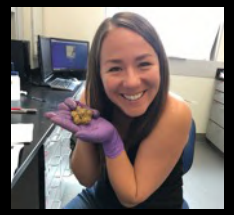


Cheryl Barnes, UAF

Anne Beaudreau, UAF

Martin Dorn, AFSC

Kirstin Holsman, AFSC

Franz Mueter, UAF

Development of a predation index to assess trophic stability in the Gulf of Alaska

POLLOCK CONSERVATION COOPERATIVE Research Center

RASMUSON FISHERIES RESEARCH CENTER

UAF COLLEGE OF FISHERIES AND OCEAN SCIENCES
University of Alaska Fairbanks

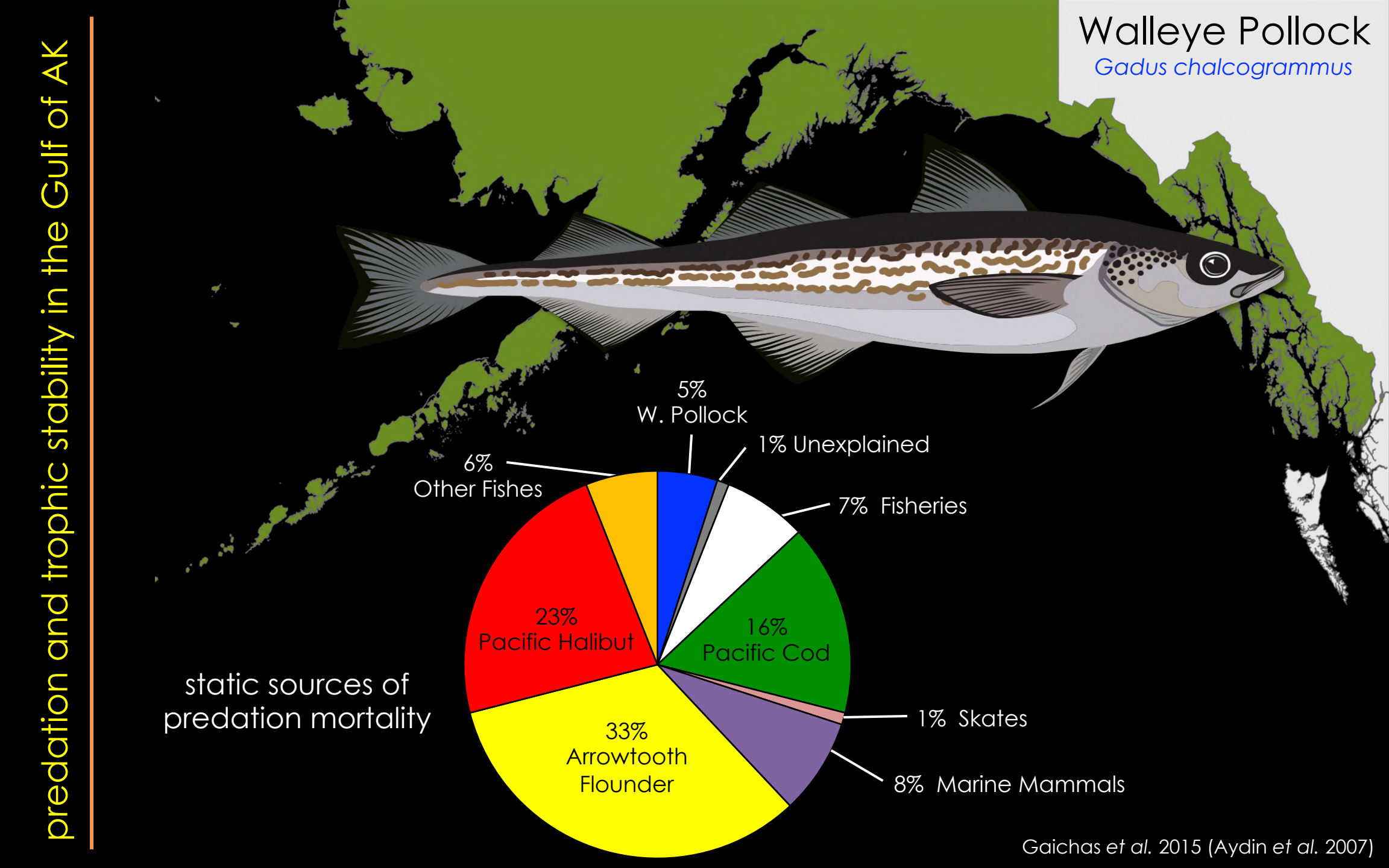
UNIVERSITY of ALASKA SOUTHEAST
SITKA CAMPUS

- N. Gulf of Alaska Applied Research Award -

predation and trophic stability in the Gulf of AK

Walleye Pollock

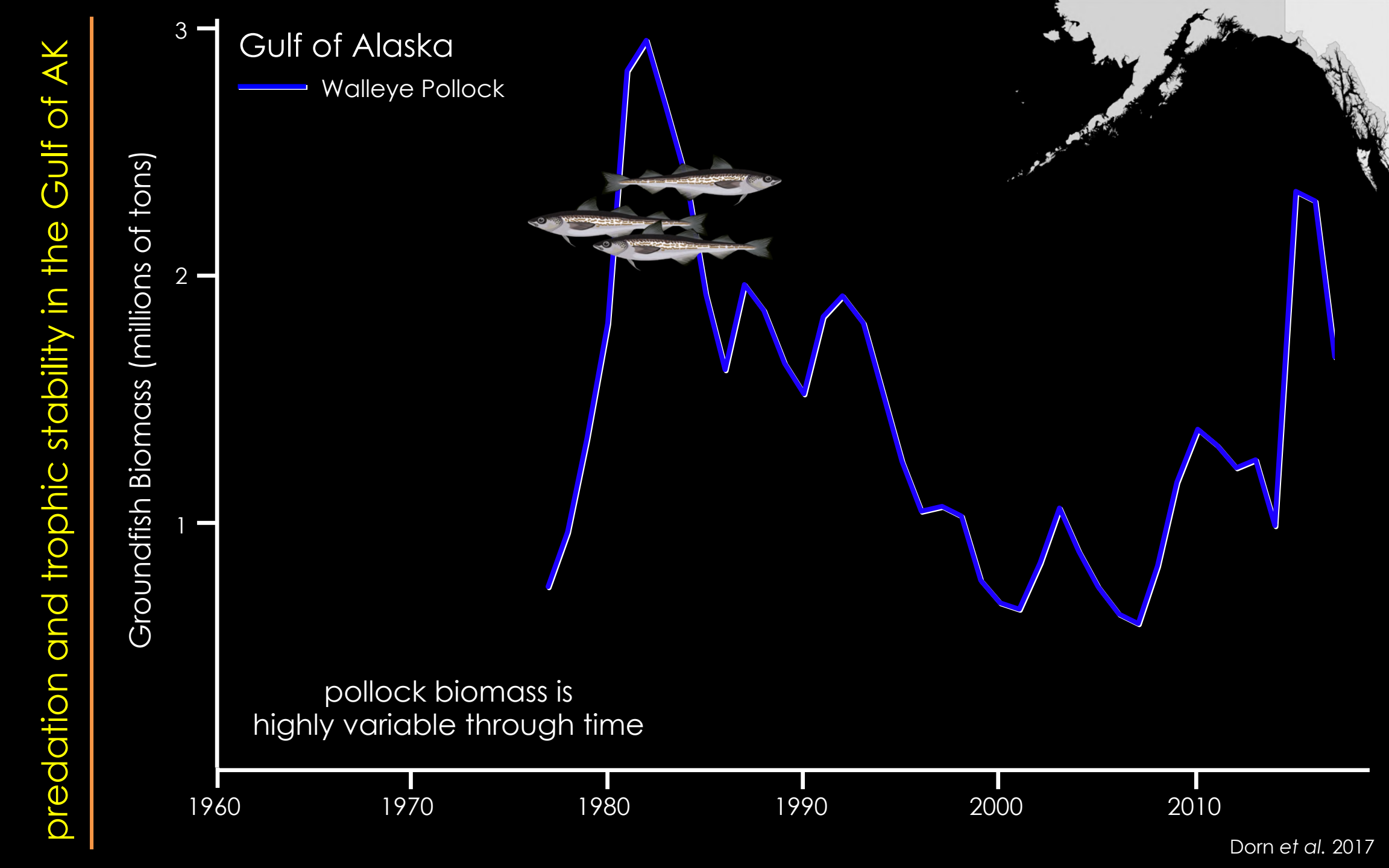
Gadus chalcogrammus



static sources of predation mortality

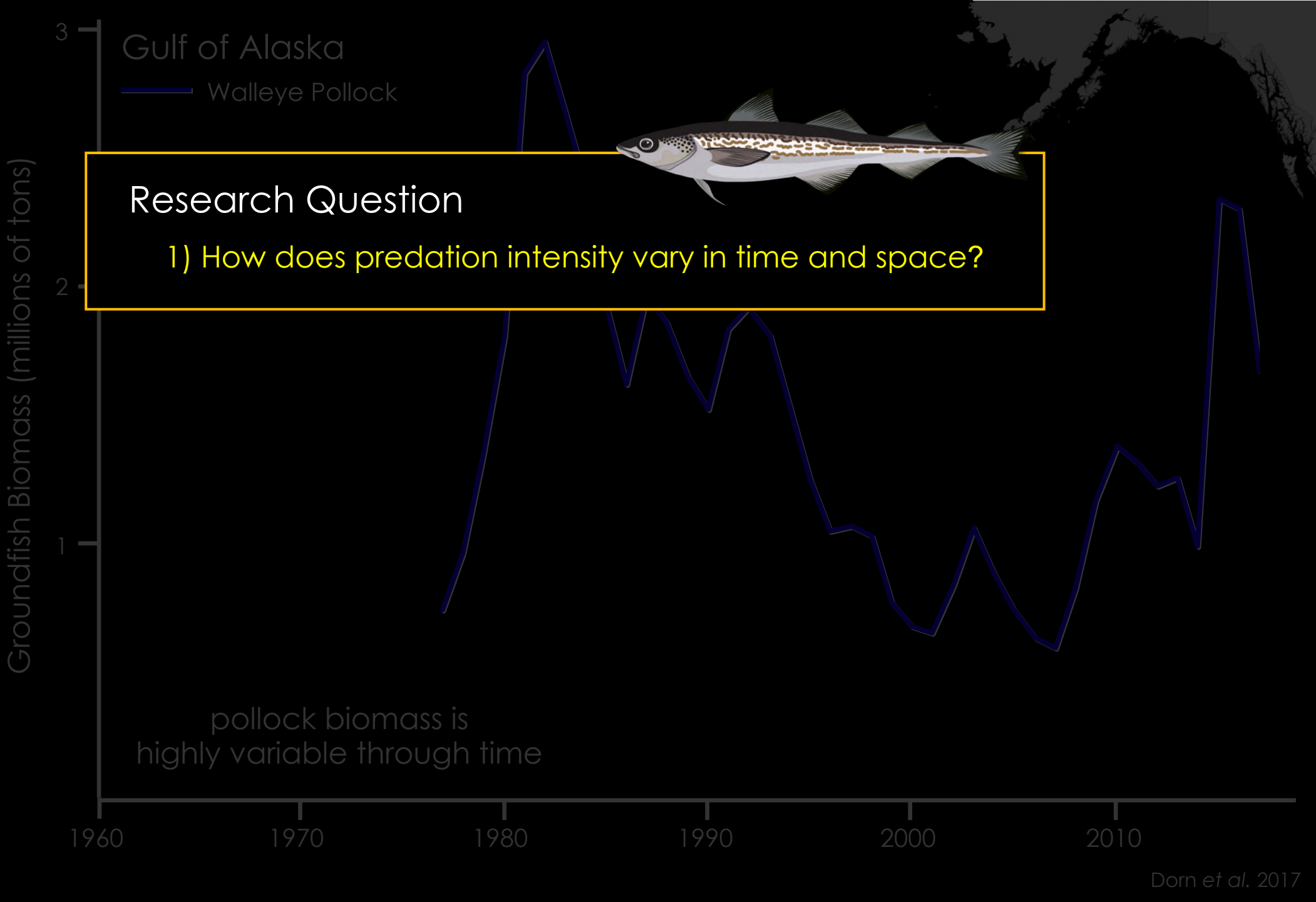
Gaichas *et al.* 2015 (Aydin *et al.* 2007)

predation and trophic stability in the Gulf of AK



Dorn *et al.* 2017

predation and trophic stability in the Gulf of AK

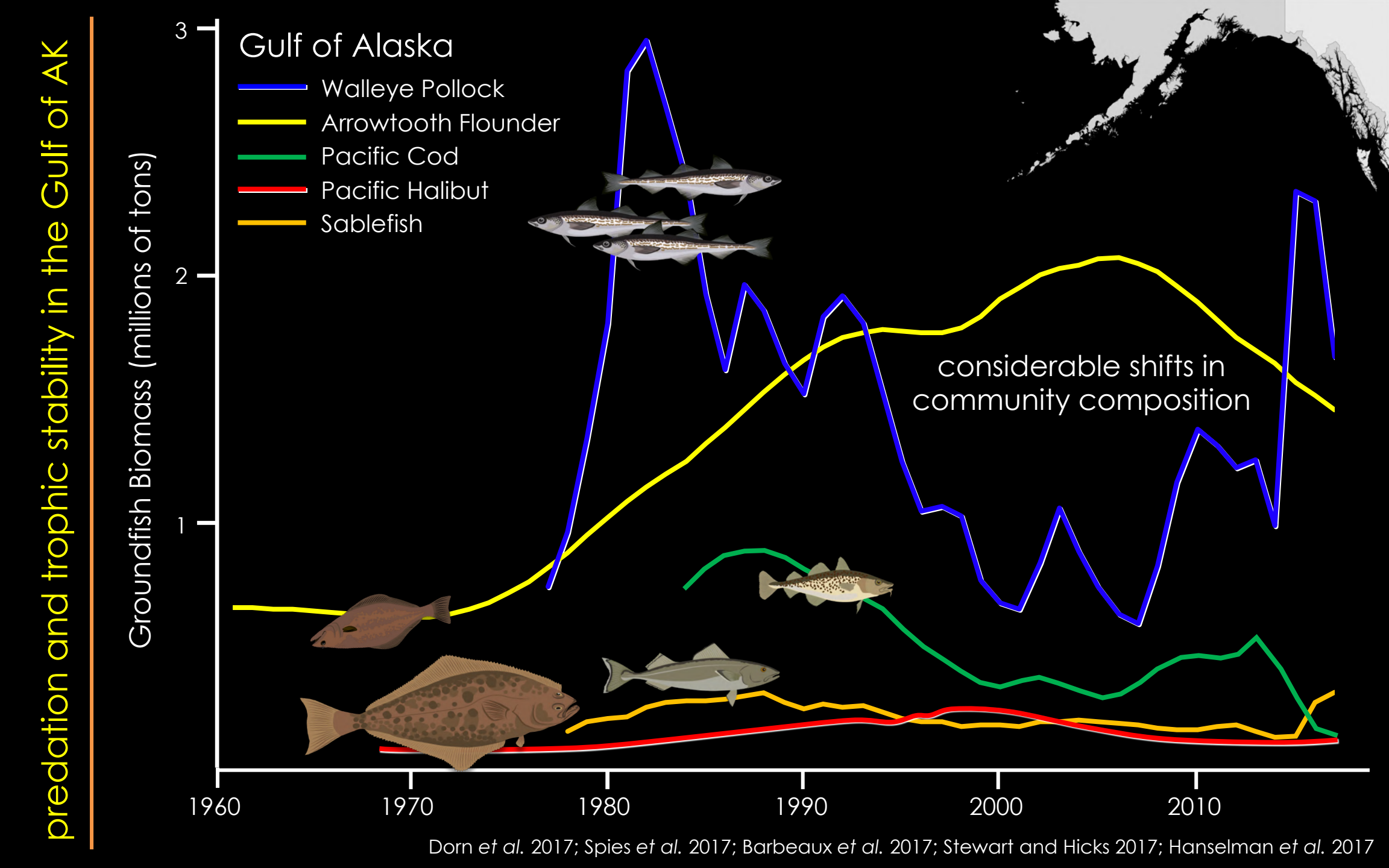


Research Question

1) How does predation intensity vary in time and space?

Dorn *et al.* 2017

predation and trophic stability in the Gulf of AK



Dorn *et al.* 2017; Spies *et al.* 2017; Barbeaux *et al.* 2017; Stewart and Hicks 2017; Hanselman *et al.* 2017

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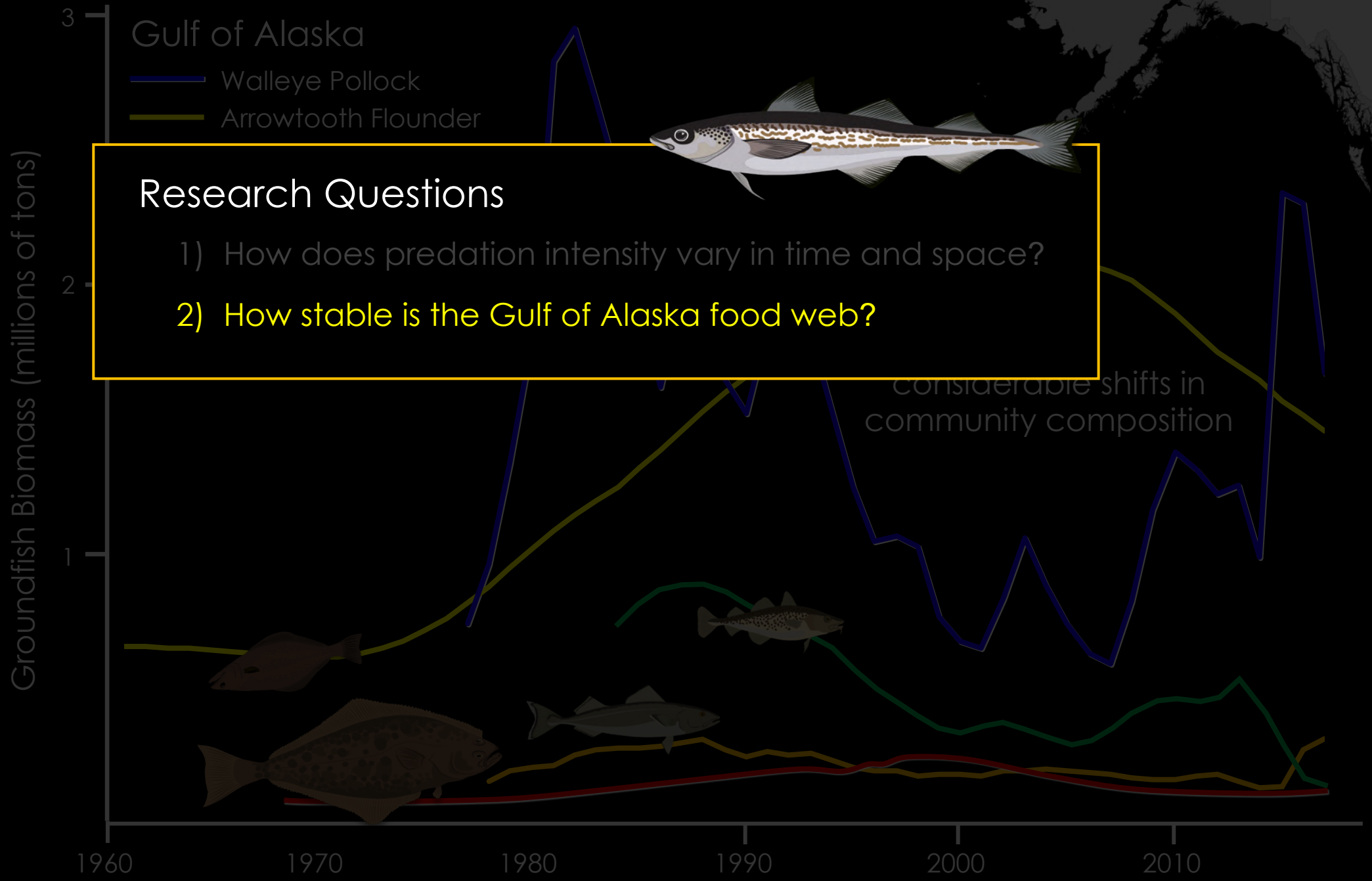
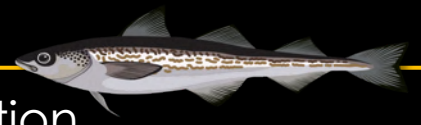


Research Questions

1) How does predation intensity vary in time and space?
2) How stable is the Gulf of Alaska food web?

Dorn *et al.* 2017; Spies *et al.* 2017; Barbeaux *et al.* 2017; Stewart and Hicks 2017; Hanselman *et al.* 2017

predation and trophic stability in the Gulf of AK



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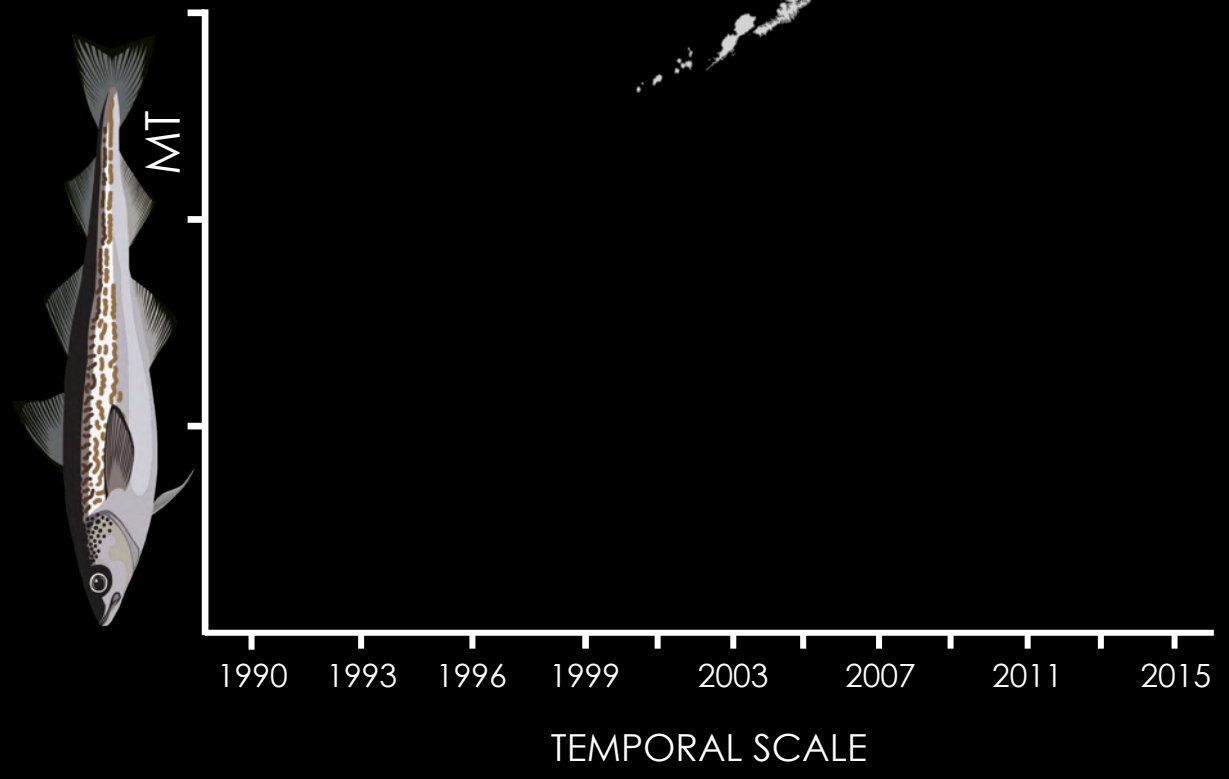
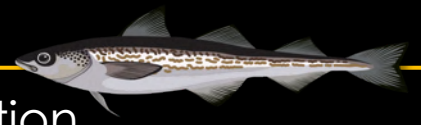
MULTIPLE SPATIAL SCALES



predation and trophic stability in the Gulf of AK



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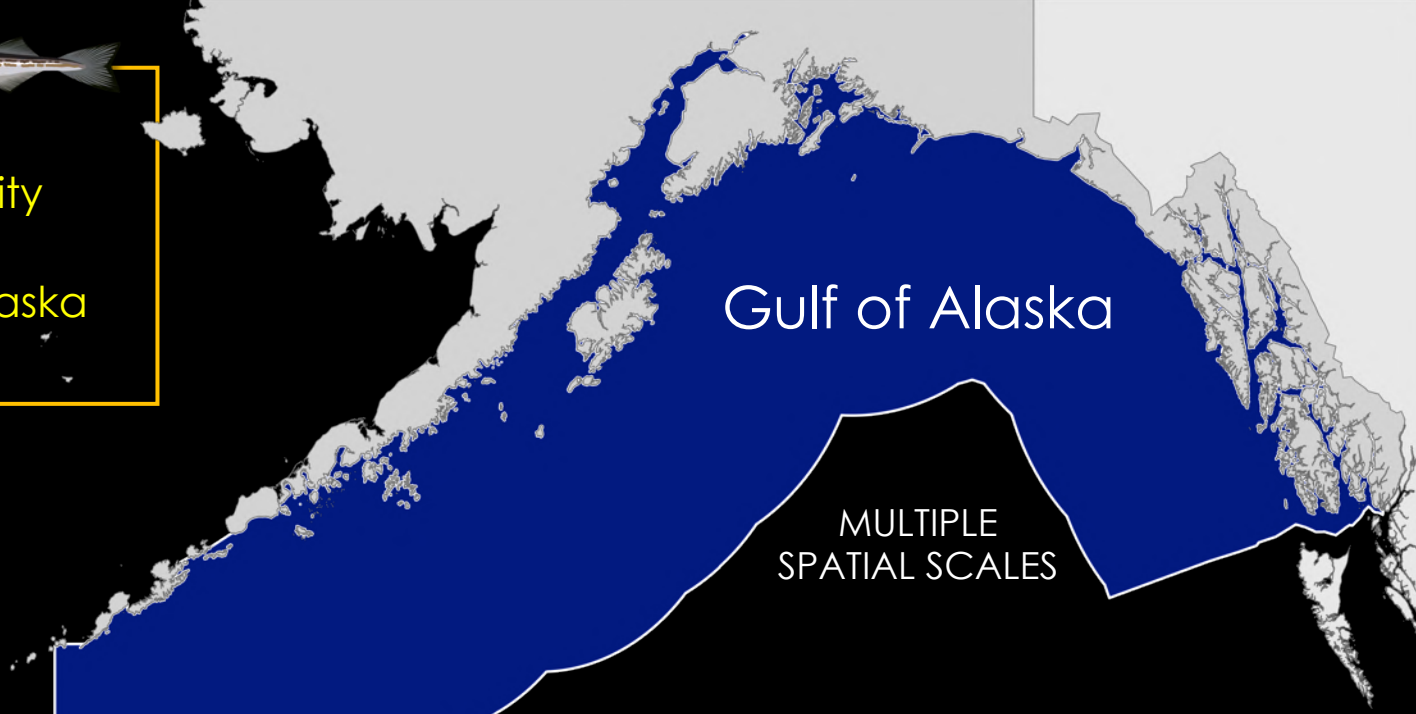
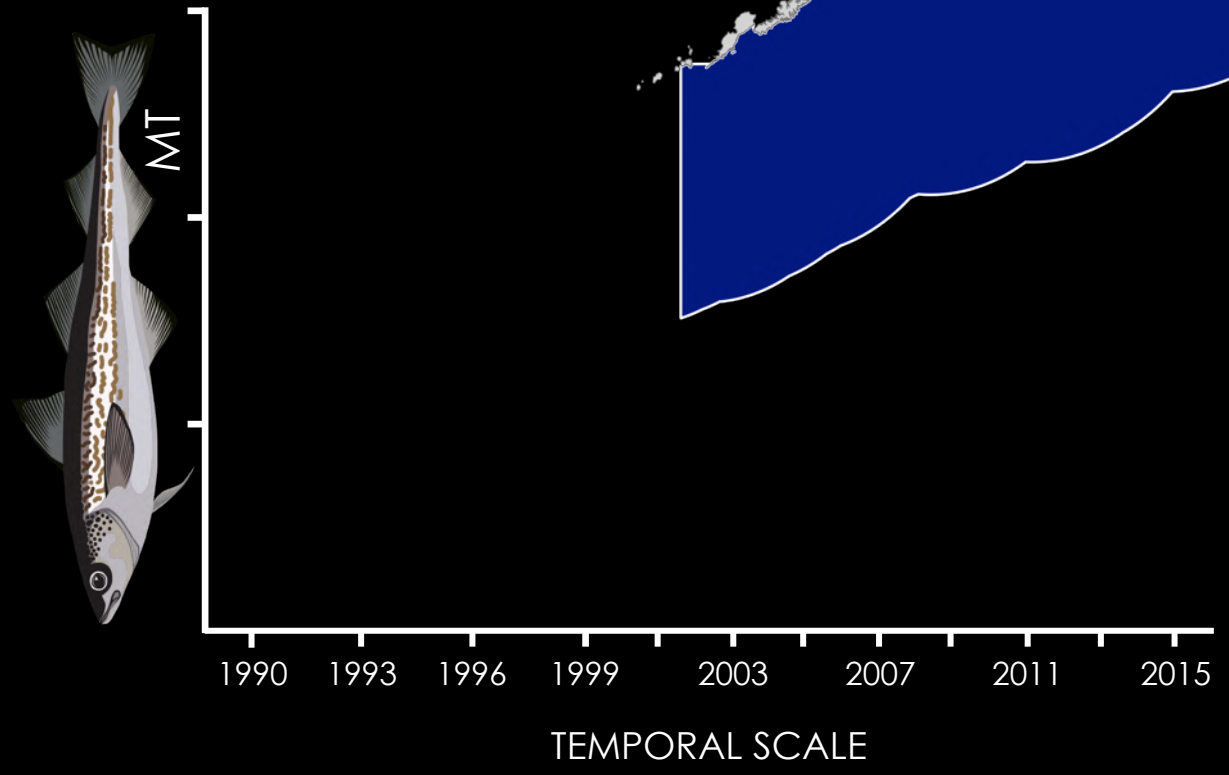
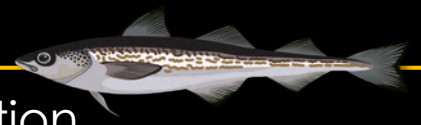




predation and trophic stability in the Gulf of AK



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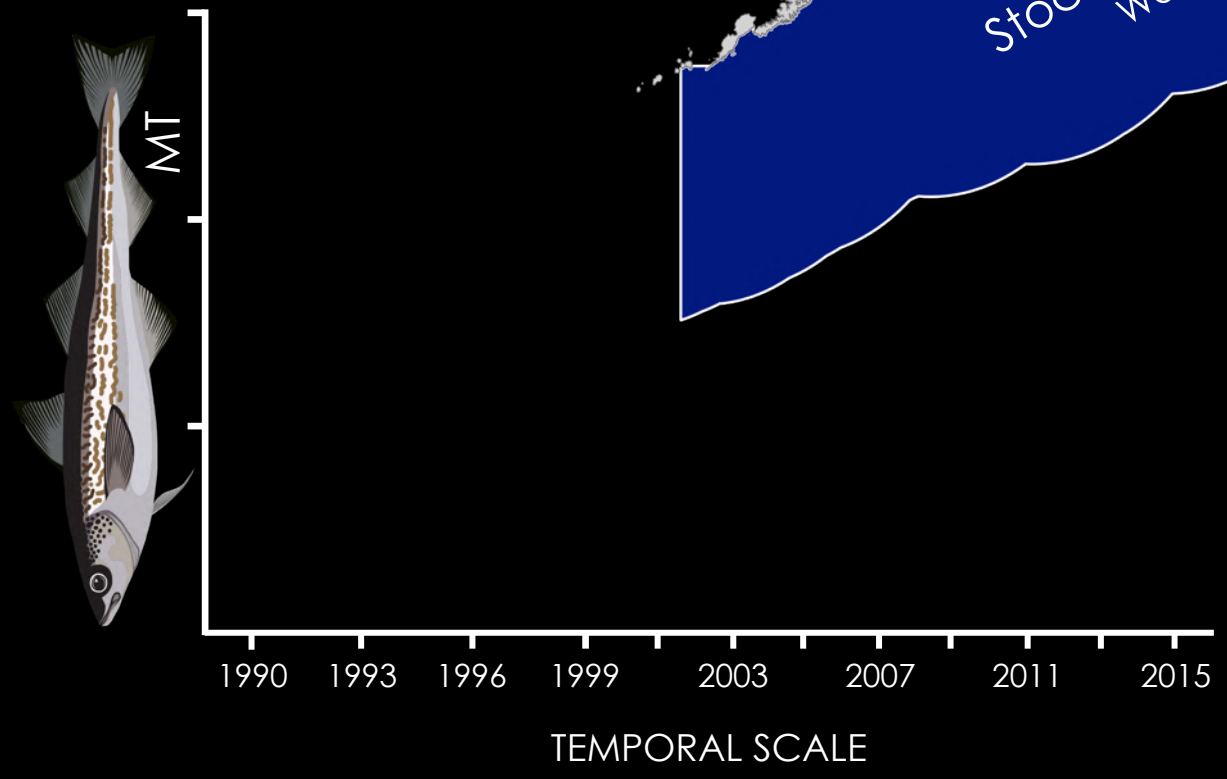

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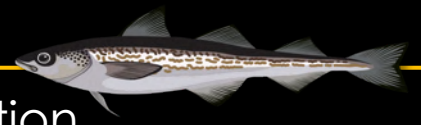

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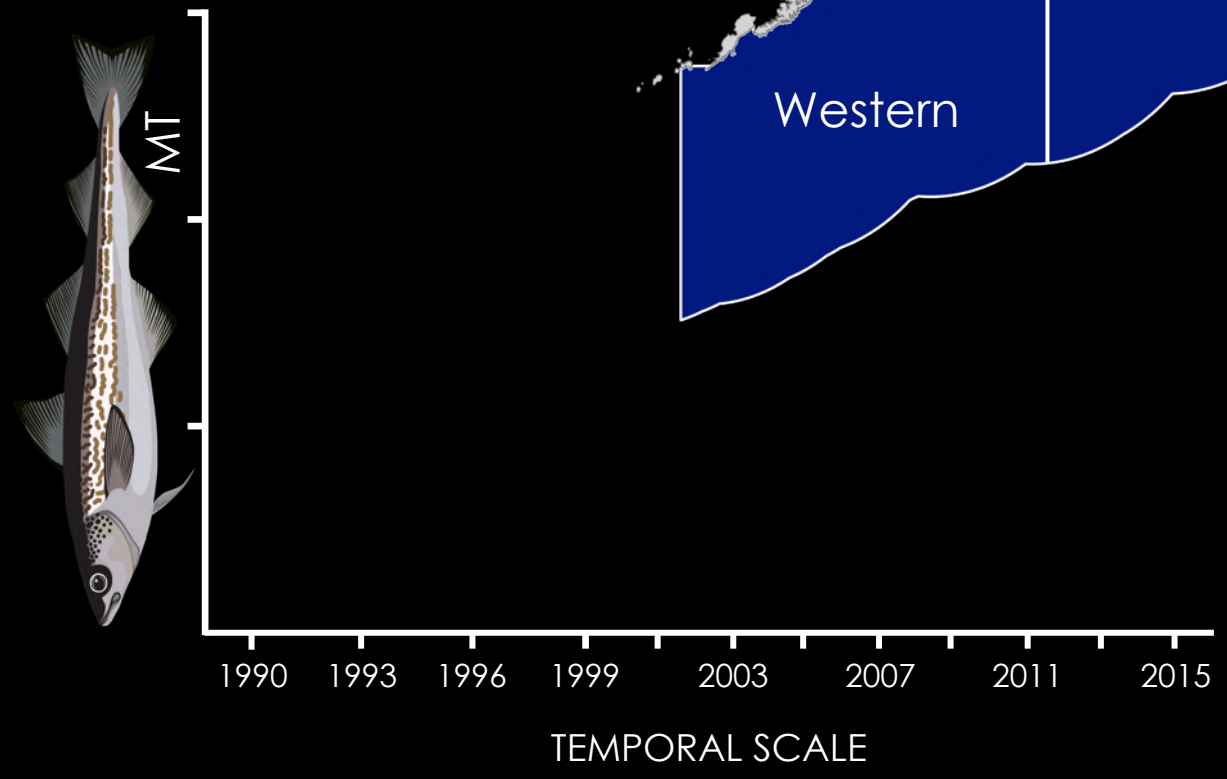

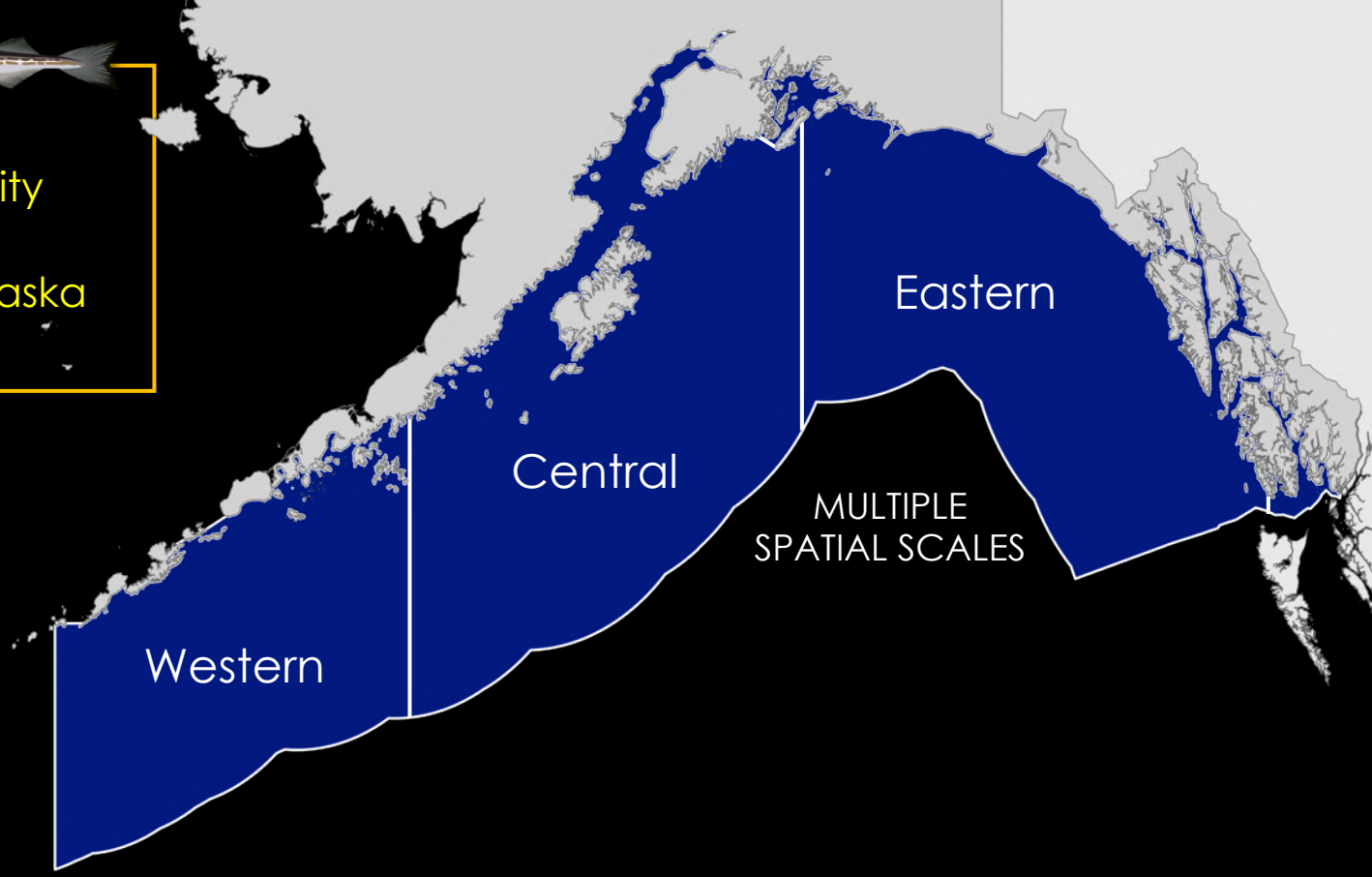

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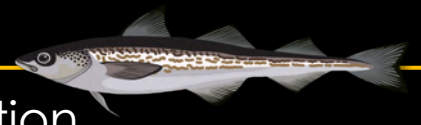

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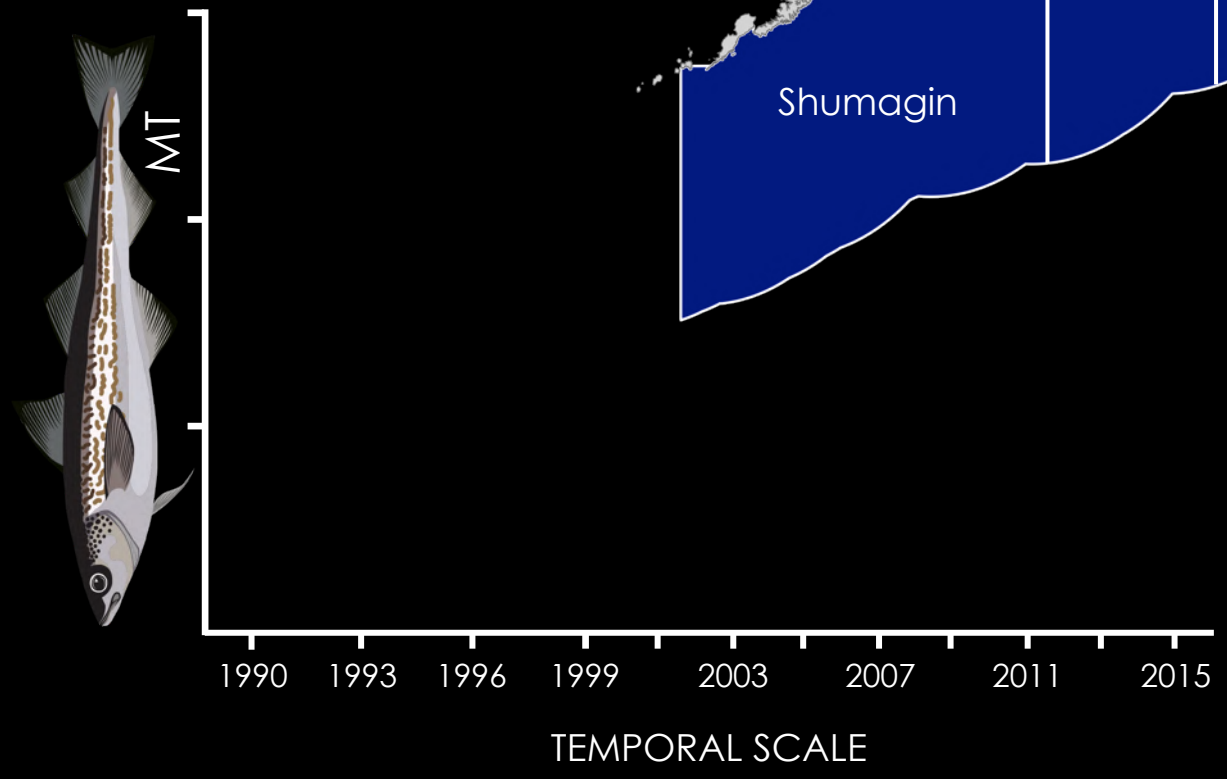

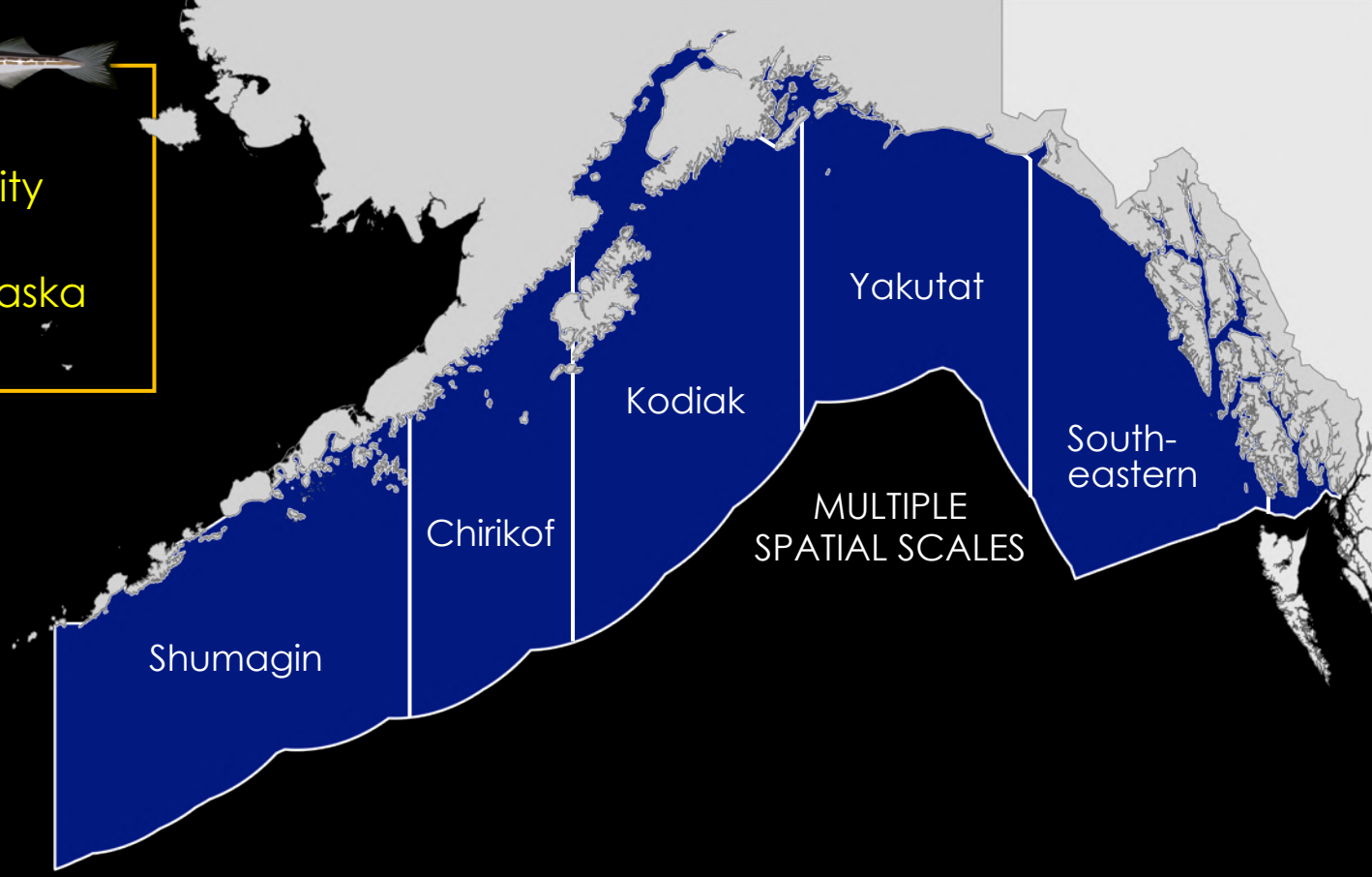

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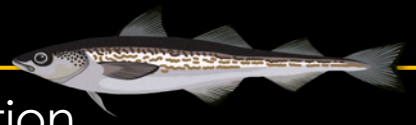

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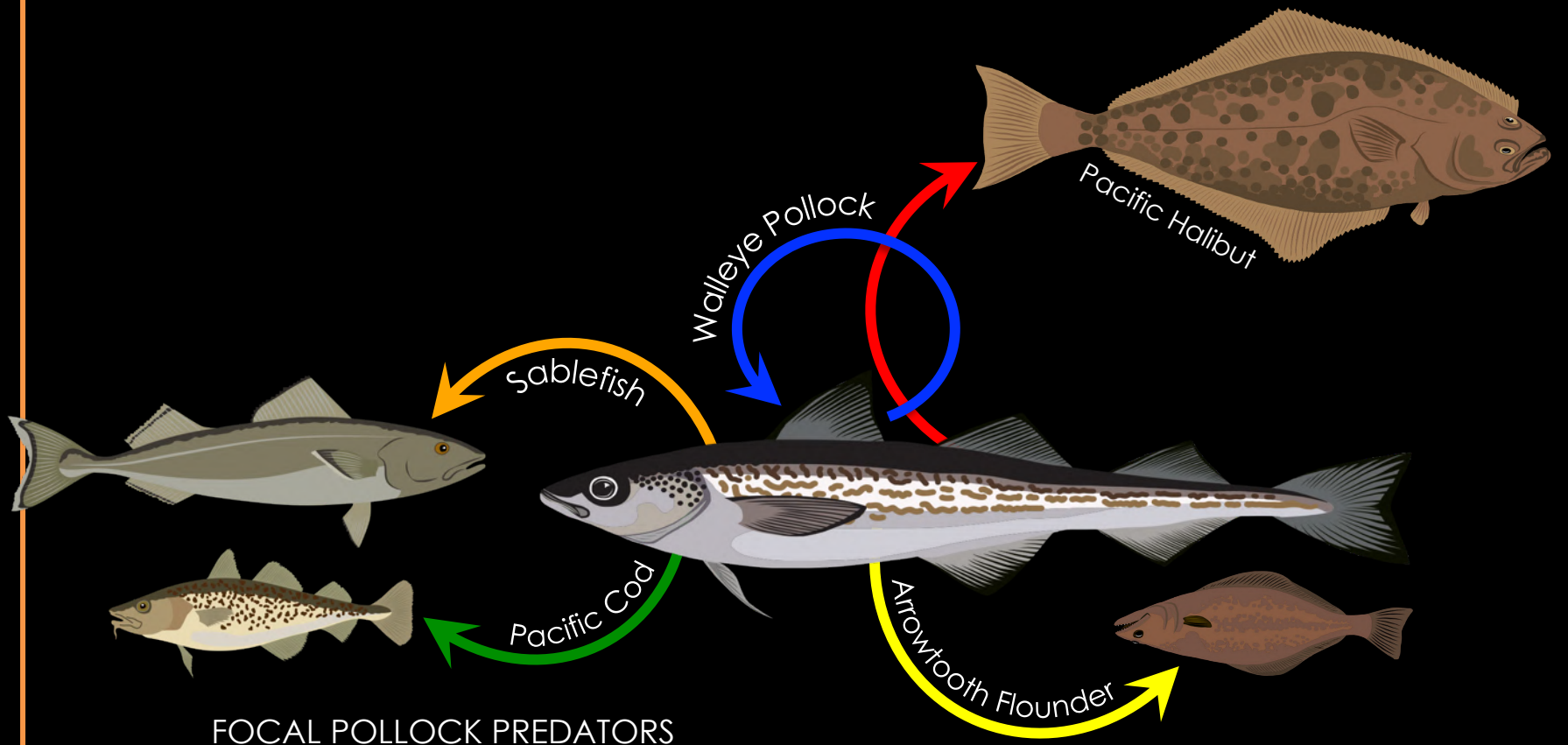

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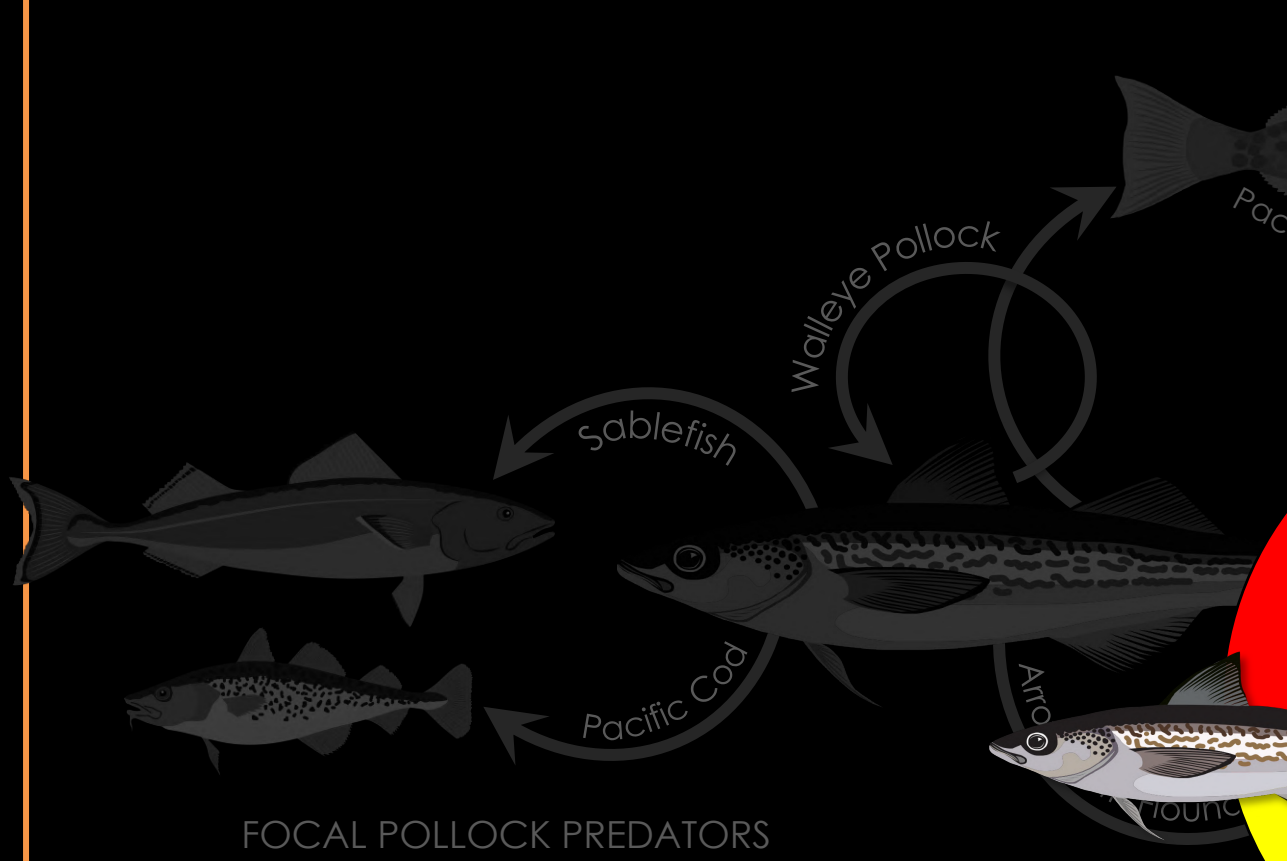

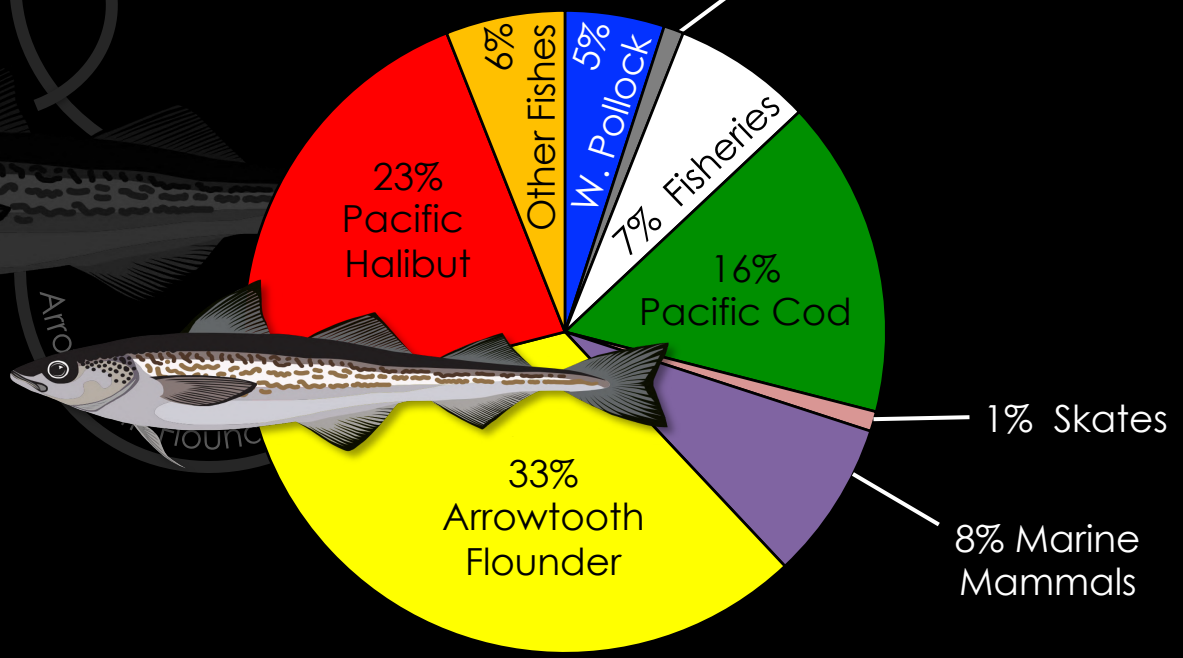

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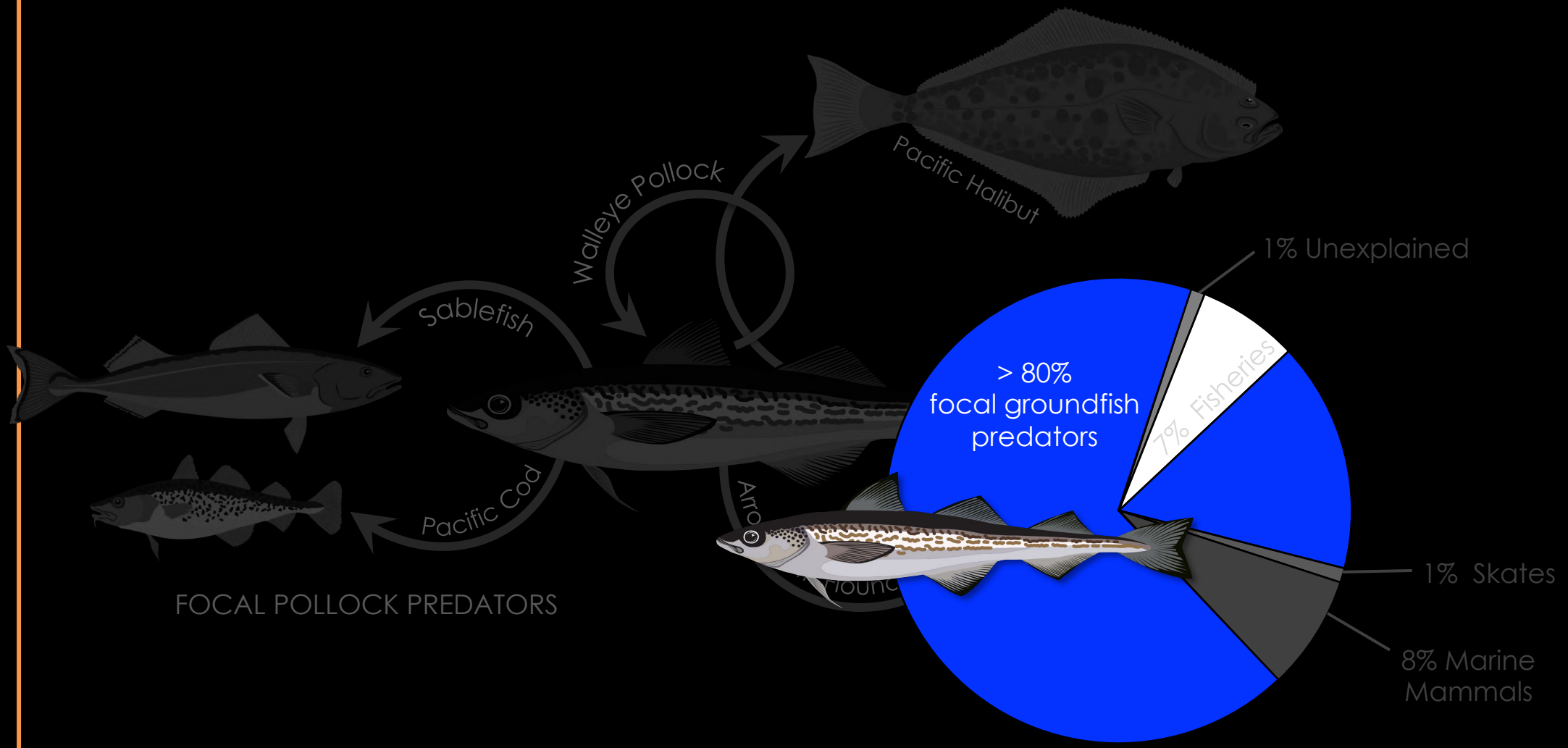
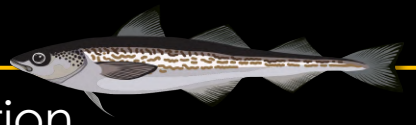


predation and trophic stability in the Gulf of AK



Research Question

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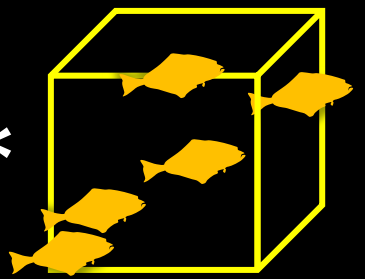
$$P_{s,a,i,j} = B_{s,i} * rD_{s,i,j} * \bar{C}_{s,i,j} * p_{s,i,j} * a_{s,i}$$

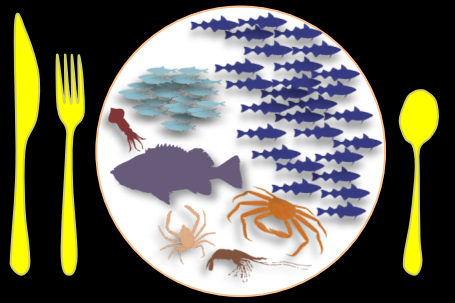
total predator biomass, $B_{s,i}$

*



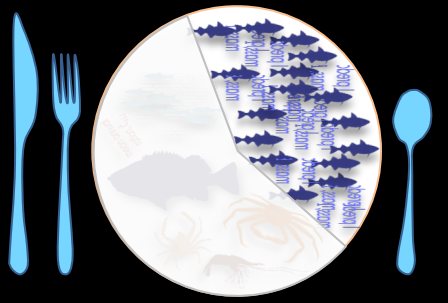
relative predator density, $rD_{s,i,j}$

*



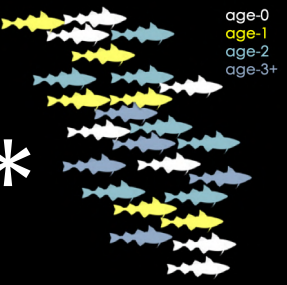
mean annual ration, $\bar{C}_{s,i,j}$

*



proportions pollock consumed, $p_{s,i,j}$

*



ages pollock consumed, $a_{s,i}$

COMPONENTS OF THE PREDATION INDEX

predation and trophic stability in the Gulf of AK

Research Question

1) How does predation intensity vary in time and space?
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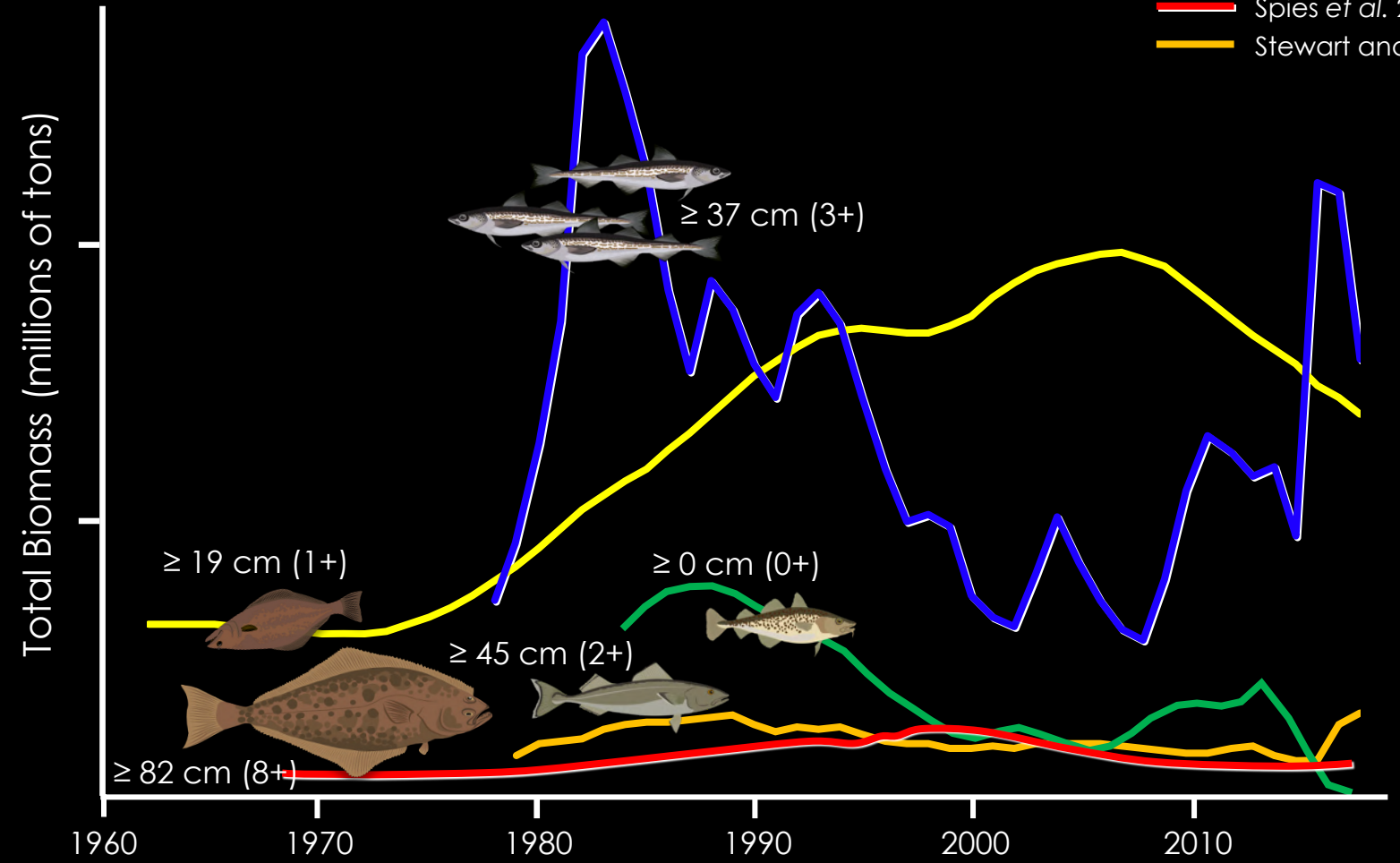
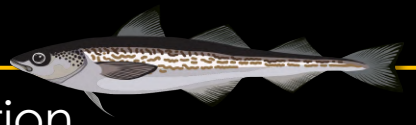
$$P_{s,a,i,j} = B_{s,i} * rD_{s,i,j} * \bar{C}_{s,i,j} * p_{s,i,j} * a_{s,i}$$



STOCK ASSESSMENTS

- Barbeaux *et al.* 2017
- Dorn *et al.* 2017
- Hanselman *et al.* 2017
- Spies *et al.* 2017
- Stewart and Hicks 2017

predation and trophic stability in the Gulf of AK



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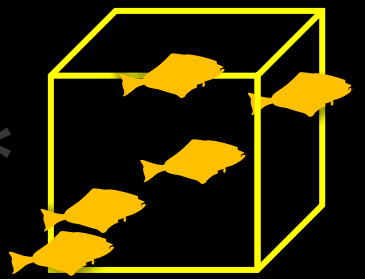
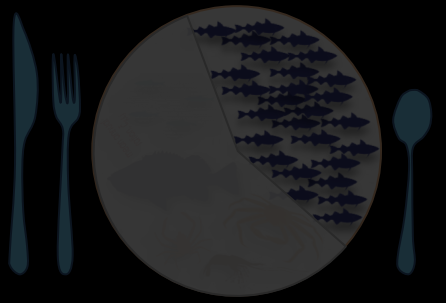
total predator biomass, $B_{s,i}$

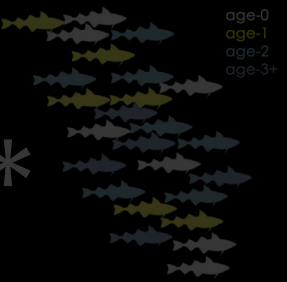


relative predator density, $rD_{s,i,j}$

mean annual ration, $\bar{C}_{s,i,j}$



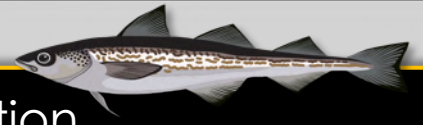
proportions pollock consumed, $p_{s,i,j}$



ages pollock consumed, $a_{s,i}$

COMPONENTS OF THE PREDATION INDEX

predation and trophic stability in the Gulf of AK



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$$log(\mu_{h,s}) = y_i + f_1(\emptyset_h, \lambda_h) + f_2(z_h) + f_3(T_h)$$
$$E(p_{h,s}) = \mu_{h,s}, p_{h,s} \sim B(1, \mu_{h,s}), var(p_{h,s}) \sim \mu_{h,s}(1 - \mu_{h,s})$$

$$x_{h,s} = y_i + f_1(\emptyset_h, \lambda_h) + f_2(z_h) + f_3(T_h) + \varepsilon_{h,s}$$

$rD_{s,i,j}^{*}$

δ GAMMs

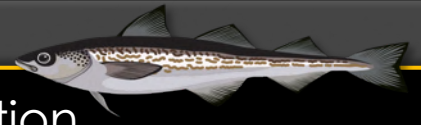
$D_{s,i,g}$

* Normalized
(all grid cells add to 1)

STANDARDIZED SURVEY DATA

- Resource Assessment and Conservation Engineering Division, AFSC
- International Pacific Halibut Commission
- Marine Ecology and Stock Assessment Program, AFSC

predation and trophic stability in the Gulf of AK



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predator biomass in area *j*

KG

$*$

$rD_{s,i,j}$

δ GAMMs

$\sum rD_{s,i,j}$

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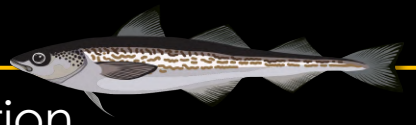

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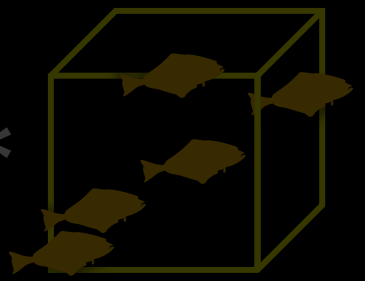
total predator biomass, $B_{s,i}$

*



relative predator density, $rD_{s,i,j}$

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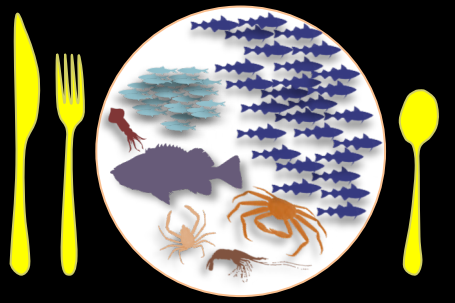

mean annual ration, $\bar{C}_{s,i,j}$

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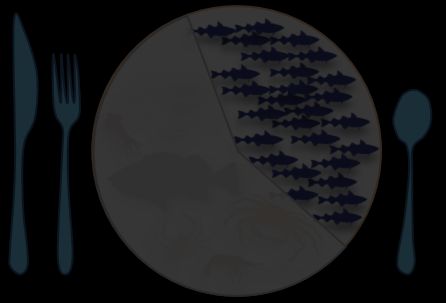
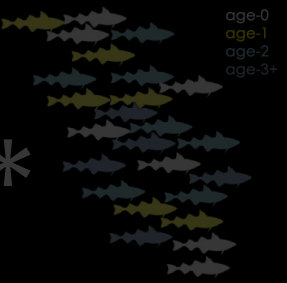


proportions pollock consumed, $p_{s,i,j}$

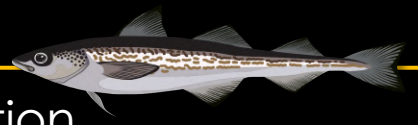
*



ages pollock consumed, $a_{s,i}$

COMPONENTS OF THE PREDATION INDEX

predation and trophic stability in the Gulf of AK



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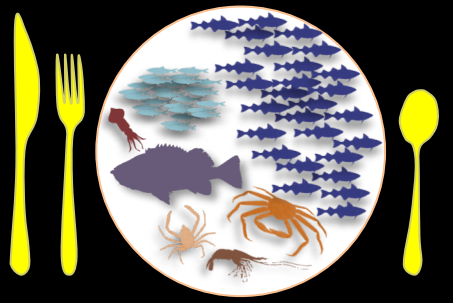


$$C_{max} = C_A * W^{C_B} * f(T)$$

ATF: Holsman and Aydin 2015
Fonds *et al.* 1992

PC: Holsman *et al.* (in prep)

PH: Holsman *et al.* 2018
Hurst 2004; Paul *et al.* 1994

SBL: Harvey 2009

WEP: Holsman and Aydin 2015
Smith *et al.* 1986, 1988

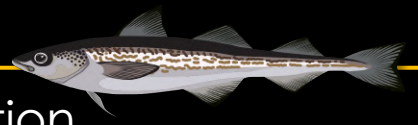
Wisconsin Bioenergetics Models ^
Maximum Daily Consumption ($g^{-1}g^{-1}d^{-1}$)

FOOD HABITS DATA

- Resource Ecology and Ecosystem Modeling Program, AFSC

^ Kitchell *et al.* 1977
Deslauriers *et al.* 2017

predation and trophic stability in the Gulf of AK



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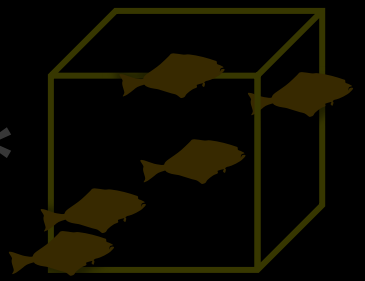

relative predator density, $rD_{s,i,j}$

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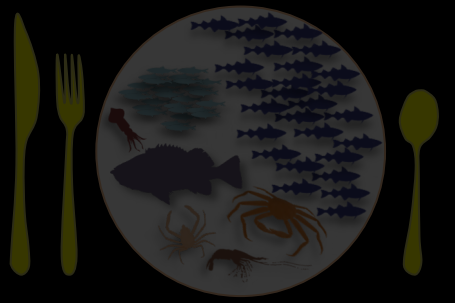

mean annual ration, $\bar{C}_{s,i,j}$

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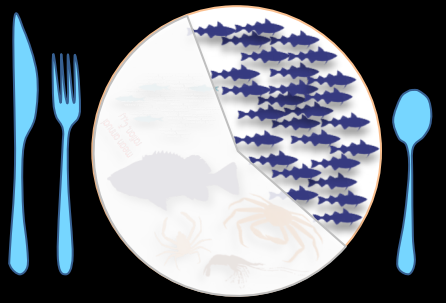


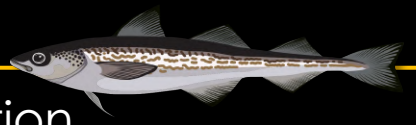
proportions pollock consumed, $p_{s,i,j}$

*

ages pollock consumed, $a_{s,i}$

COMPONENTS OF THE PREDATION INDEX

predation and trophic stability in the Gulf of AK



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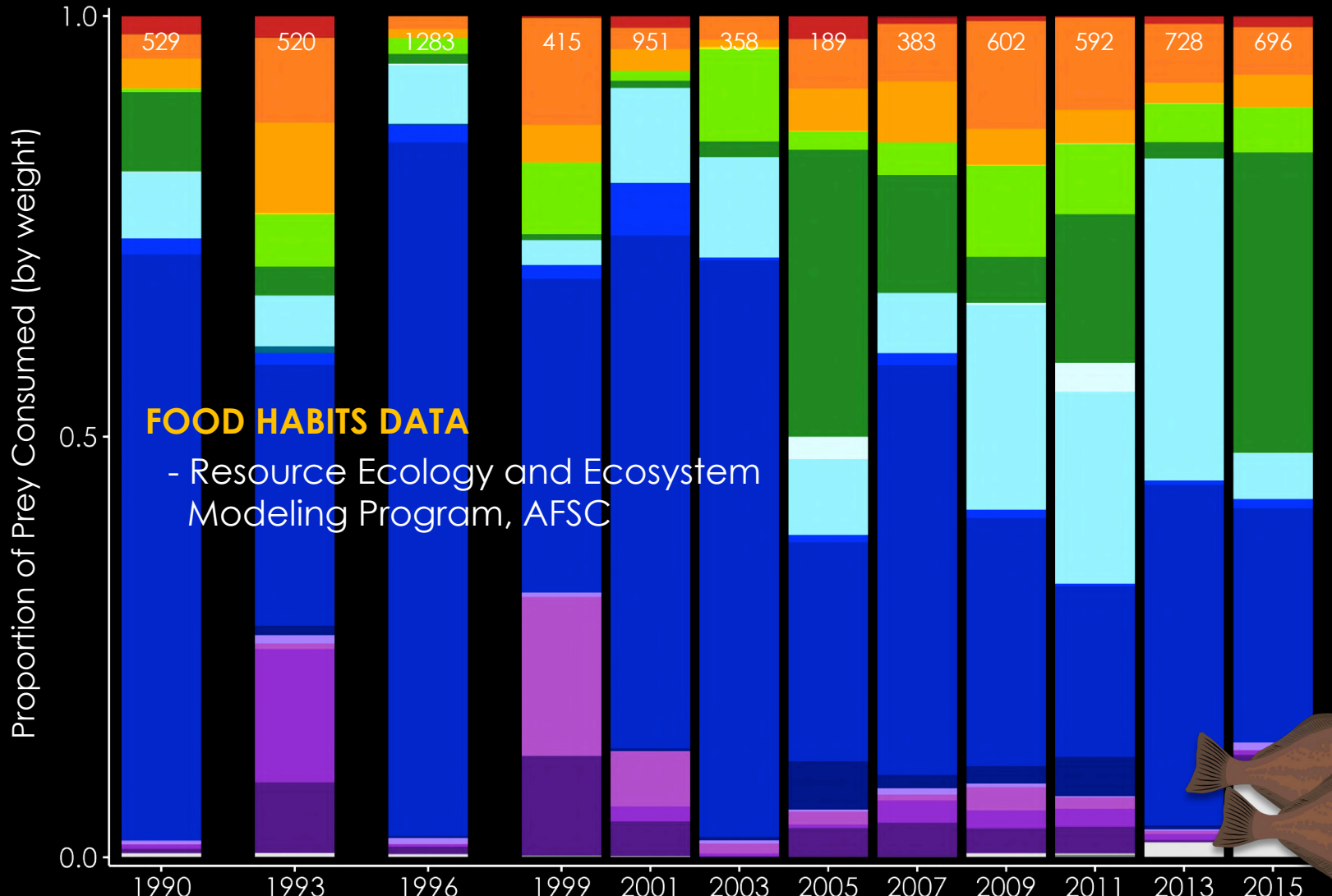

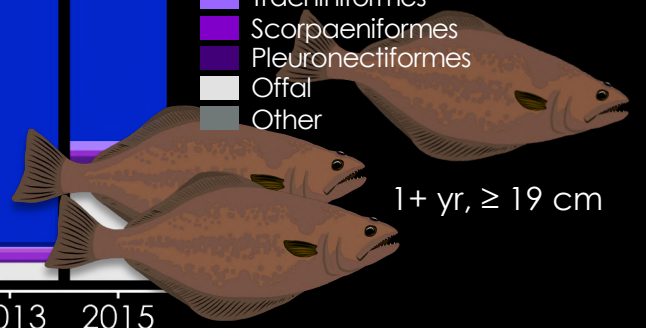

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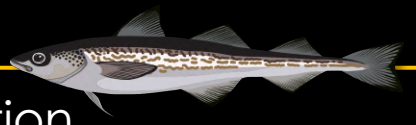

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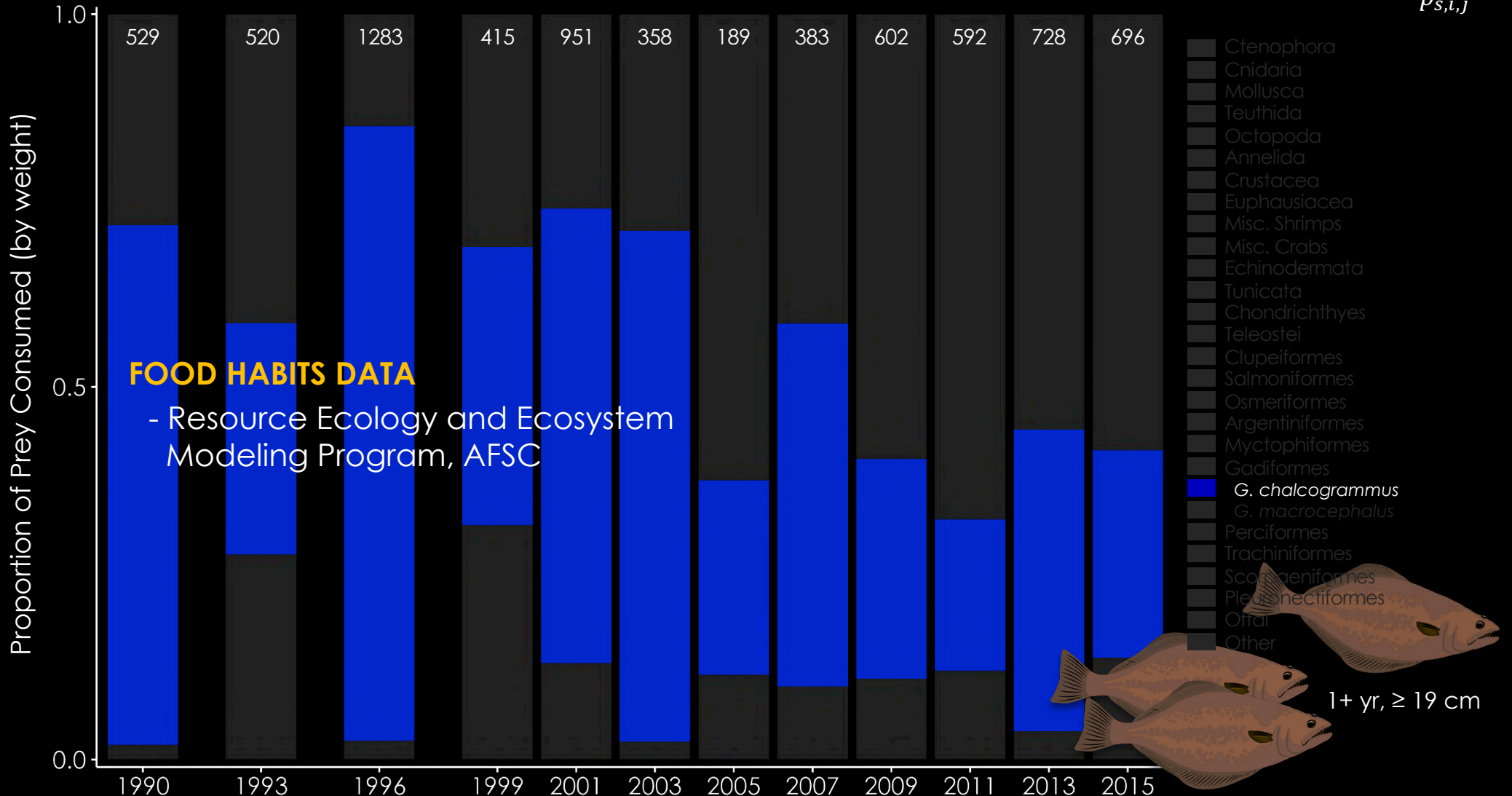

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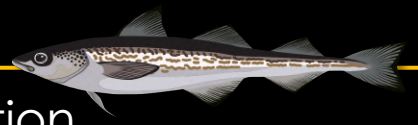

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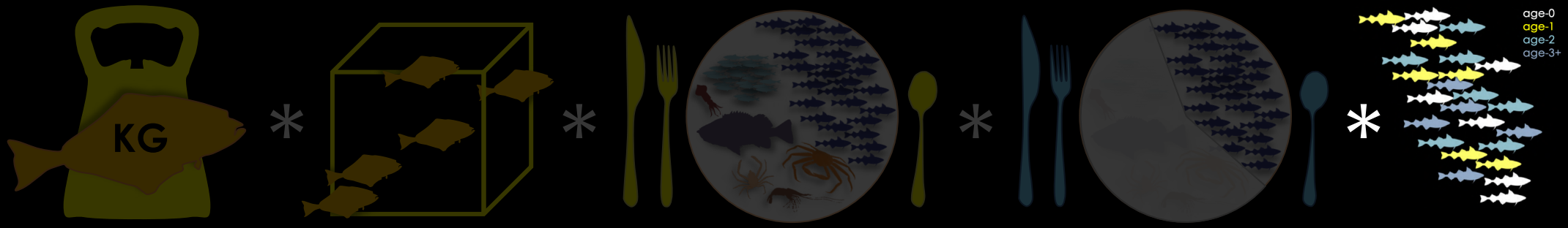
$$P_{s,a,i,j} = B_{s,i} * rD_{s,i,j} * \bar{C}_{s,i,j} * p_{s,i,j} * a_{s,i}$$



total predator biomass, $B_{s,i}$

relative predator density, $rD_{s,i,j}$

mean annual ration, $\bar{C}_{s,i,j}$

proportions pollock consumed, $p_{s,i,j}$

ages pollock consumed, $a_{s,i}$

STANDARDIZED SURVEY DATA

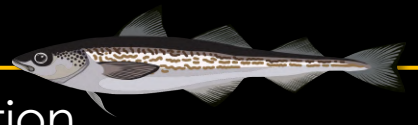
- Resource Assessment and Conservation Engineering Division, AFSC

FOOD HABITS DATA

- Resource Ecology and Ecosystem Modeling Program, AFSC

COMPONENTS OF THE PREDATION INDEX

predation and trophic stability in the Gulf of AK



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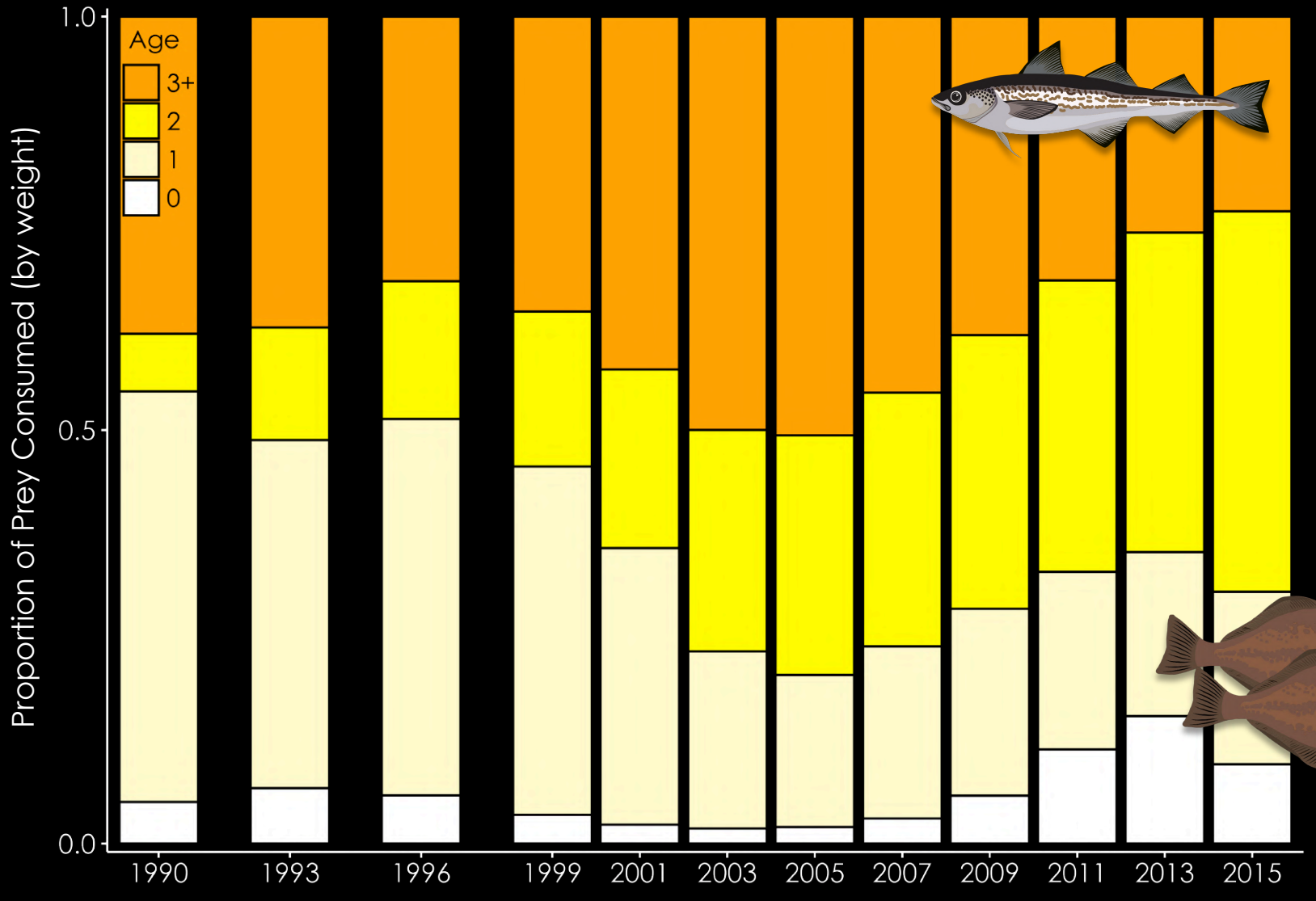
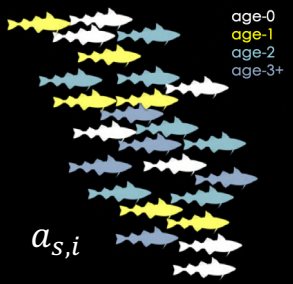
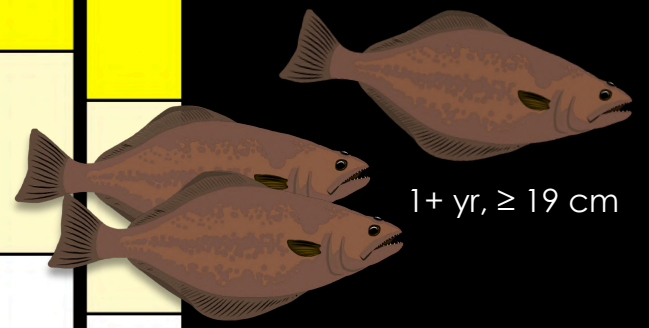


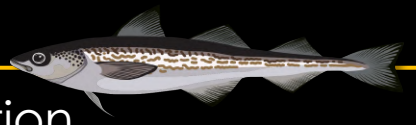
Multinomial Logistic GAMs





1+ yr, ≥ 19 cm

predation and trophic stability in the Gulf of AK



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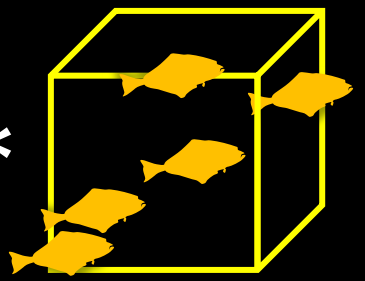
total predator biomass, $B_{s,i}$

*



relative predator density, $rD_{s,i,j}$

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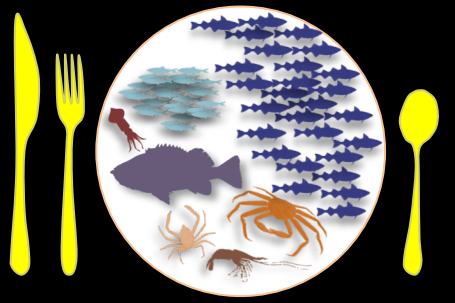
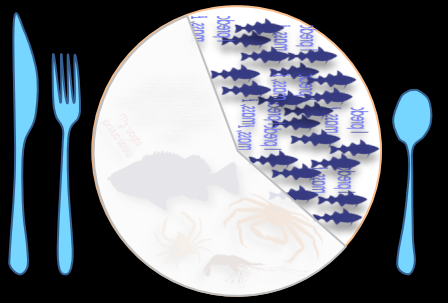


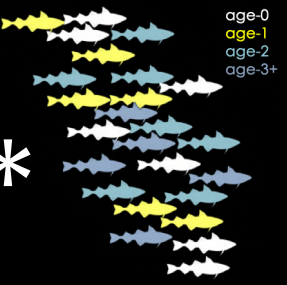
mean annual ration, $\bar{C}_{s,i,j}$

*



proportions pollock consumed, $p_{s,i,j}$

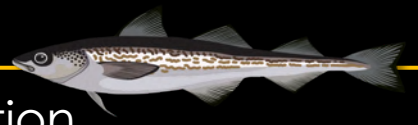
*



ages pollock consumed, $a_{s,i}$

PREDATOR-SPECIFIC CONSUMPTION

predation and trophic stability in the Gulf of AK



Research Question

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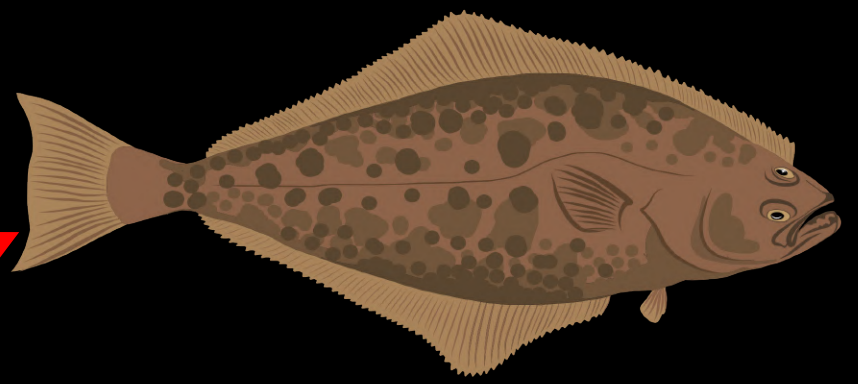
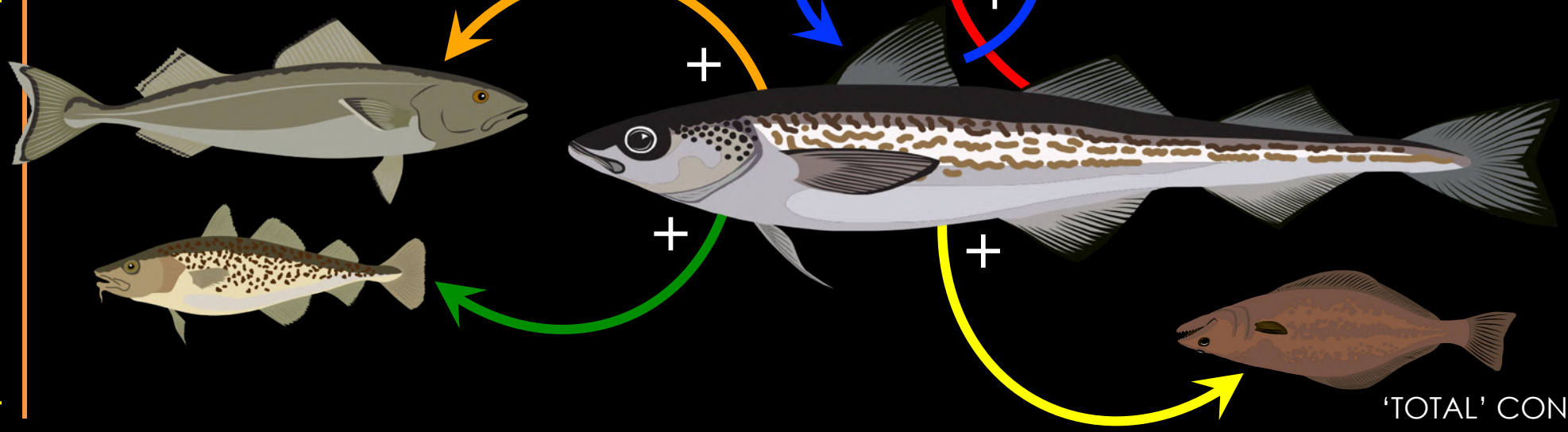
$$P_{s,a,i,j} = B_{s,i} * rD_{s,i,j} * \bar{C}_{s,i,j} * p_{s,i,j} * a_{s,i}$$

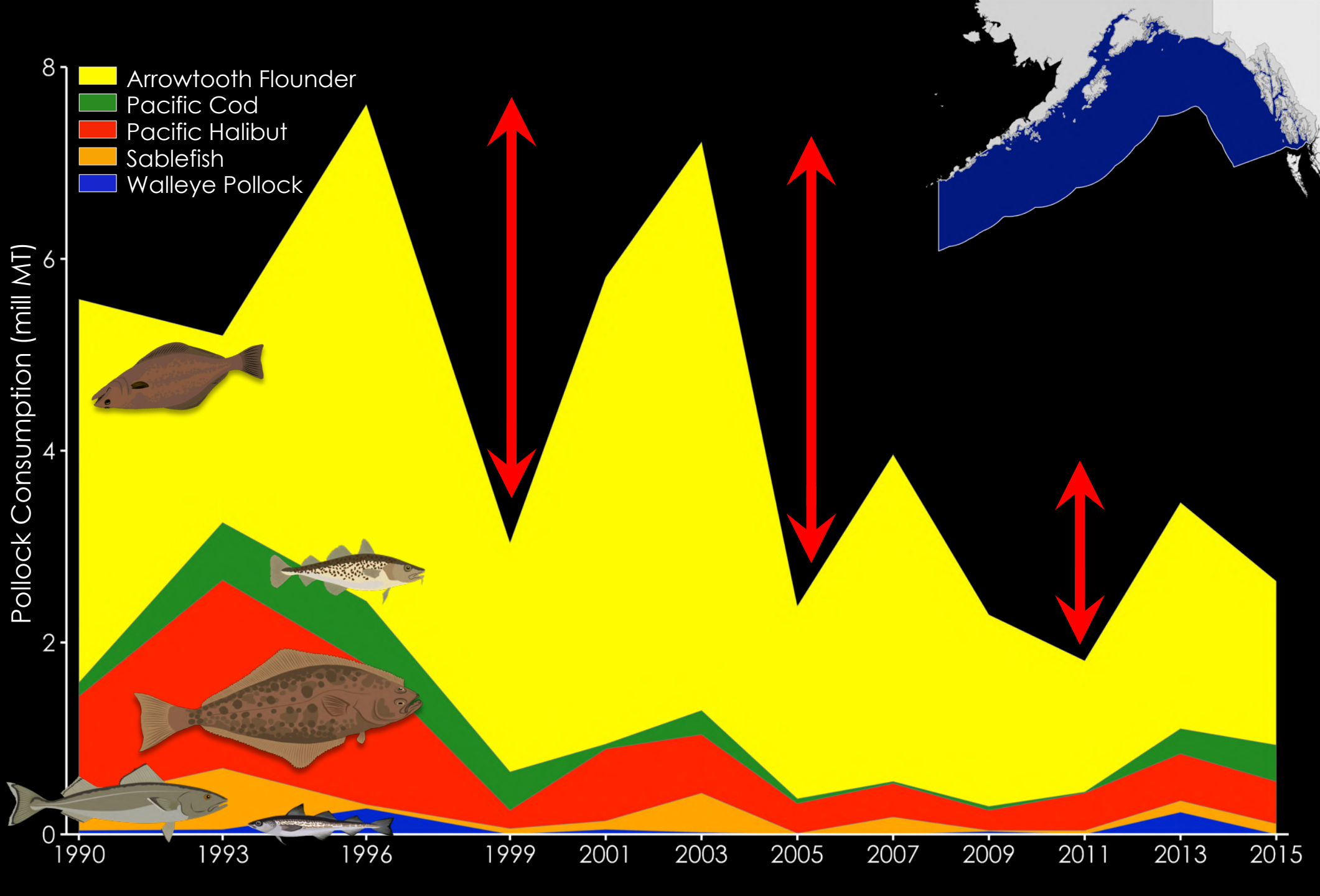
$$P_{a,i,j} = \sum_{s=1}^{S} P_{s,a,i,j}$$





'TOTAL' CONSUMPTION

predation and trophic stability in the Gulf of AK



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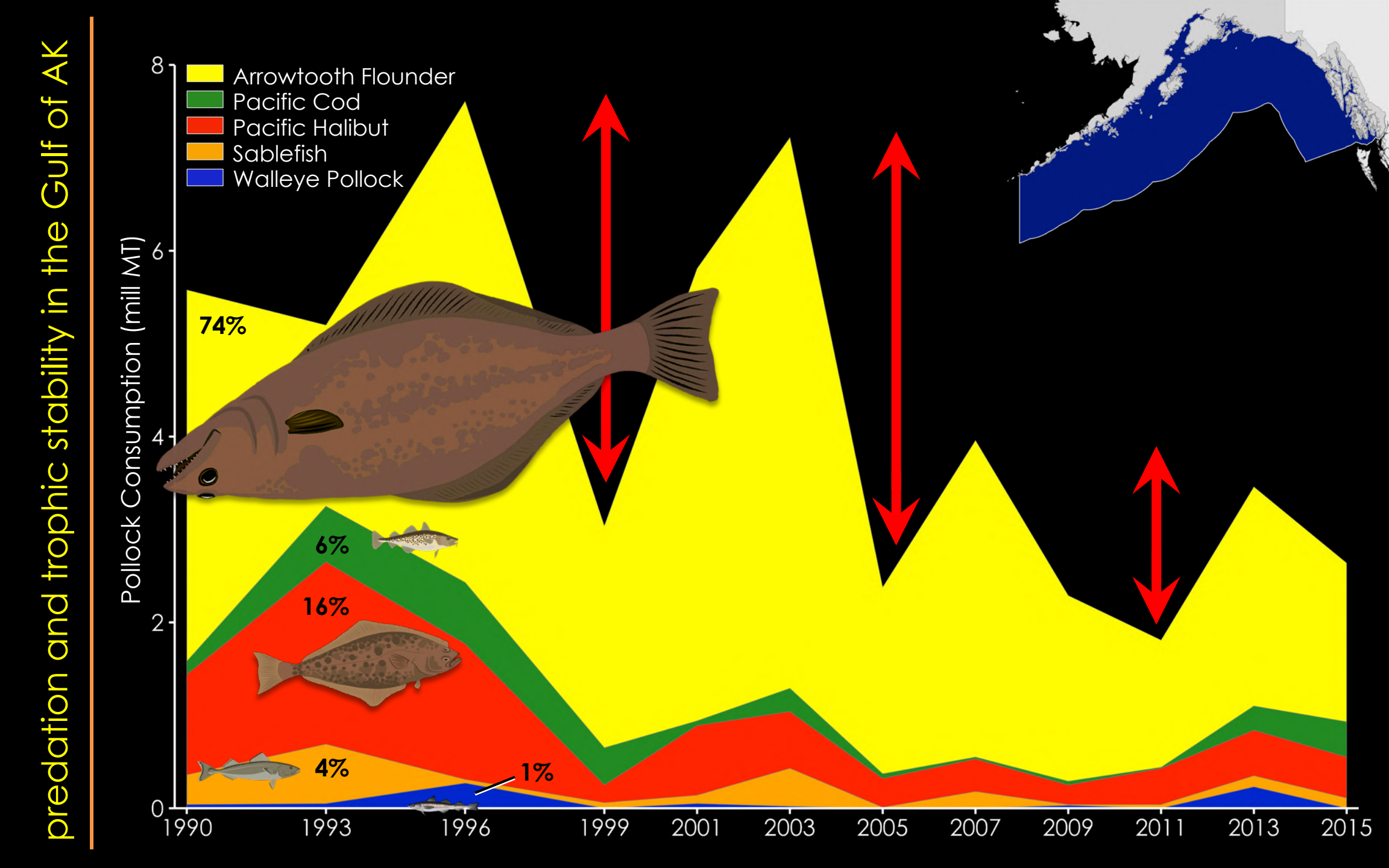

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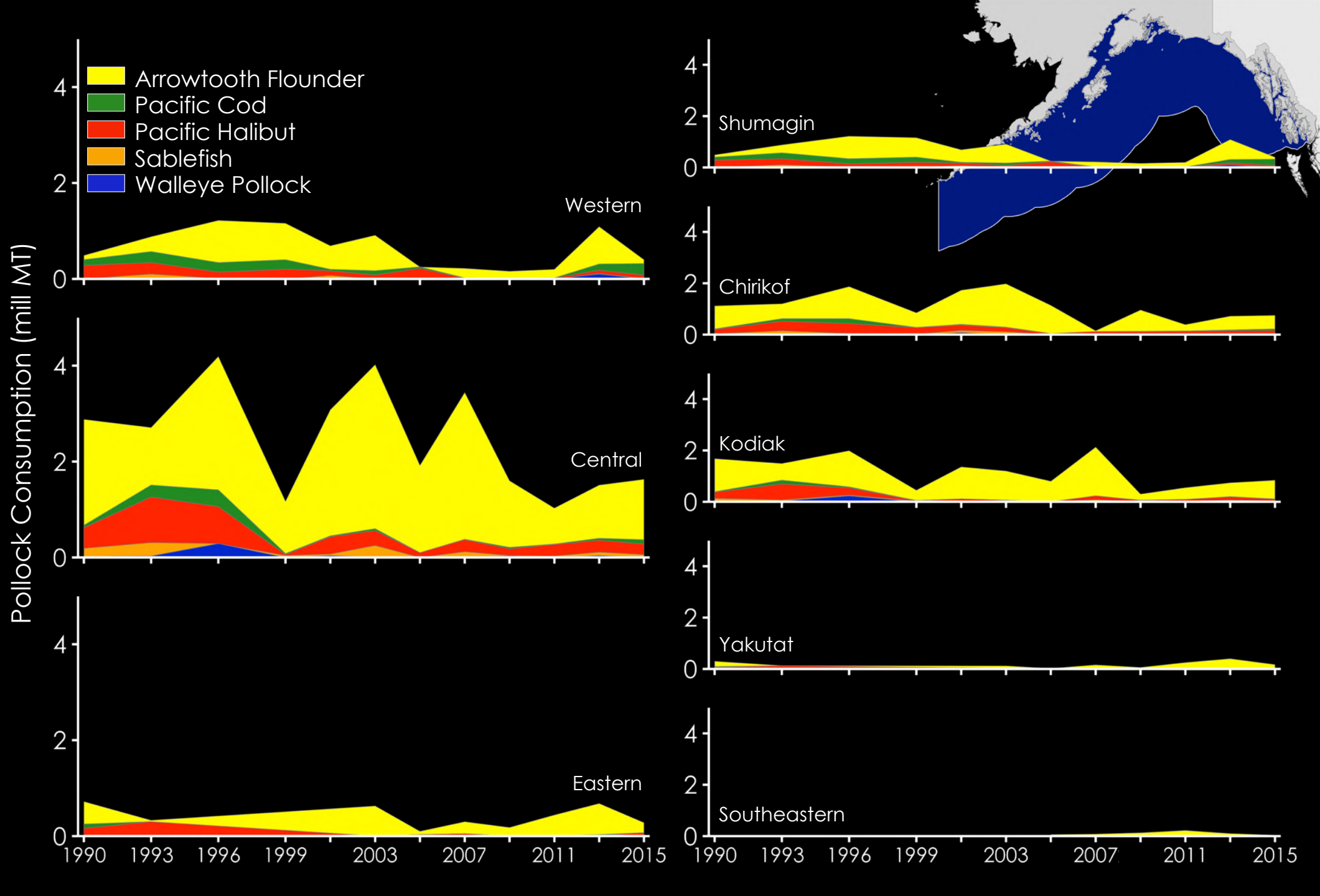

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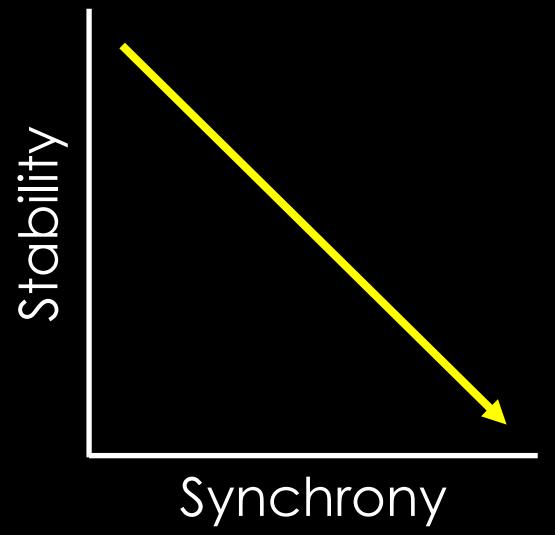

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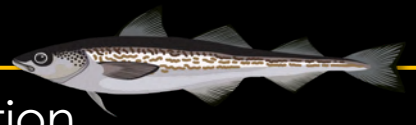

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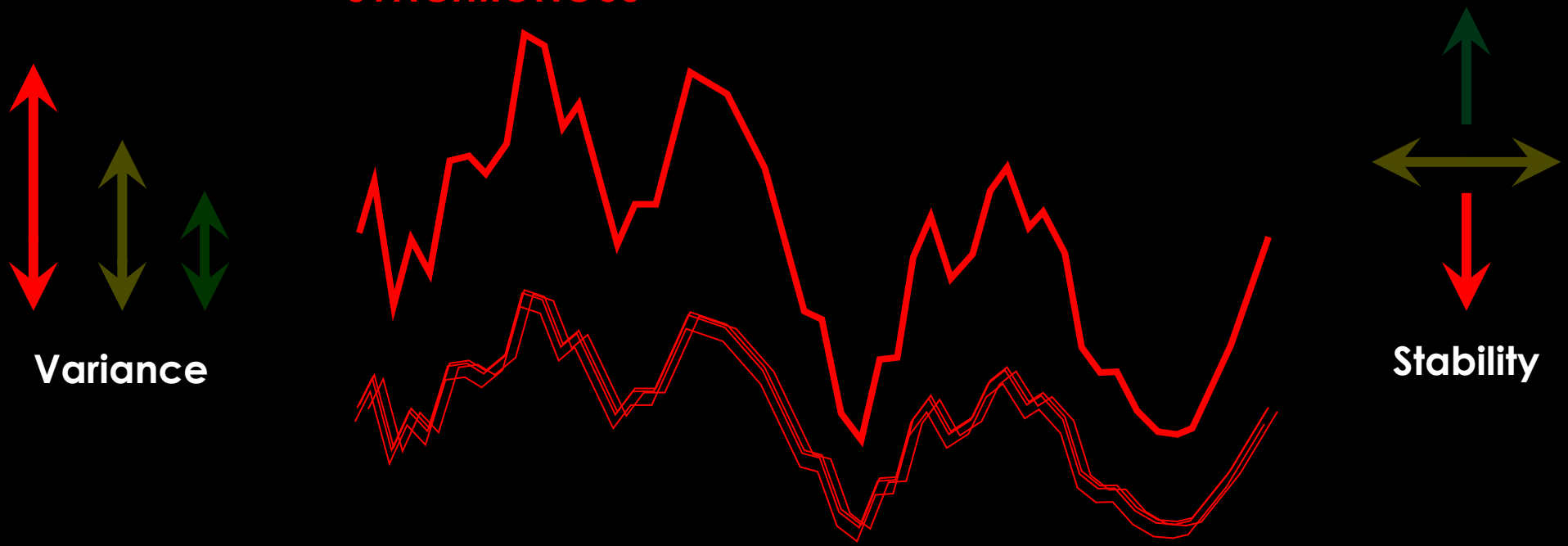
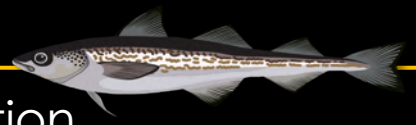


Adapted from Oken *et al.* 2018



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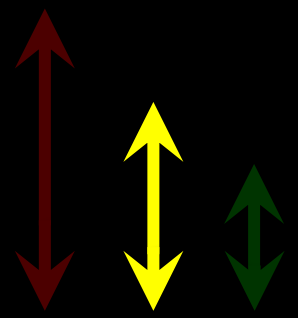
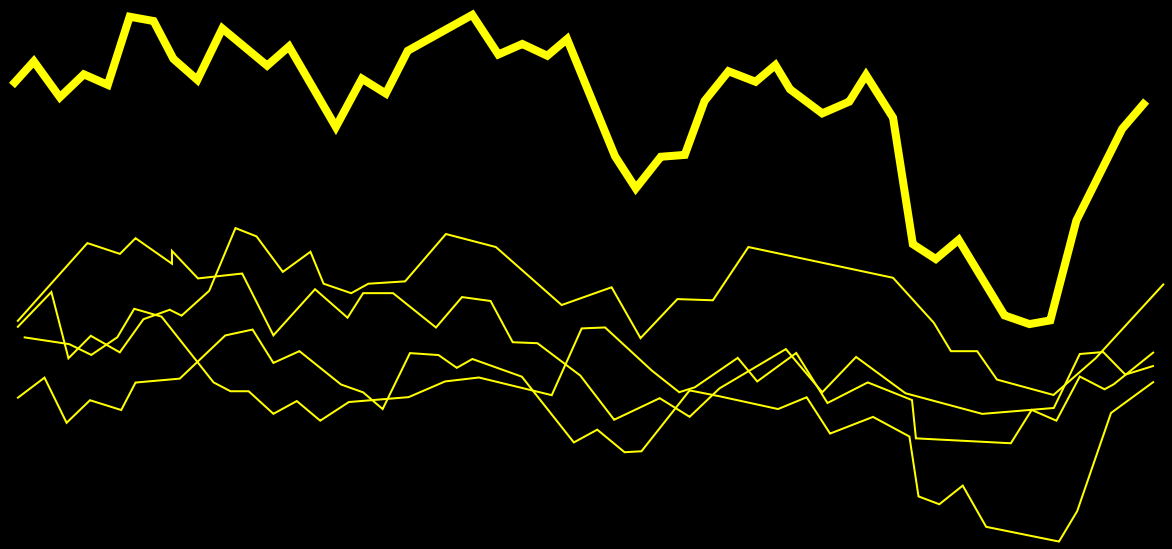
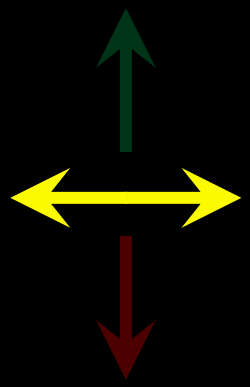
STATISTICALLY INDEPENDENT



Variance

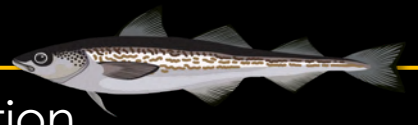




Stability

Adapted from Oken *et al.* 2018

predation and trophic stability in the Gulf of AK



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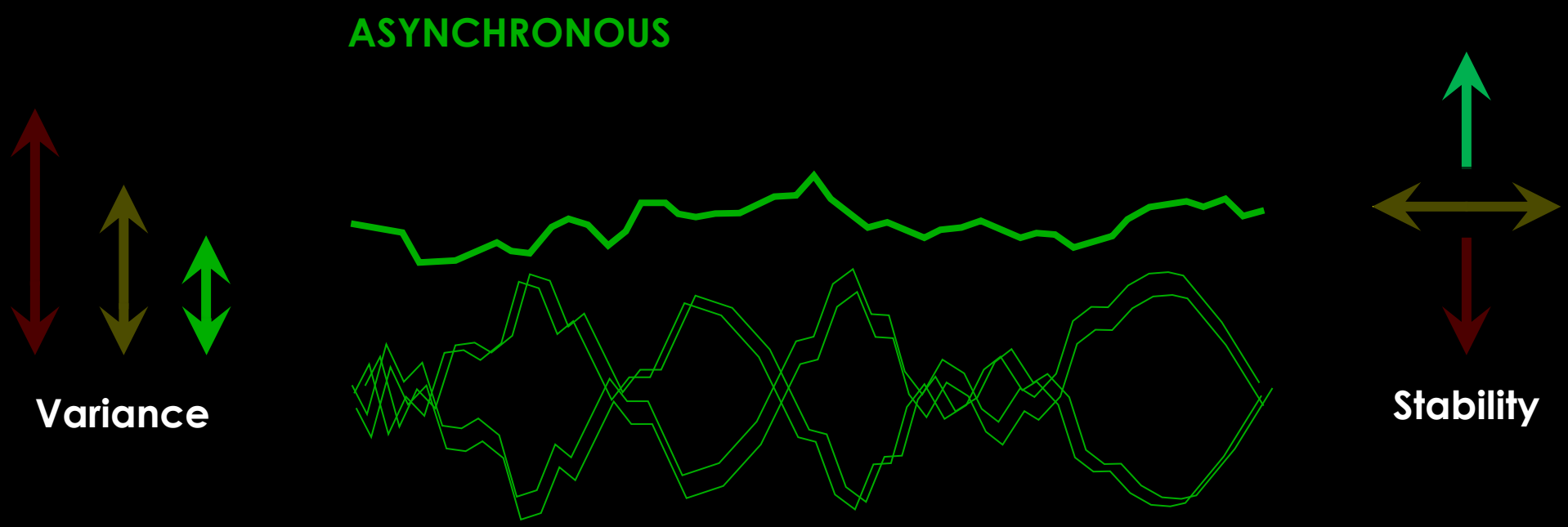

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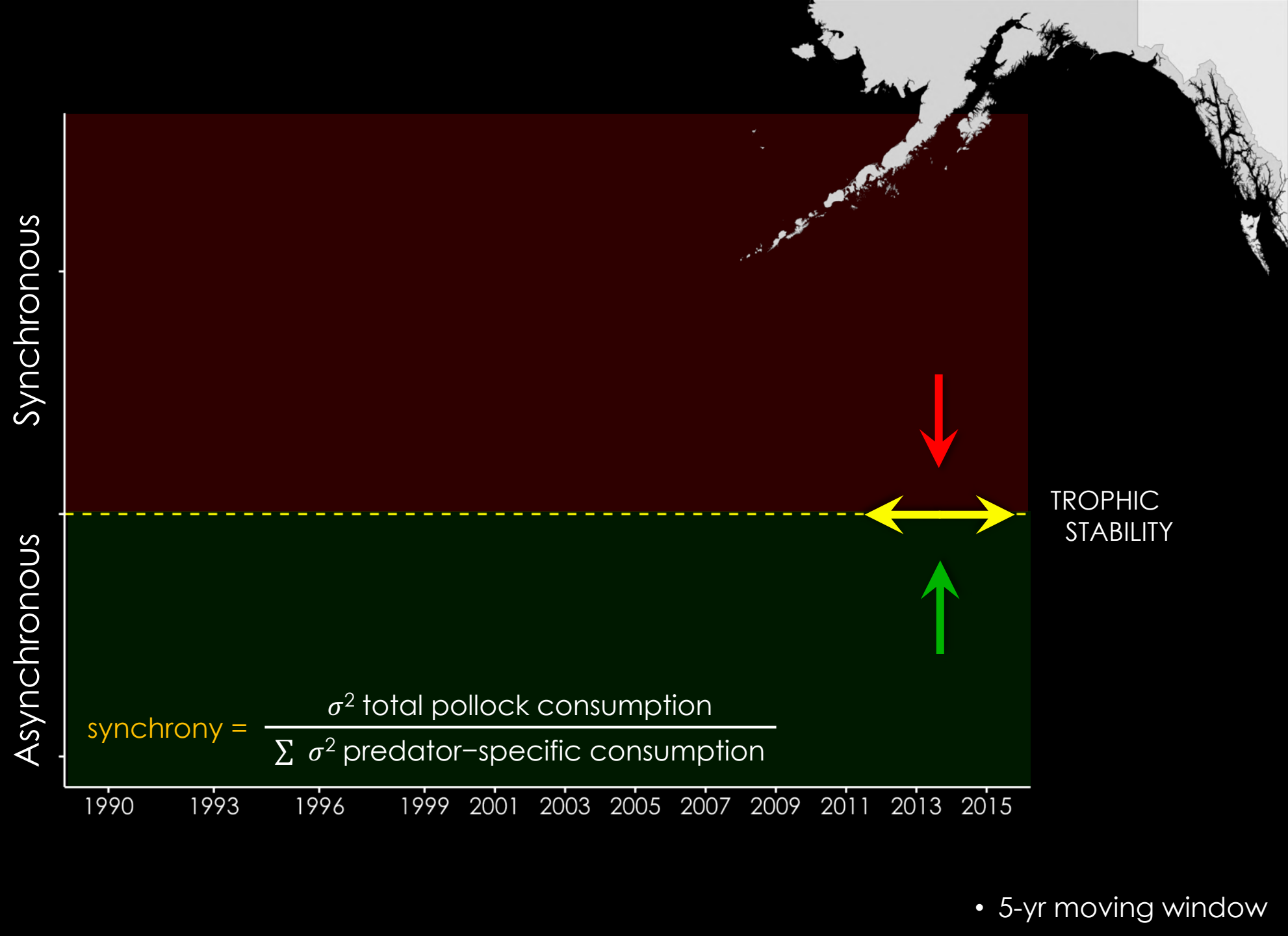
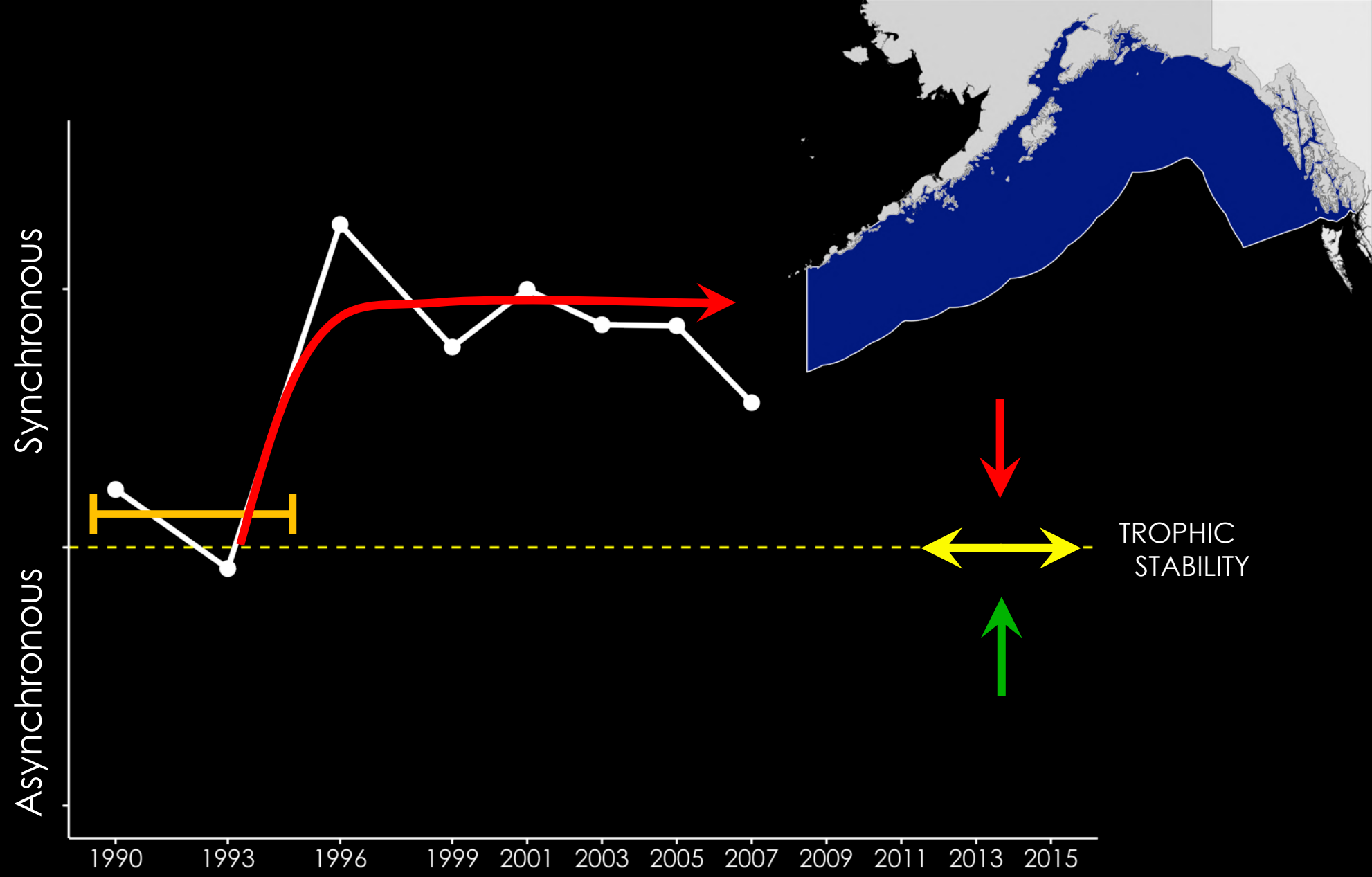


- 5-yr moving window

predation and trophic stability in the Gulf of AK



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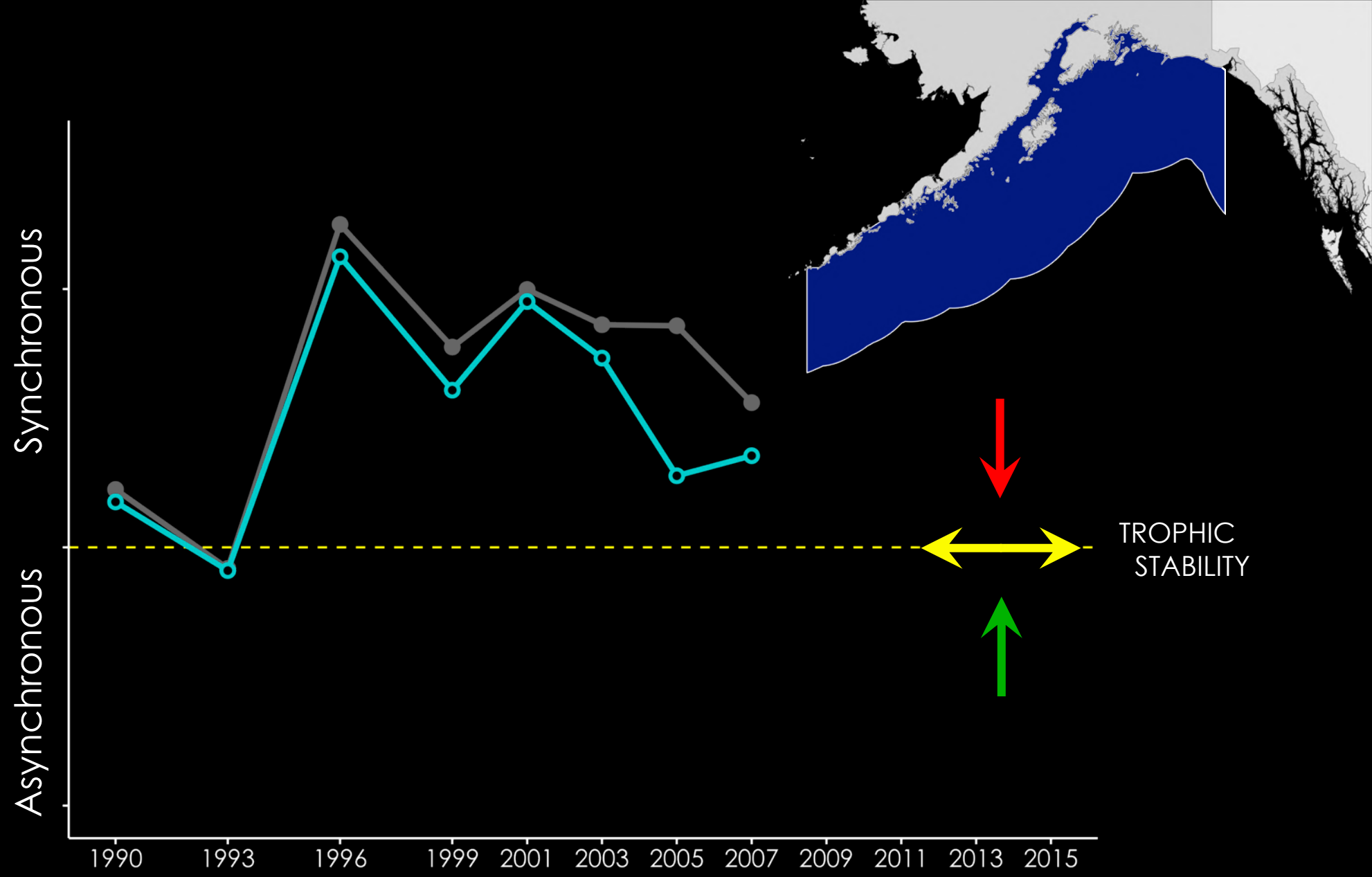

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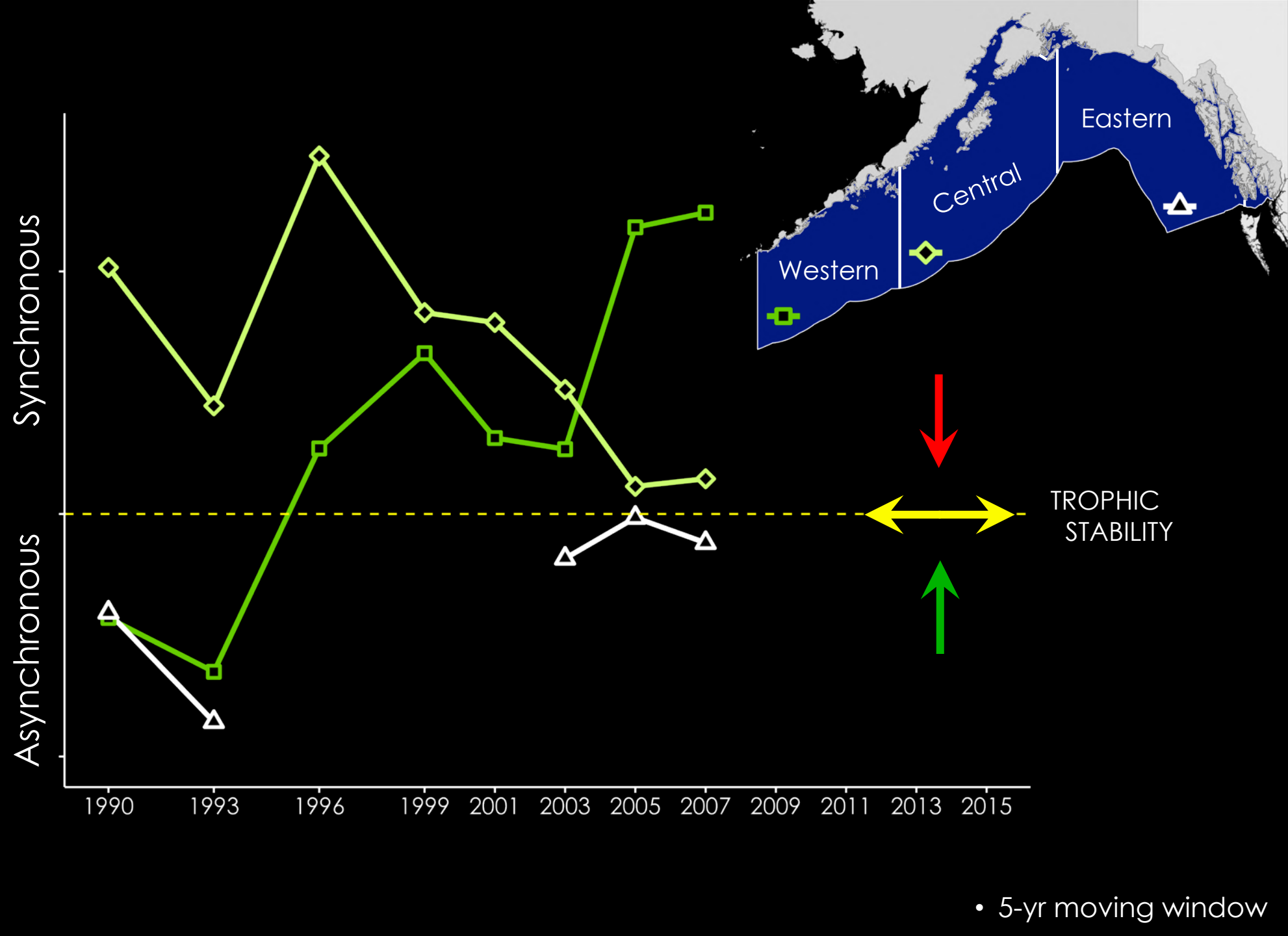

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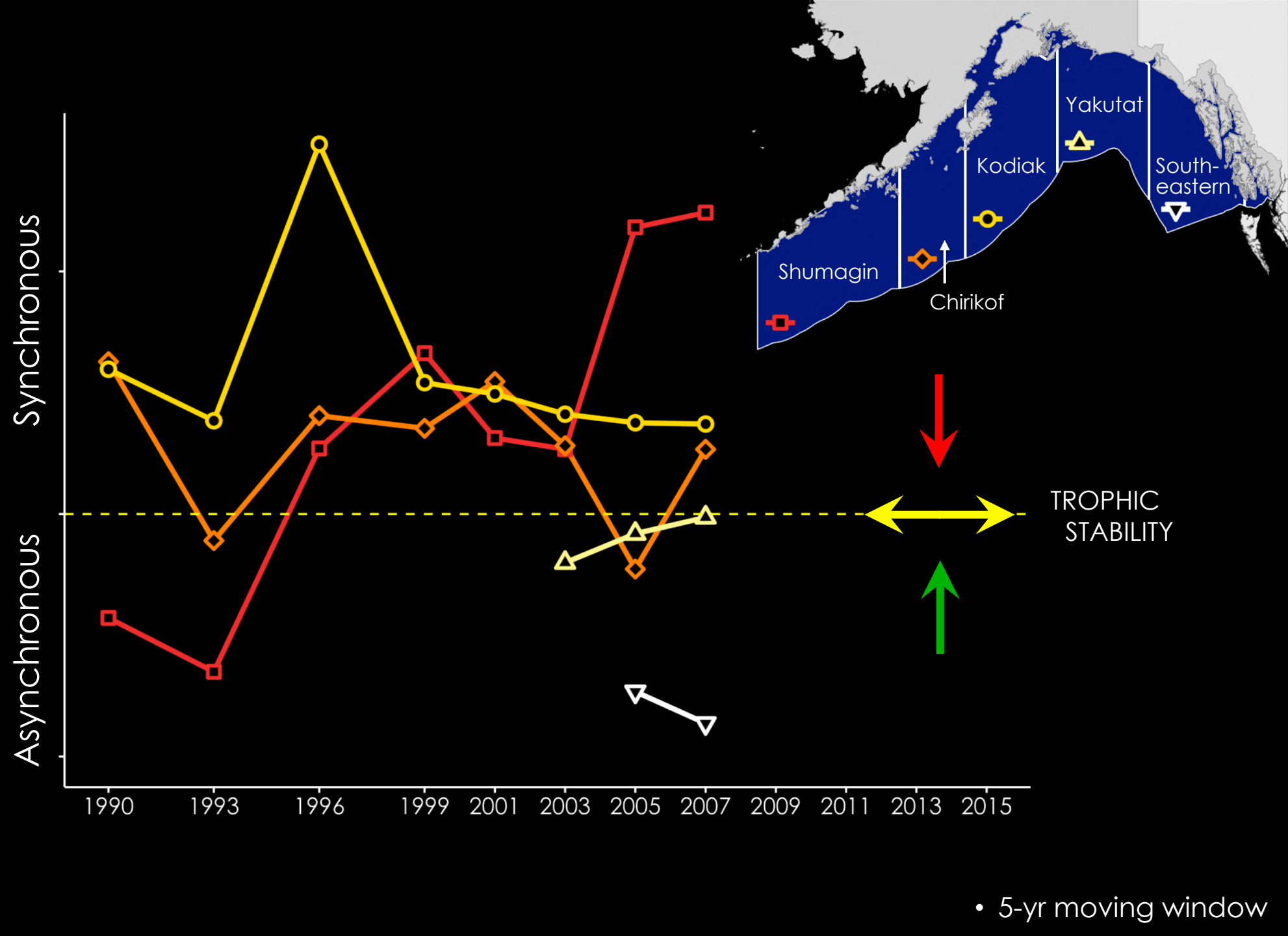
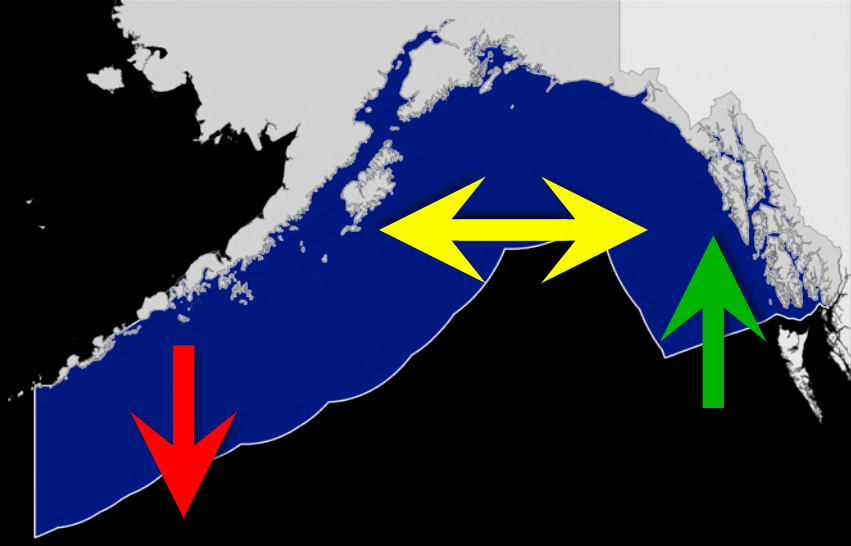


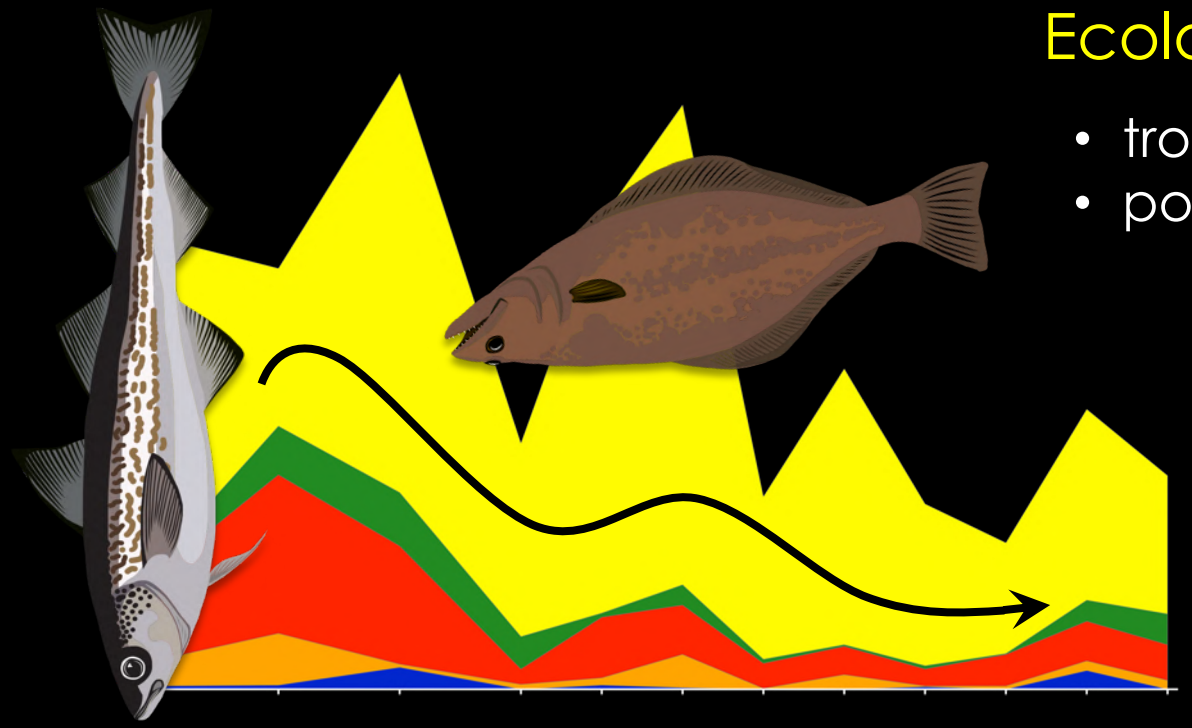
- 5-yr moving window

predation and trophic stability in the Gulf of AK

Key Findings

- intense and highly-variable predation
- Arrowtooth Flounder = dominant predator
- synchronous consumption dynamics
  - dependent on scale/location





Ecological Inferences

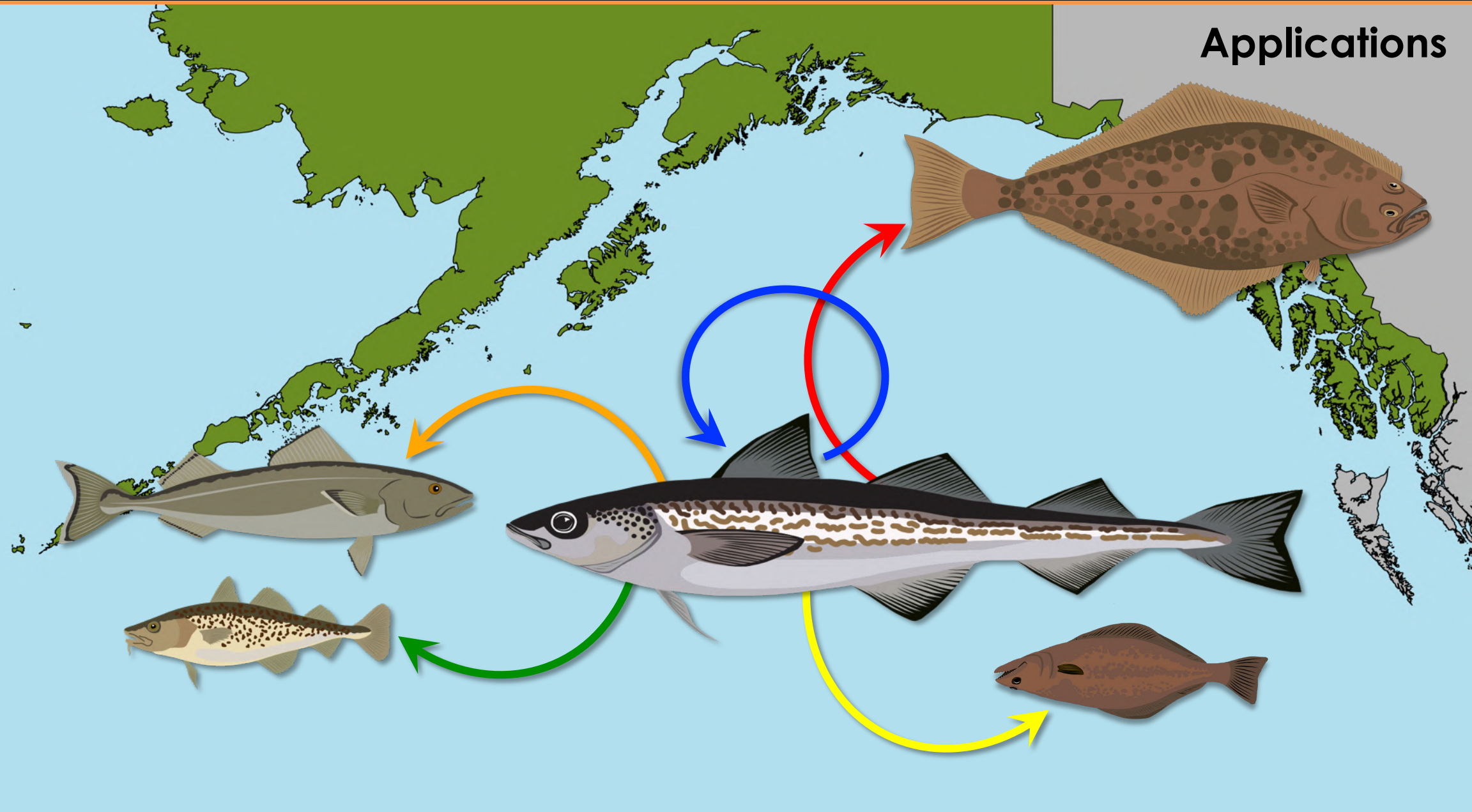
- trophic instability in the Gulf of Alaska
- potential for strong top-down control

e.g., Gaichas *et al.* 2015

- spatial heterogeneity: buffer

e.g., Thorson *et al.* 2018

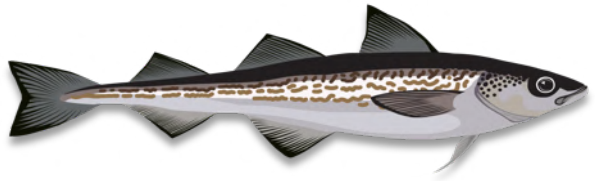
predation and trophic stability in the Gulf of Alaska



predation and trophic stability in the Gulf of Alaska

Applications

Ecosystem and Socioeconomic Profile (ESP)
Appendix to SAFE Report



S. Kalei Shotwell
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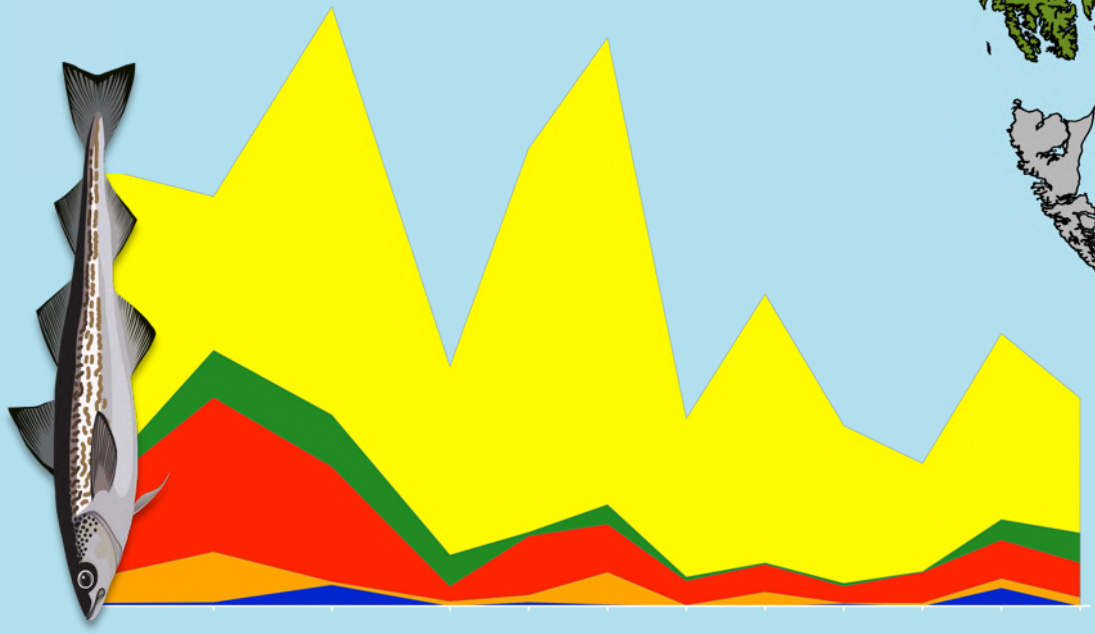
Lauren Rogers
Stephani Zador

September 2019

- predator-specific predation on pollock



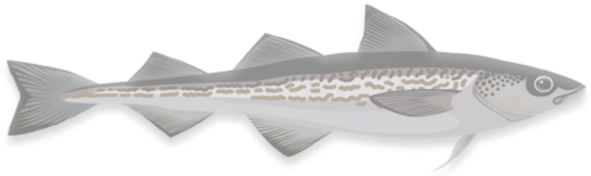
predation and trophic stability in the Gulf of Alaska

Applications

Martin Dorn
AFSC, NOAA

- age-specific predation on pollock
  - modifier for constant natural mortality

Ecosystem and Socioeconomic Profile (ESP)
Appendix to SAFE Report



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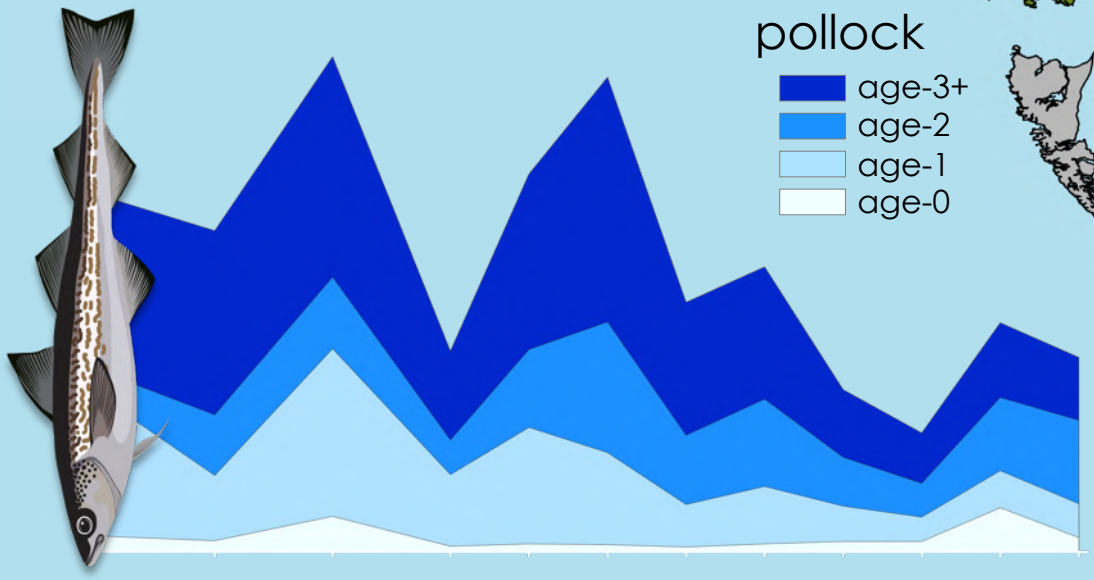
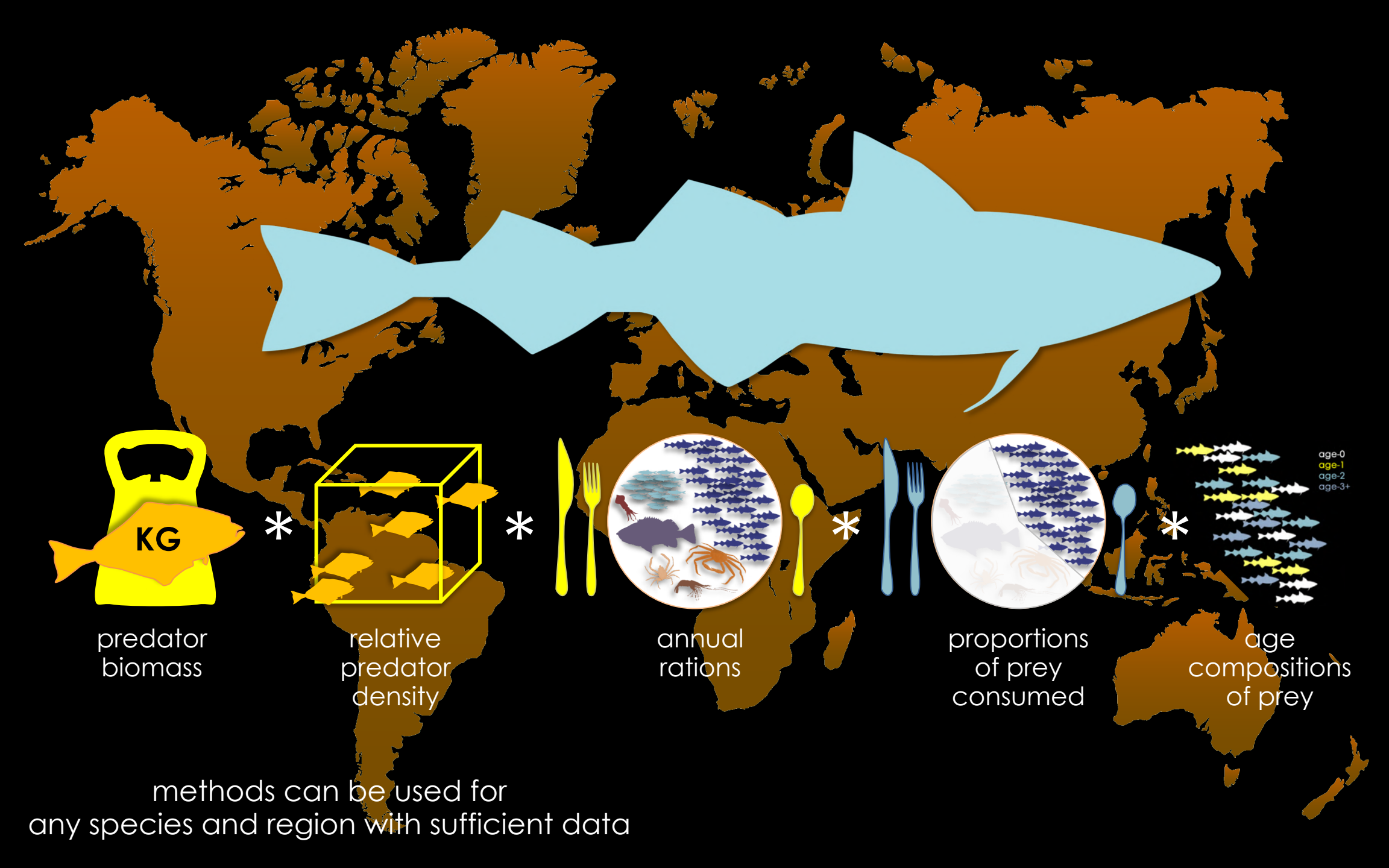
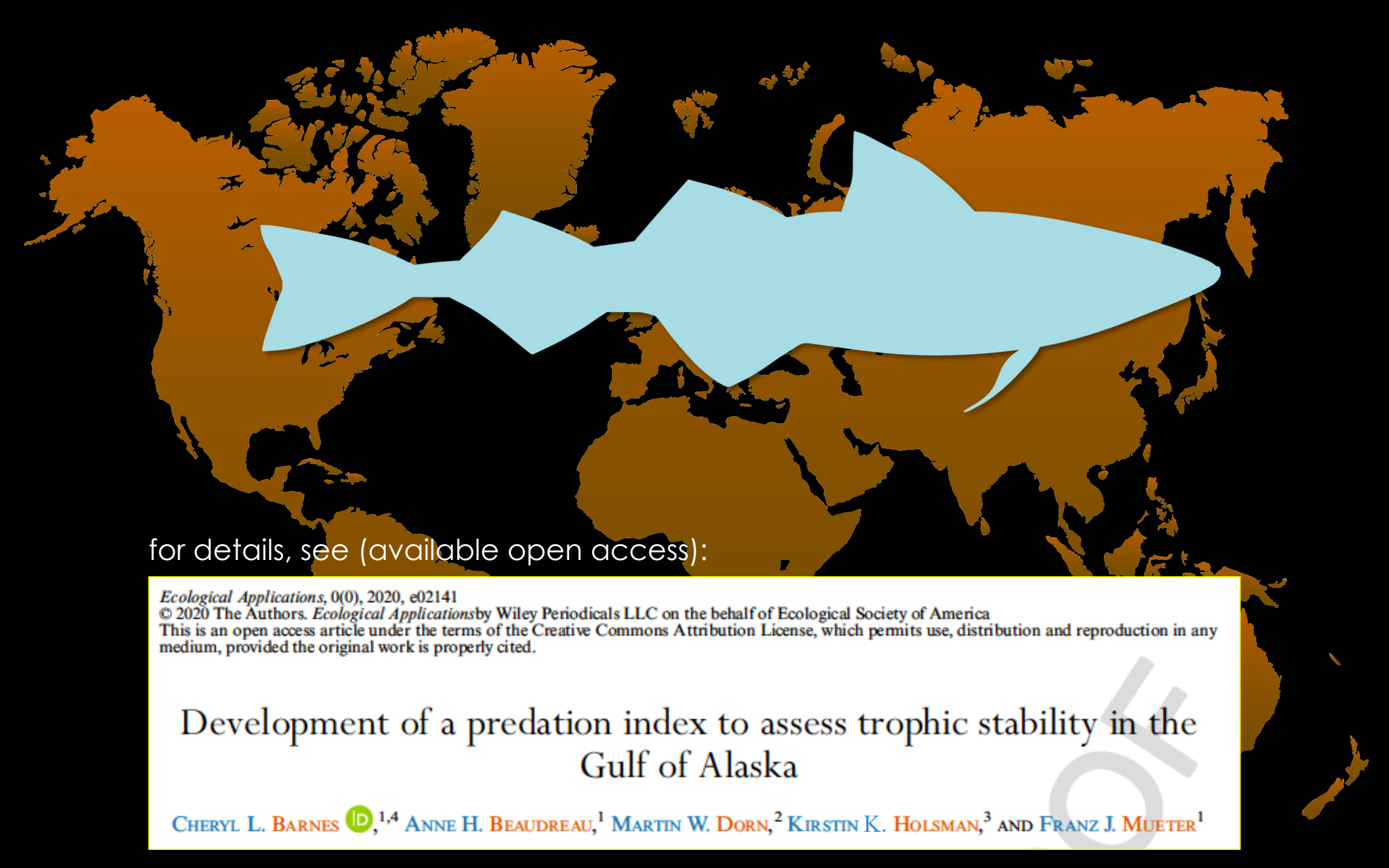


case study focused on
pollock in the Gulf of Alaska


KG
age-0
age-1
age-2
age-3+
predator biomass
relative predator density
annual rations
proportions of prey consumed
age compositions of prey
methods can be used for
any species and region with sufficient data



for details, see (available open access):

Ecological Applications, 0(0), 2020, e02141

Development of a predation index to assess trophic stability in the Gulf of Alaska

Cheryl L. Barnes [1,4] Anne H. Beaudreau,[1] Martin W. Dorn,[2] Kirstin K. Holsman,[3] and Franz J. Mueter[1]

Acknowledgments

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Wayne Palsson
Nancy Roberson
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IPHC

Ian Stewart
Thomas Kong

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W. Pollock, P. Halibut, and Arrowtooth Flounder
Nick Ingram

Subsurface Style

P. Cod and Sablefish
Madison Kosma

UAF College of Fisheries and Ocean Sciences
University of Alaska Fairbanks

University of Alaska Southeast
Sitka Campus

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NOAA Fisheries | Alaska Fisheries Science Center
National Oceanic and Atmospheric Administration

International Pacific Halibut Commission