Development of a predation index to assess trophic stability in the Gulf of Alaska
PICES-2019 Annual Meeting:
Connecting Science and Communities
in a Changing North Pacific

Oct 16 – Oct 27, 2019
Victoria, BC, Canada
Predation: important source of mortality for marine fishes

- shapes size and age structures
- impacts recruitment and survival

Mortality due to predation by other fish

Bax 1991

Predation and trophic stability in the Gulf of AK

Predation and trophic stability in the Gulf of AK

- S. Benguela
- Georges Bank
- Balsfjorden
- E. Bering Sea
- North Sea
- Barents Sea

> larval and early juvenile stages
Walleye Pollock (Gadus chalcogrammus)
Walleye Pollock (*Gadus chalcogrammus*)

Predation and trophic stability in the Gulf of AK

Walleye Pollock (W. Pollock) 23%  Pacific Halibut 6%  Arrowtooth Flounder 33%  Pacific Cod 16%  Other Fishes 1%  Marine Mammals 8%  Unexplained 1%  Skates 1%

Gaichas et al. 2015
Walleye Pollock (*Gadus chalcogrammus*)

- 6% Other Fishes
- 5% W. Pollock
- 1% Unexplained
- 1% Skates
- 8% Marine Mammals
- 7% Fisheries

84% mortality due to predation by fish

- 84% mortality due to predation by fish
- 8% mortality due to predation by other fishes

Gaichas et al. 2015
predation and trophic stability in the Gulf of AK

Groundfish Biomass (millions of tons)

Gulf of Alaska

Walleye Pollock

Dom et al. 2017
Prediction and trophic stability in the Gulf of AK

Groundfish Biomass (millions of tons)

- Walleye Pollock
- Arrowtooth Flounder
- Pacific Cod
- Pacific Halibut
- Sablefish

Gulf of Alaska

- 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

Groundfish Biomass (millions of tons)

Gulf of Alaska

- Walleye Pollock
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- Pacific Cod
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Dom et al. 2017; Spies et al. 2017; Barbeaux et al. 2017; Stewart and Hicks 2017; Hanselman et al. 2017
Research Questions

1) How does predation intensity change through time and space?
Groundfish Biomass (millions of tons)

Research Questions

1) How does predation intensity change through time and space?

2) How stable is the demersal food web in the Gulf of Alaska?

Dom et al. 2017; Spies et al. 2017; Barbeaux et al. 2017; Stewart and Hicks 2017; Hanselman et al. 2017
Research Question

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

pollock consumed per year and area (MT) =
Research Question

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pollock consumed per year and area (MT) =

total predator biomass

KG
Research Question

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pollock consumed per year and area (MT) =

\( KG \times \) total predator biomass \ast \) relative predator density
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pollock consumed per year and area (MT) =

- total predator biomass
- relative predator density
- mean annual ration
Research Question

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\[
\text{pollock consumed per year and area (MT)} = \text{total predator biomass} \times \text{relative predator density} \times \text{mean annual ration} \times \text{proportions of pollock consumed} \times \text{ages of pollock consumed}
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\]

- Resource Assessment and Conservation Engineering Division
- Marine Ecology and Stock Assessment Program
- Alaska Fisheries Science Center, NOAA
- International Pacific Halibut Commission

- Resource Ecology and Ecosystem Modeling Program
- Alaska Fisheries Science Center, NOAA
- Livingston et al. 2017

Barbeaux et al. 2017
Dorn et al. 2017
Hanselman et al. 2017
Spies et al. 2017
Stewart and Hicks 2017
Kitchell et al. 1977
Hanson et al. 1997
Harvey 2009
Holsman and Aydin 2015
Holsman et al. 2019
Research Question

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

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predation and trophic stability in the Gulf of AK

- Arrowtooth Flounder
- Pacific Cod
- Pacific Halibut
- Sablefish
- Walleye Pollock
Research Questions

1) How does predation intensity change through time and space?

2) How stable is the demersal food web in the Gulf of Alaska?
the portfolio effect
the portfolio effect

$\text{diversity } \propto \text{ stability}$
the portfolio effect

Adapted from Oken et al. 2018

Predation and trophic stability in the Gulf of AK
the portfolio effect

Adapted from Oken et al. 2018
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Adapted from Oken et al. 2018

Community Biomass vs. Time

Variance

Statistic ally Independent

Synchronous

LESS STABLE

Asynchronous

MORE STABLE
the portfolio effect
predation and trophic stability in the Gulf of AK

Time Series: 1990 to 2015

Spatial Scales:
- Basin
- Pollock Stock Assessment Area
- Subregion
- INPFC Statistical Area

\[
\text{synchrony} = \frac{\text{variance in total consumption}}{\text{sum of predator-specific variances}}
\]

\[
\text{portfolio effect} = 1 - \text{synchrony}
\]
Gulf of Alaska

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predation and trophic stability in the Gulf of AK

1990 to 2015

Gulf of Alaska
Predation and trophic stability in the Gulf of AK

1990 to 2003

2005 to 2015

- 0.42
predation and trophic stability in the Gulf of AK

1990 to 2003

1990 to 2015

2005 to 2015

-0.42

0.13
predation and trophic stability in the Gulf of AK
predation and trophic stability in the Gulf of AK
Predation and trophic stability in the Gulf of AK

1990 to 2003
- 0.30

1990 to 2015
N/A
- 0.34

2005 to 2015
predation and trophic stability in the Gulf of AK

1990 to 2003

1900 to 2015

N/A

0.31

-0.17

0.30

-0.34

-0.30
Predation and trophic stability in the Gulf of AK
Key Findings

- intense and highly-variable predation
- Arrowtooth Flounder = dominant predator
- synchronous consumption dynamics
  - increased through time
  - dep. on scale/location

Ecological Inferences

- trophic instability in the Gulf of Alaska

Adapted from Oken et al. 2016
Key Findings

- intense and highly-variable predation
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Potential for Top-Down Control

Ecological Inferences

- trophic instability in the Gulf of Alaska

Adapted from Oken et al. 2016
Key Findings

- intense and highly-variable predation
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Potential for Top-Down Control

Ecological Inferences

- trophic instability in the Gulf of Alaska
- strong top-down control over pollock
  - spatial heterogeneity: buffer
  e.g., Thorson et al. 2018

Adapted from Oken et al. 2016
Development of a predation index to assess trophic stability in the Gulf of Alaska

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

Applications

GOA: Ecosystem Status Report

- temporal variation in portfolio effects
Development of a predation index to assess trophic stability in the Gulf of Alaska

Applications

- spatially-explicit, time-varying, age-specific estimates of predation
- modifier for constant natural mortality

GOA: Ecosystem and Socioeconomic Profile (ESP)
- appendix to SAFE Report
“gross caricatures of complex natural systems” - Nicholas J. Bax 1991
“gross caricatures of complex natural systems” – Bax 1991
Acknowledgments

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NOAA FISHERIES
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

ALASKA FISHERIES SCIENCE CENTER

INTERNATIONAL PACIFIC HALIBUT COMMISSION
Top down control in the Gulf of Alaska

A Comparison of the Bering Sea, Gulf of Alaska, and Aleutian Islands Large Marine Ecosystems Through Food Web Modeling
by
K. Aydin, S. Gaichas, I. Ortiz, D. Kinzey, and N. Friday

A multispecies age-structured assessment model for the Gulf of Alaska
Kray F. Van Kirk, Terrance J. Quinn II, and Jeremy S. Collie

Quantifying food web interactions in the North Pacific – a data-based approach
Patricia A. Livingston · Kerim Aydin · Troy W. Buckley · Geoffrey M. Lang · Mei-Sun Yang · Bruce S. Miller

Comparative methods for evaluating climate change impacts on the foraging ecology of Alaskan groundfish
Kirstin K. Holmstam¹ ¹, Kerim Aydin²
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What drives dynamics in the Gulf of Alaska? Integrating hypotheses of species, fishing, and climate relationships using ecosystem modeling
Sarah K. Gaichas, Kerim Y. Aydin, and Robert C. Francis

Using food web model results to inform stock assessment estimates of mortality and production for ecosystem-based fisheries management
Sarah K. Gaichas, Kerim Y. Aydin, and Robert C. Francis

Wasp waist or beer belly? Modeling food web structure and energetic control in Alaskan marine ecosystems, with implications for fishing and environmental forcing
Sarah Gaichas³ ³, Kerim Aydin⁴, Robert C. Francis⁵
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⁵University of Washington, School of Aquatic and Fisheries Sciences, Seattle, WA 98115, United States
predation and trophic stability in the Gulf of AK

Consumption of Walleye Pollock (mill MT)

Walleye Pollock (mill MT)

<table>
<thead>
<tr>
<th>Year</th>
<th>Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>1.51</td>
</tr>
<tr>
<td>1993</td>
<td>1.34</td>
</tr>
<tr>
<td>1996</td>
<td>2.76</td>
</tr>
<tr>
<td>1999</td>
<td>1.53</td>
</tr>
<tr>
<td>2001</td>
<td>3.57</td>
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<tr>
<td>2003</td>
<td>3.05</td>
</tr>
<tr>
<td>2005</td>
<td>2.37</td>
</tr>
<tr>
<td>2007</td>
<td>2.90</td>
</tr>
<tr>
<td>2009</td>
<td>0.74</td>
</tr>
<tr>
<td>2011</td>
<td>0.48</td>
</tr>
<tr>
<td>2013</td>
<td>0.74</td>
</tr>
<tr>
<td>2015</td>
<td>0.45</td>
</tr>
</tbody>
</table>
predation and trophic stability in the Gulf of AK

1990 to 2003

Predation and trophic stability varied across the Gulf of AK from 1990 to 2003. The values shown indicate the degree of predation and trophic stability, with higher numbers indicating higher stability. The maps display the distribution of these values, with red arrows indicating a decrease and green arrows indicating an increase.

1990 to 2015

The maps for 1990 to 2015 show a similar pattern of predation and trophic stability, with values ranging from 0.64 to 1.31. The changes over this period are depicted by the red arrows, indicating a decrease in stability.

2005 to 2015

The maps for 2005 to 2015 continue to show the distribution of predation and trophic stability values, with red arrows again indicating a decrease in stability.

N/A

Some areas are marked as N/A, indicating that data is not available for those regions.
predation and trophic stability in the Gulf of AK
$P_{s,a,i,j} = B_{s,i} \times rD_{s,i,j} \times \tilde{C}_{s,i,j} \times \tilde{p}_{s,i,j} \times \propto a_{s,a,i}$
predation and trophic stability in the Gulf of AK

\[ P_{s,a,i,j} = B_{s,i} \times rD_{s,i,j} \times \bar{C}_{s,i,j} \times \bar{P}_{s,i,j} \times \alpha_{s,a,i} \]
predation and trophic stability in the Gulf of AK

\[ P_{s,a,i,j} = B_{s,i} \ast rD_{s,i,j} \ast \tilde{C}_{s,i,j} \ast \bar{p}_{s,i,j} \ast \alpha a_{s,a,i} \]
predation and trophic stability in the Gulf of AK

\[ P_{s,a,i,j} = B_{s,i} \times r D_{s,i,j} \times \bar{C}_{s,i,j} \times \bar{\rho}_{s,i,j} \times \alpha a_{s,a,i} \]