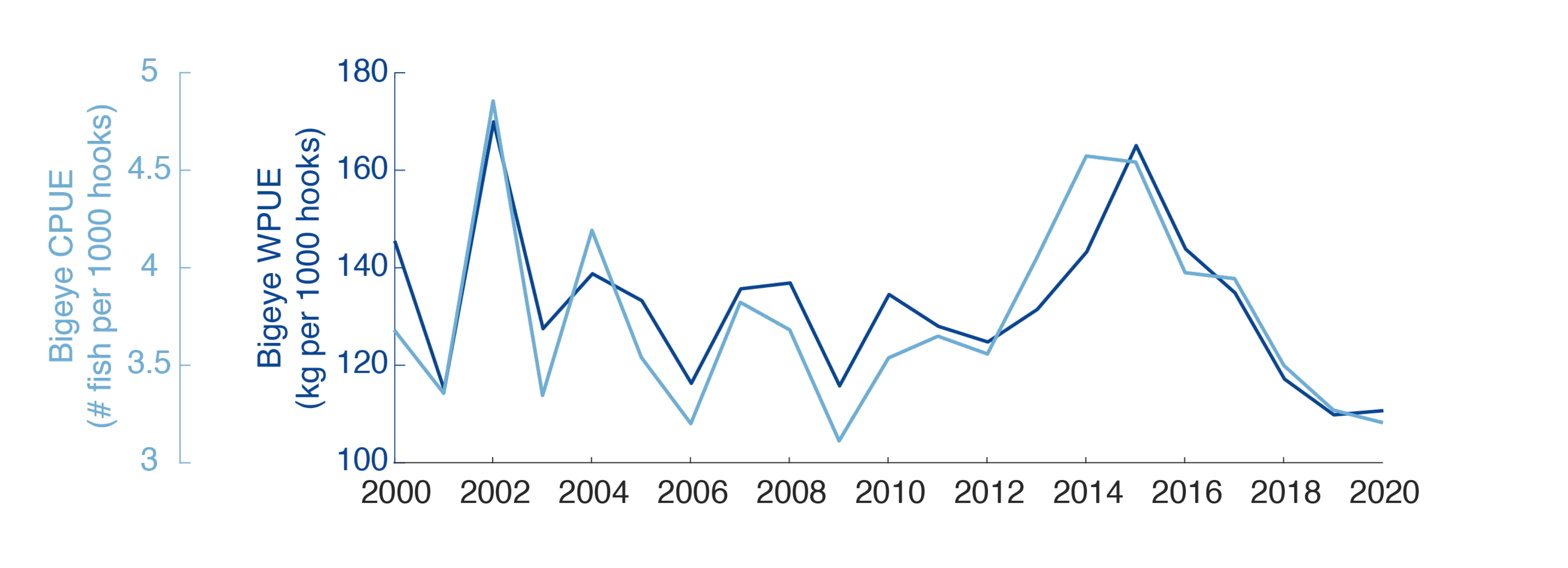


Recruitment Index

CPUE:
catch per unit effort

WPUE:
weight per unit effort

Effort:
hooks set



Wren and Polovina, In Review
WPRFMC 2021: Annual SAFE Report Pacific Island Pelagic FEP 2020

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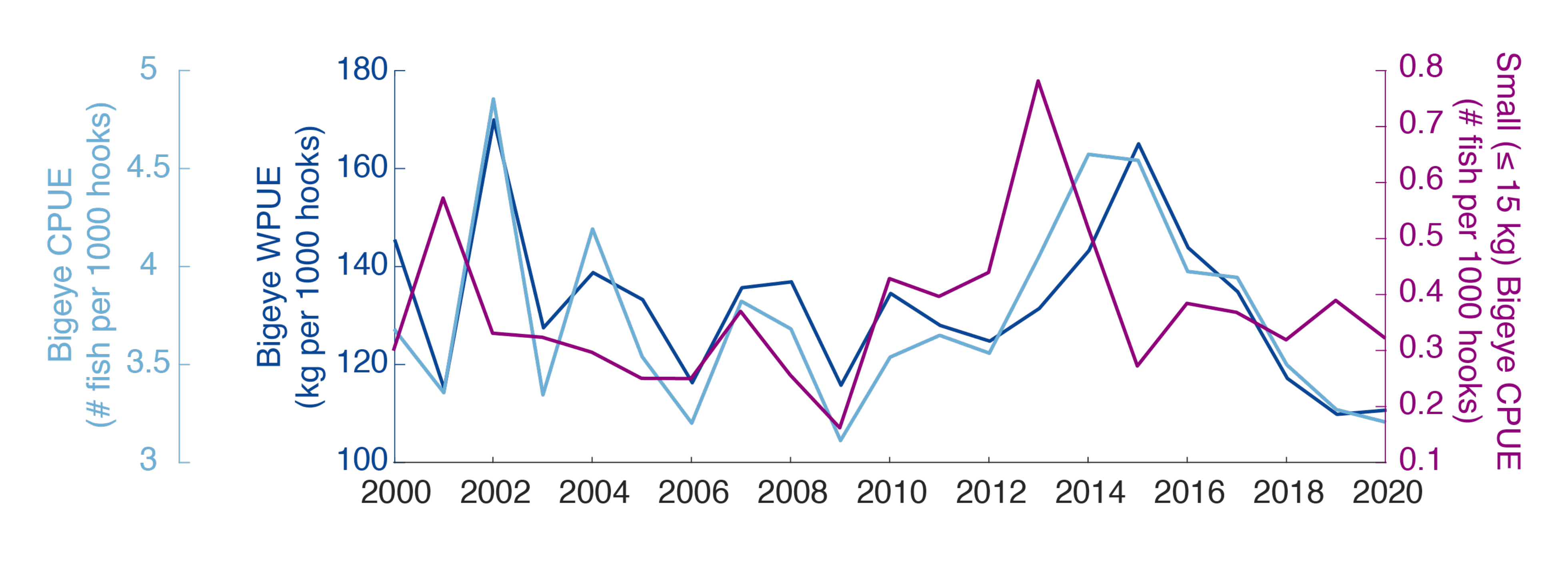

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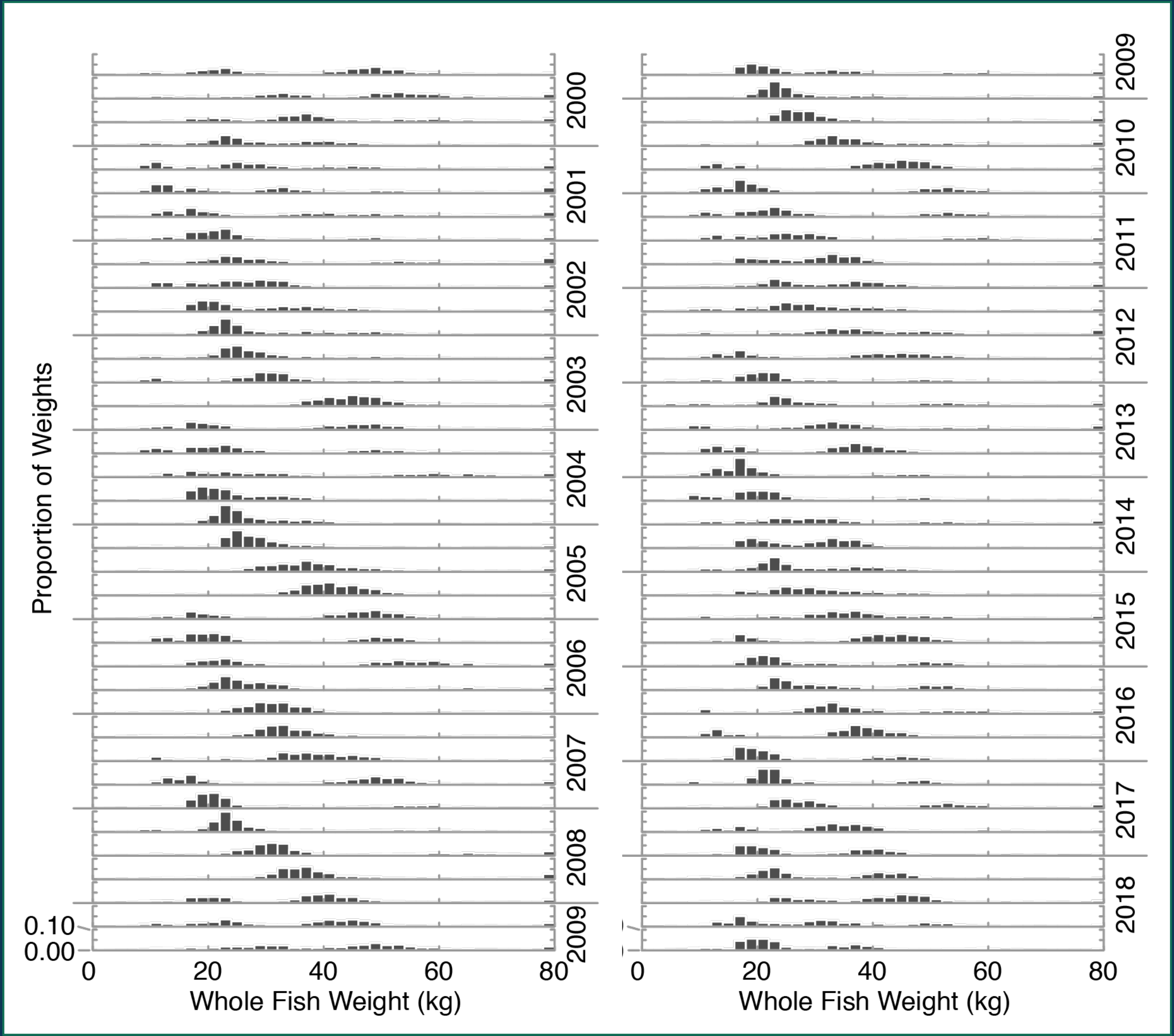


Coherent stock structure

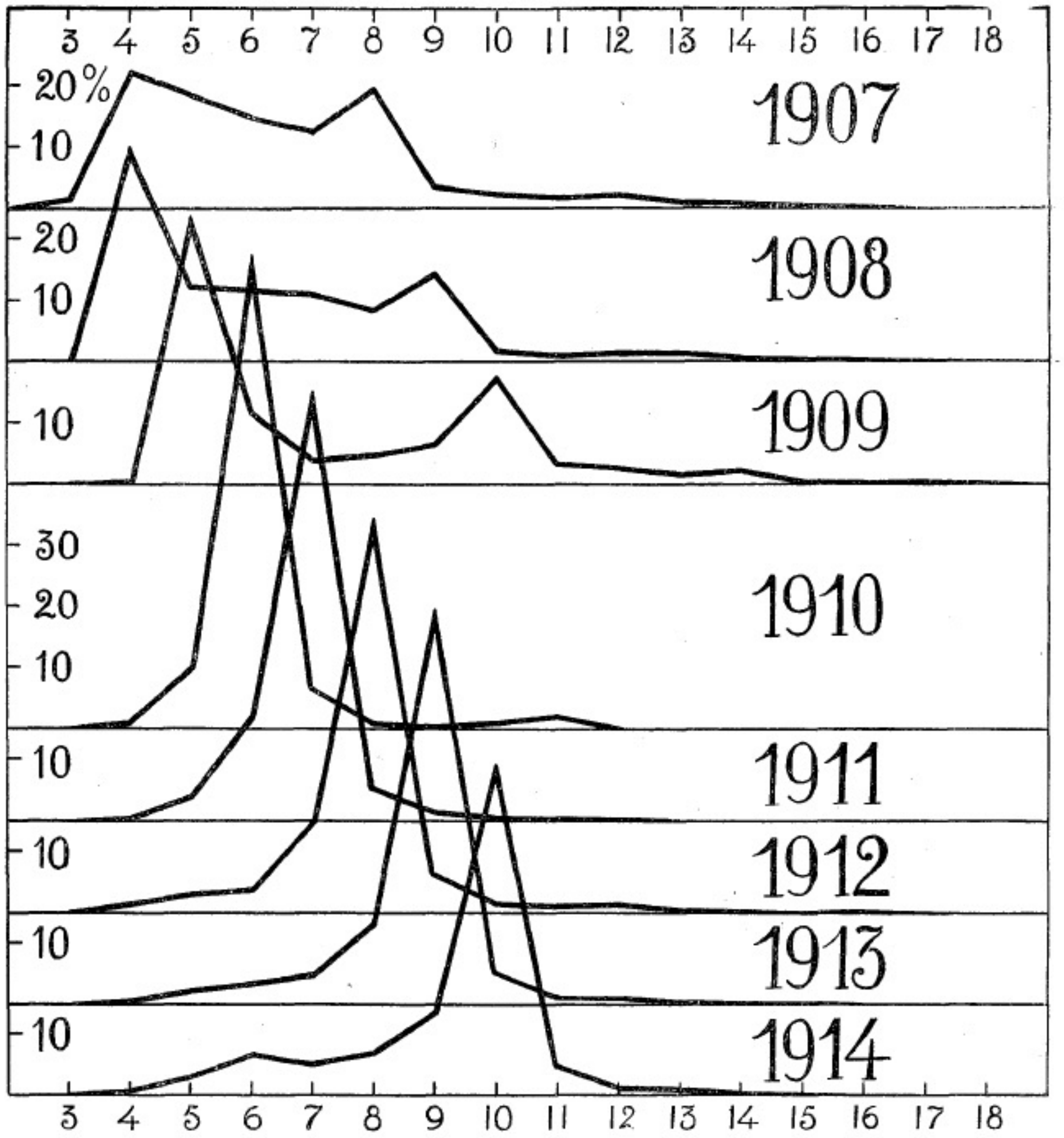
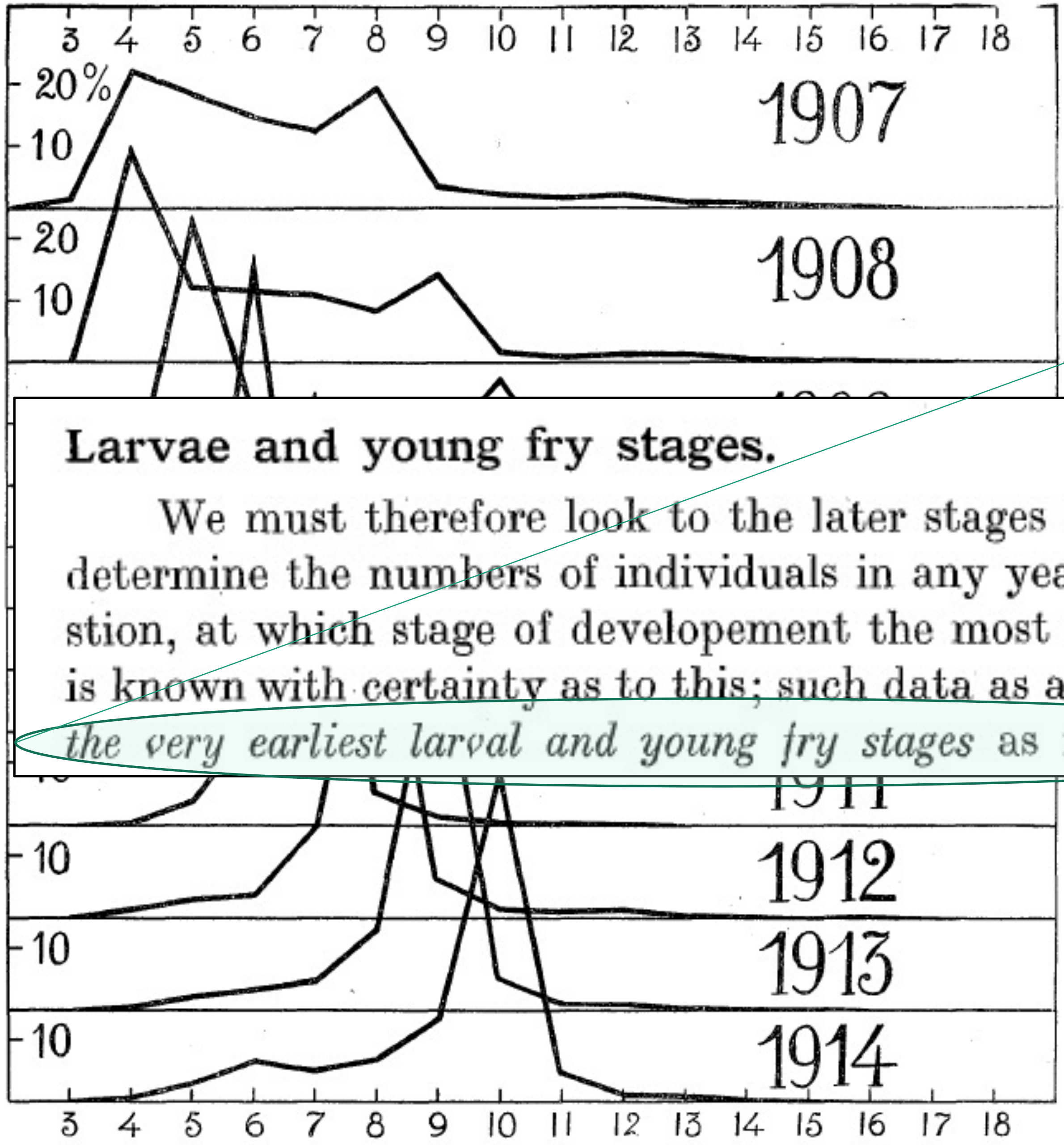


Fig. 133. Composition in point of age of spring herring for the years 1907—1914; average of all samples examined in each year. For 1914 only samples from February included.

Hjort
1914



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Larvae and young fry stages.

We must therefore look to the later stages of the eggs to find the conditions which determine the numbers of individuals in any year class. This again leads us to the question, at which stage of developement the most critical period is to be sought. Nothing is known with certainty as to this; such data as are available, however, appear to indicate *the very earliest larval and young fry stages* as most important.

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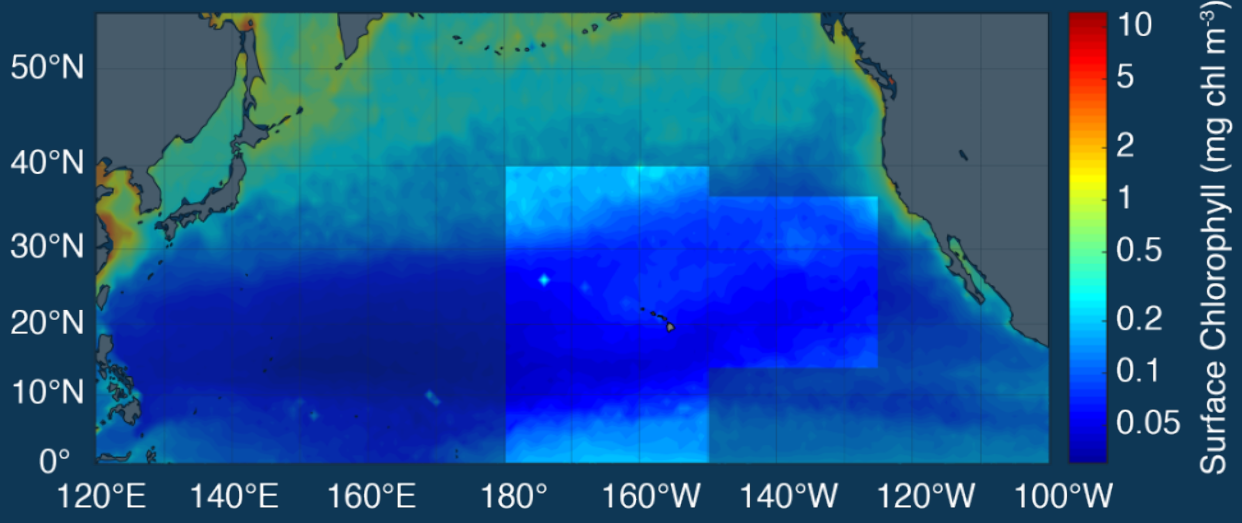
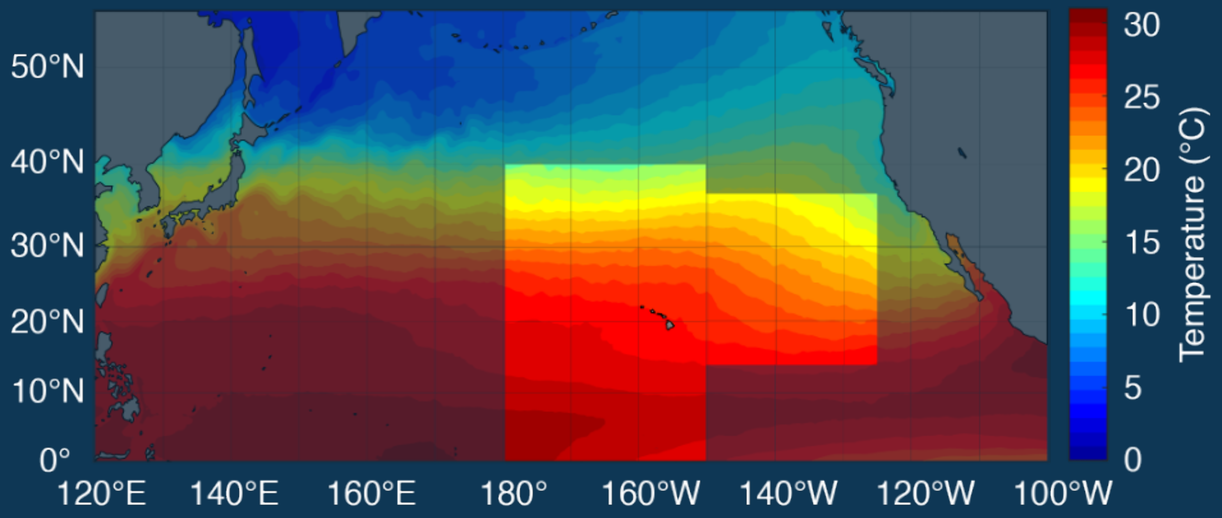
1914

Chlorophyll-a concentration — ESA OC CCI v5.0



Sea Surface Temperature — CoralTemp v3.1



Median phytoplankton mass, M_{B50}:

$$\log_{10}(M_{B50}) = 0.929 \log_{10}(chl\text{−}a) - 0.043\,(SST) + 1.340$$

Median phytoplankton size, M_{D50}:

$$M_{D50} = 2.138\,(M_{B50})^{0.355}$$

- M_{D50} calculated for each monthly grid cell
- Averaged annually to match management time frame and over the spatial domain of the fishery

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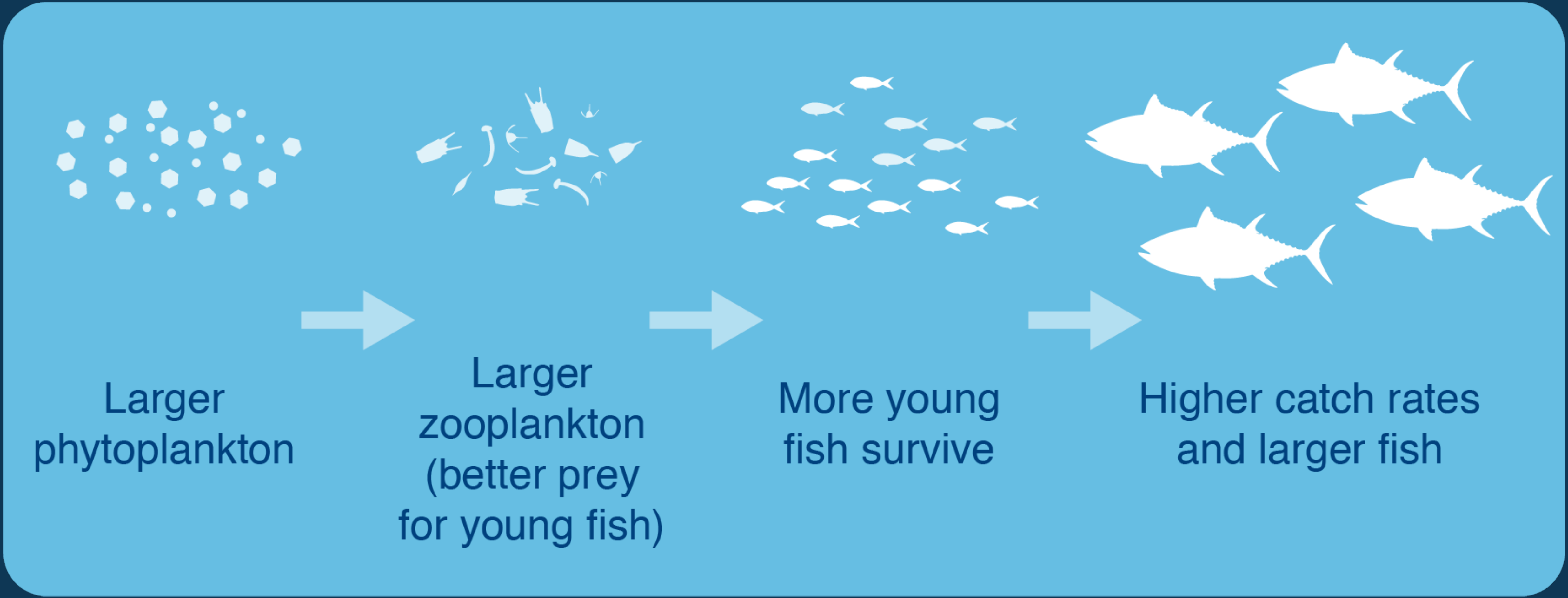
Barnes et al. 2011; Menden-Deuer and Lessard 2000; Polovina and Woodworth 2012

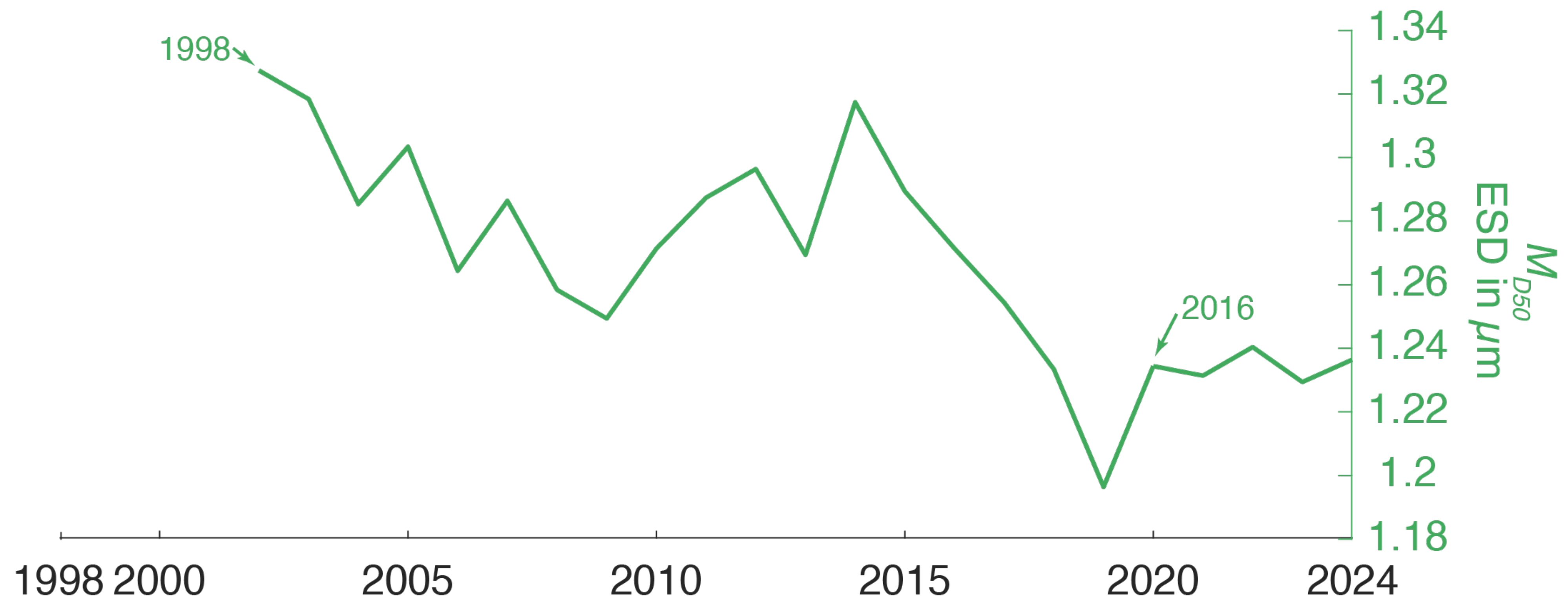


Larger phytoplankton
Larger zooplankton (better prey for young fish)
More young fish survive
Higher catch rates and larger fish

Estimated phytoplankton size

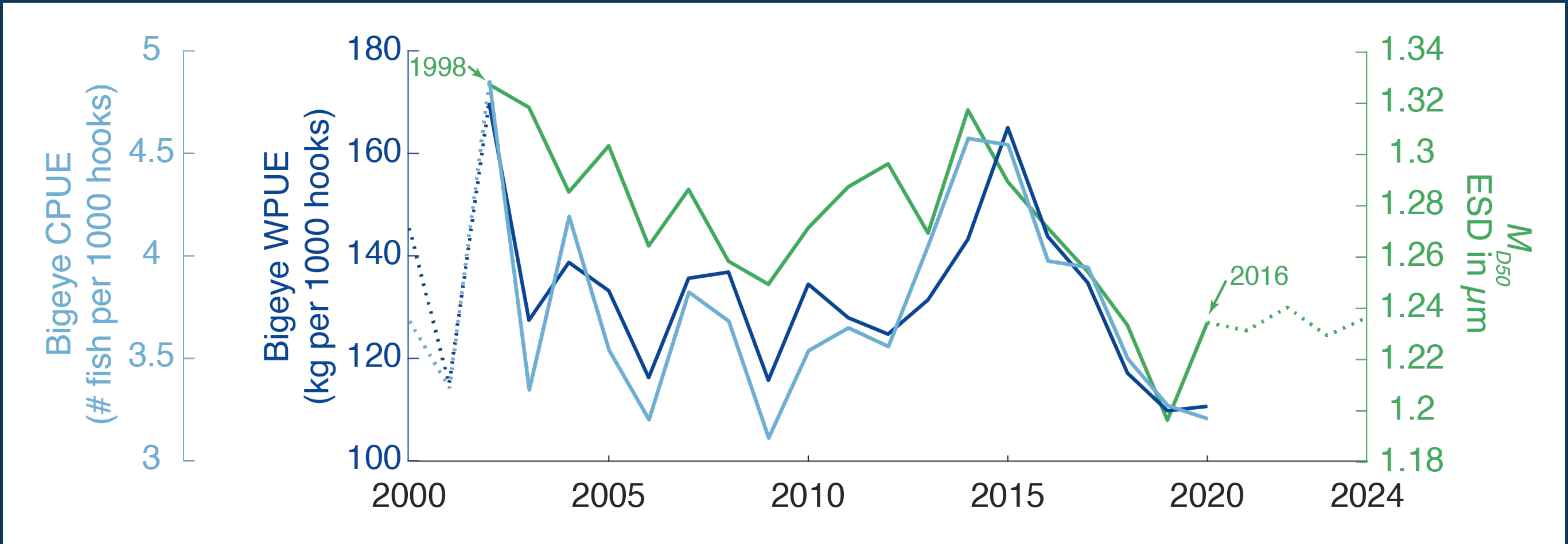
WPRFMC 2021: Annual SAFE Report Pacific Island Pelagic FEP 2020; Woodworth-Jefcoats and Wren 2020

Estimated phytoplankton size



WPRFMC 2021: Annual SAFE Report Pacific Island Pelagic FEP 2020; Woodworth-Jefcoats and Wren 2020

Comparison between CPUE, WPUE, and 4-year-lagged M_{D50}



$r = 0.57$ $r = 0.66$

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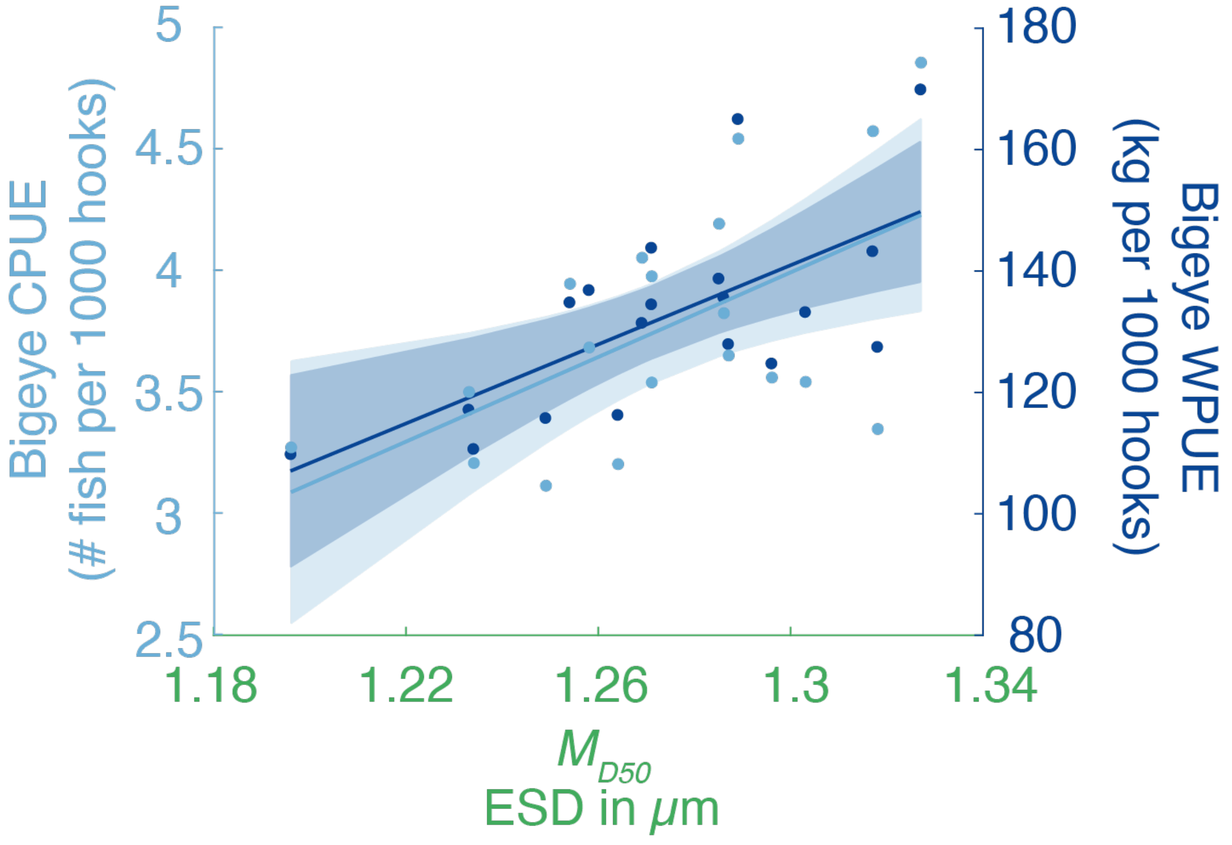
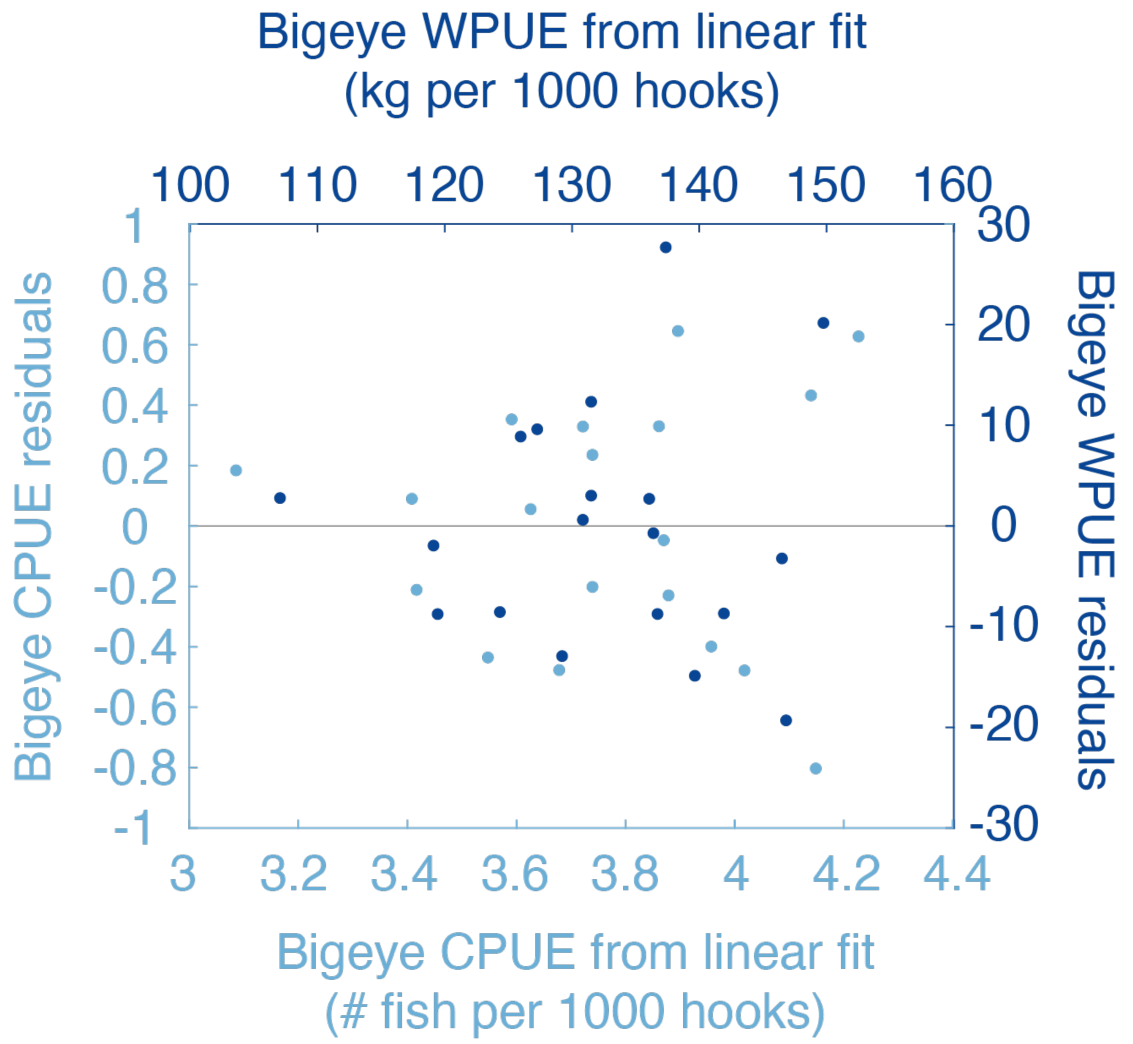
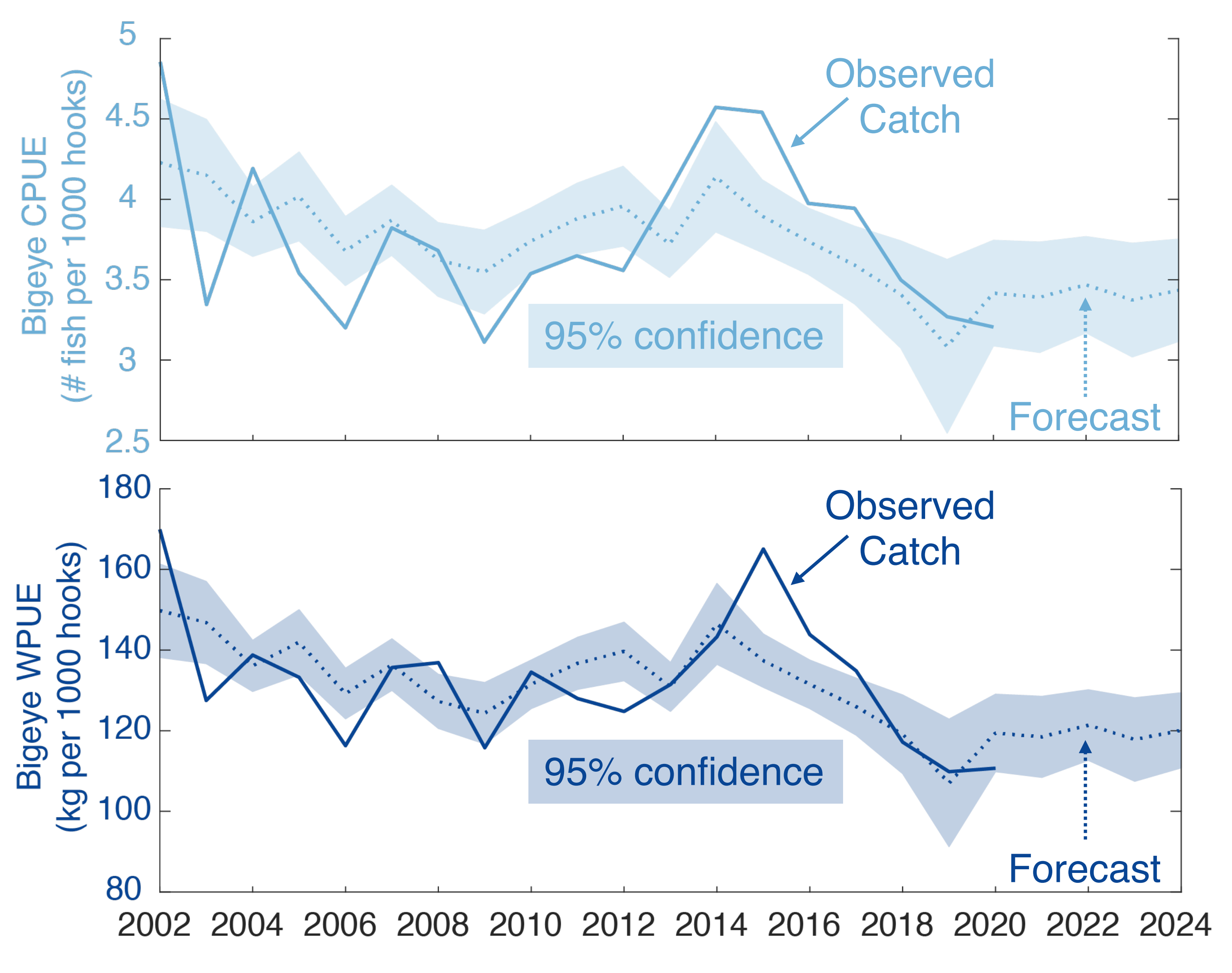




Bigeye Tuna Catch Rate Forecast

Based on linear regression

Able to forecast 4 years into the the future due to the average age of fish landed



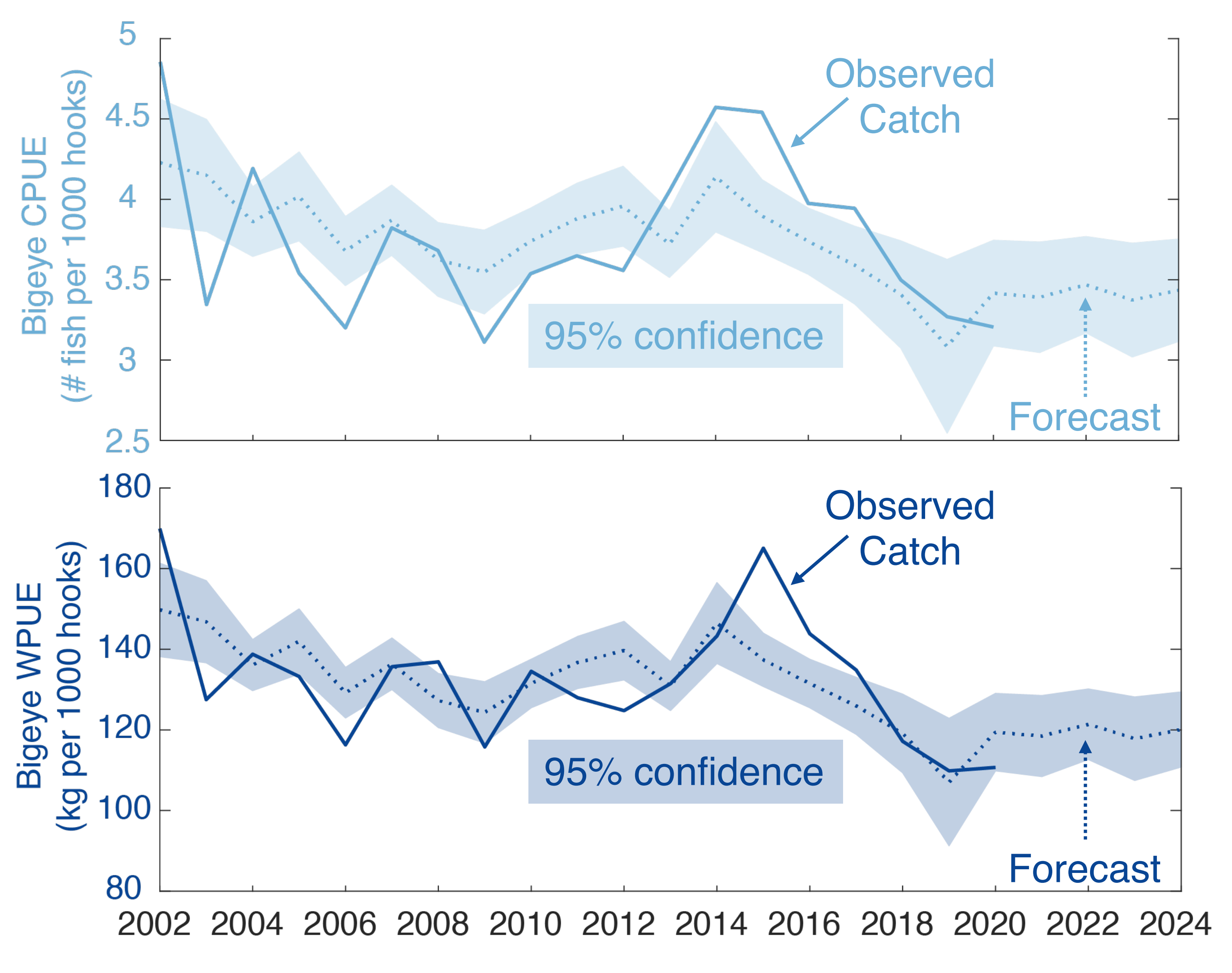
Forecast skill: $\sum|forecast\ - observation|$

Three forecast methods tested:

Plankton-based, shown here

Persistence, assuming each year's catch rate will be equal to the prior year's

Climatology, assuming each year will be equal to the average of all prior years



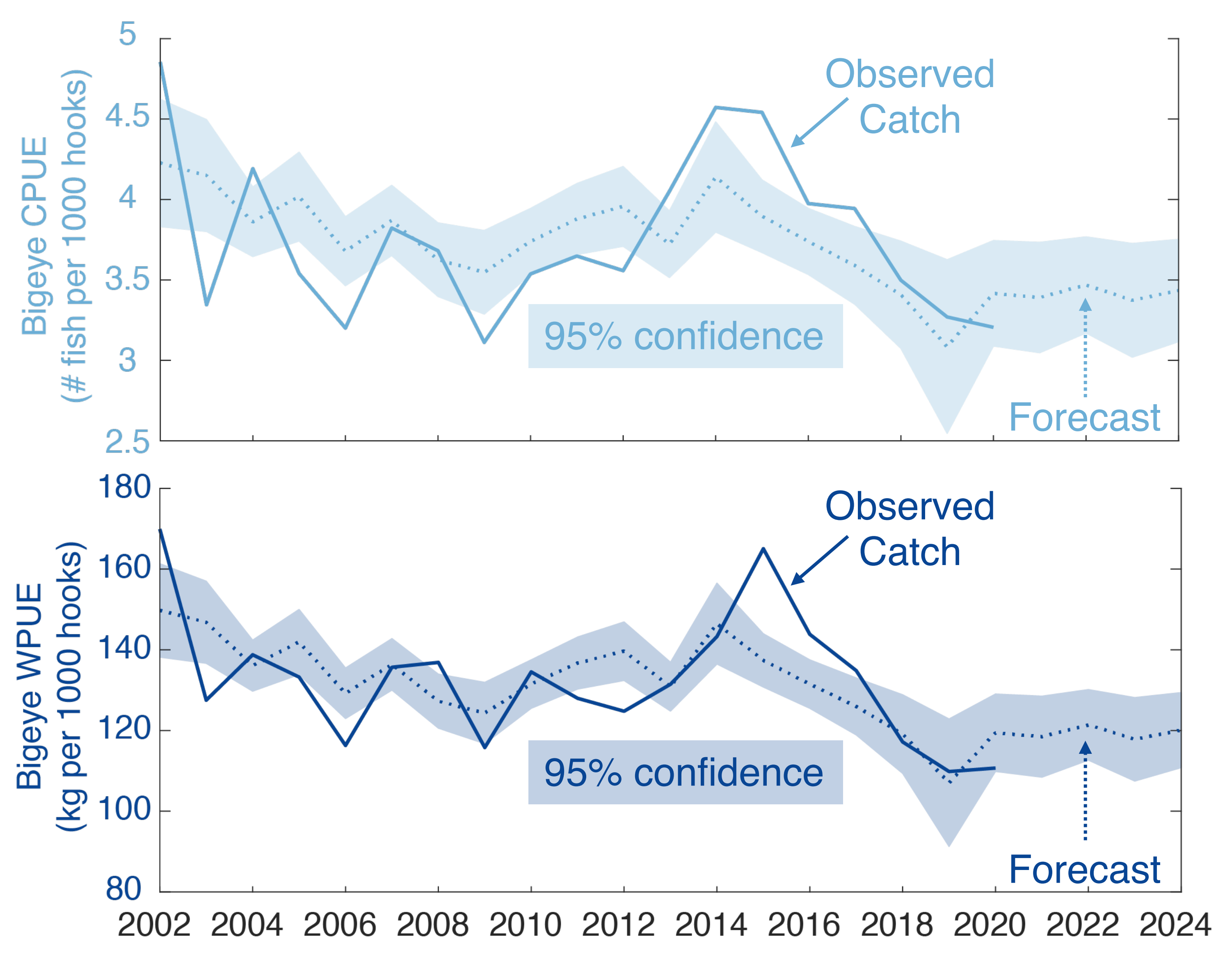
Forecast skill: $\sum|forecast - observation|$

CPUE skill (# fish per 1,000 hooks)

Plankton-based:	6.6
Persistence:	9.0
Climatology:	8.2

WPUE skill (kg per 1,000 hooks)

Plankton-based:	175
Persistence:	298
Climatology:	335



Next steps

Specific to Hawai‘i’s deep-set longline fishery and bigeye tuna

- Additional estimates of juvenile mortality, e.g., purse seine catch
- Advanced statistical approaches
- Evaluating the influence of climate variability

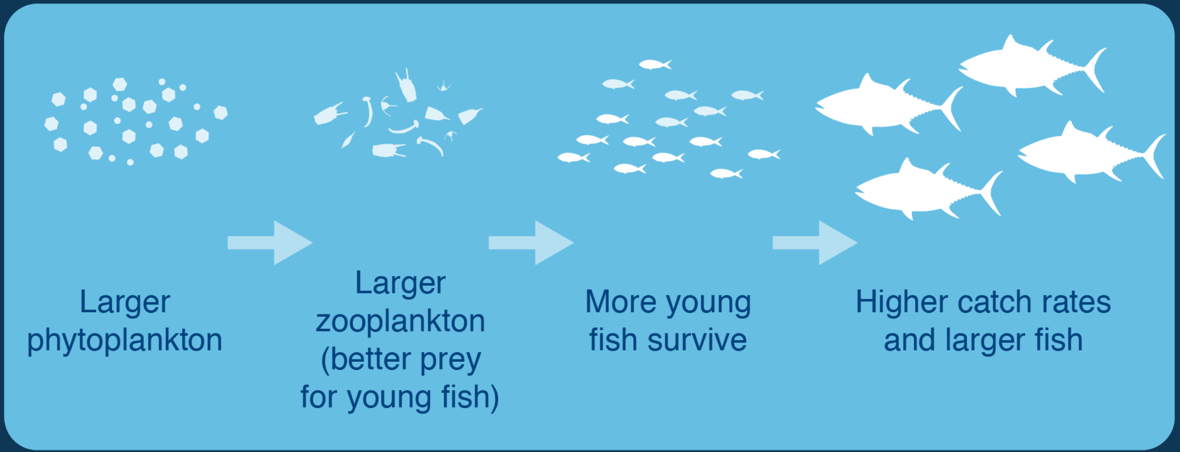
Advancing stock assessments

- Working with stock assessment program on swordfish assessment
- Potential for use with other species and regions

Verification of methods

- Upcoming cruises to verify the methodology and hypothesized mechanism in oligotrophic and equatorial waters across the fishery’s footprint

Conclusions



- Satellite-derived estimates of phytoplankton size can be used to skillfully forecast bigeye tuna catch rates up to four years into the future
- Working to incorporate the underlying ecological relationship in additional fishery applications
- Upcoming cruises to verify algorithm and ecosystem size structure

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