Progress and prospects for predicting distribution shifts under ecosystem and climate changes
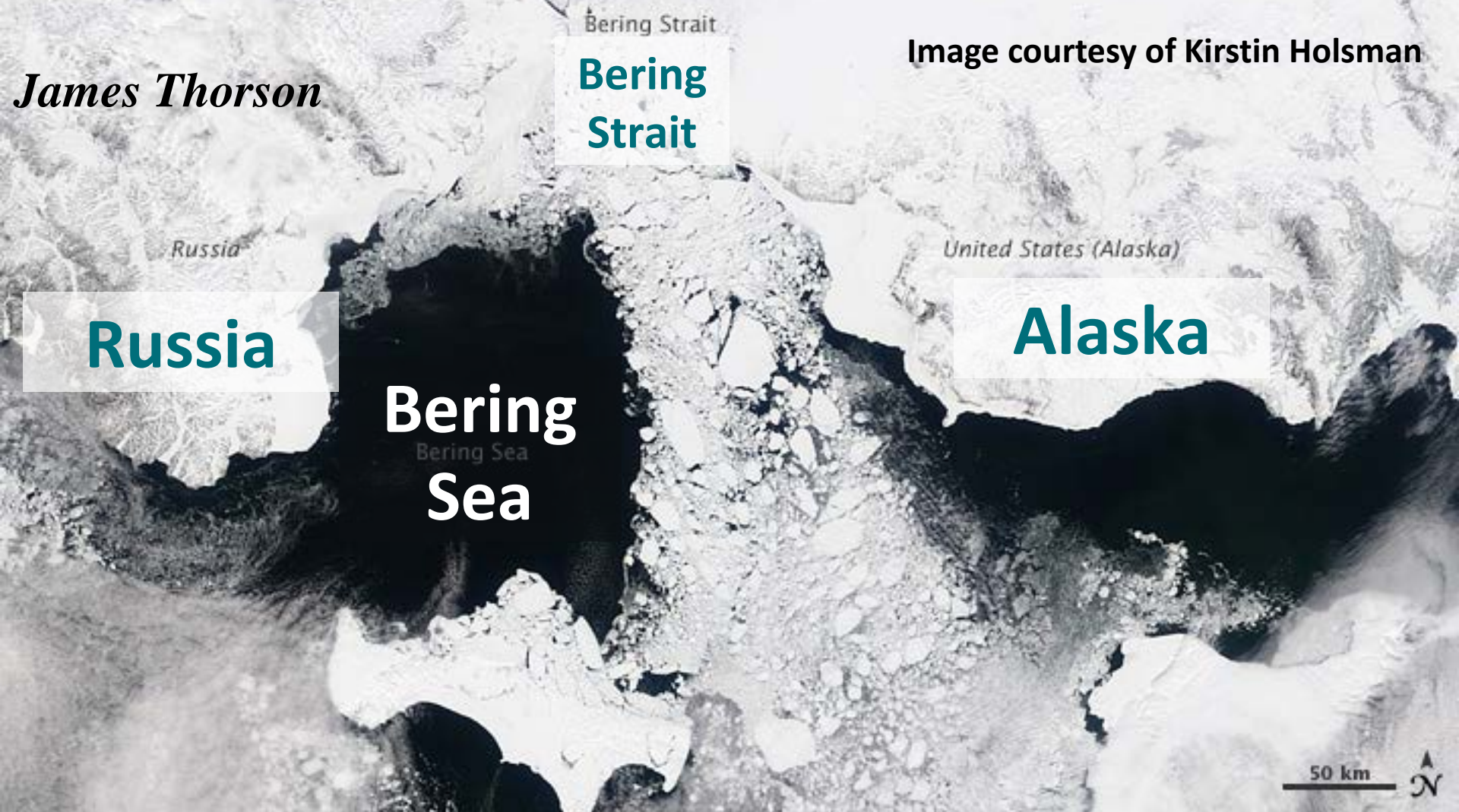
James Thorson

Image courtesy of Kirstin Holsman

Bering Strait

Russia

Bering Sea

Alaska

NASA MODIS image by Jesse Allen

50 km

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Introduction

Pacific cod shifts

2010 surveys

2017 surveys
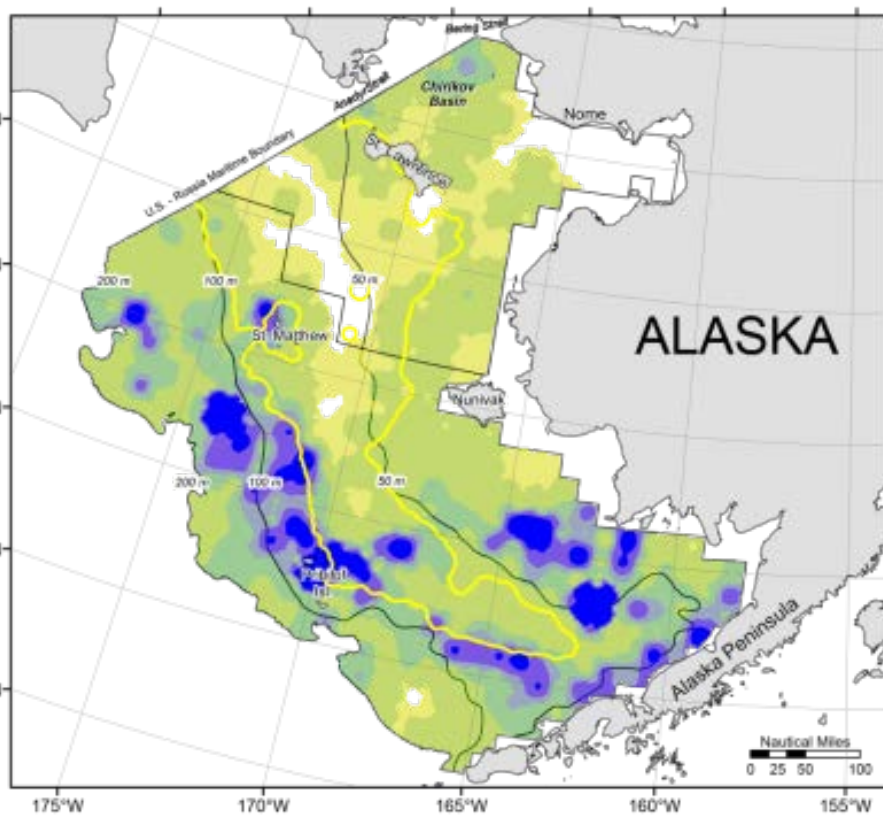

Image courtesy of Bob Lauth

Introduction

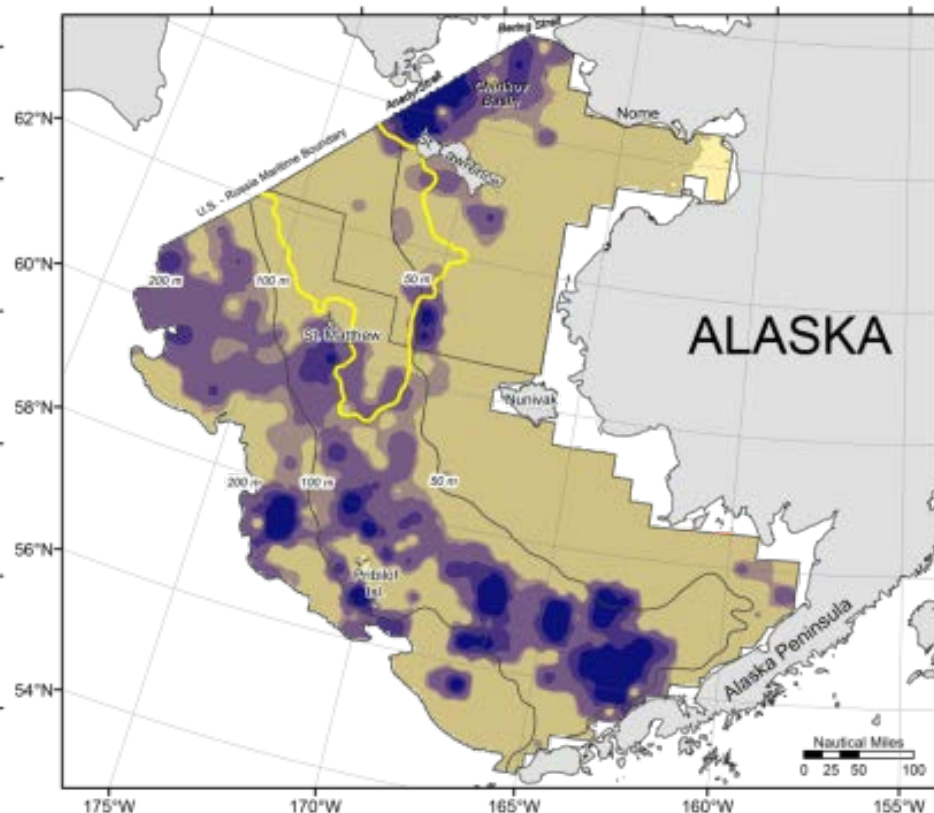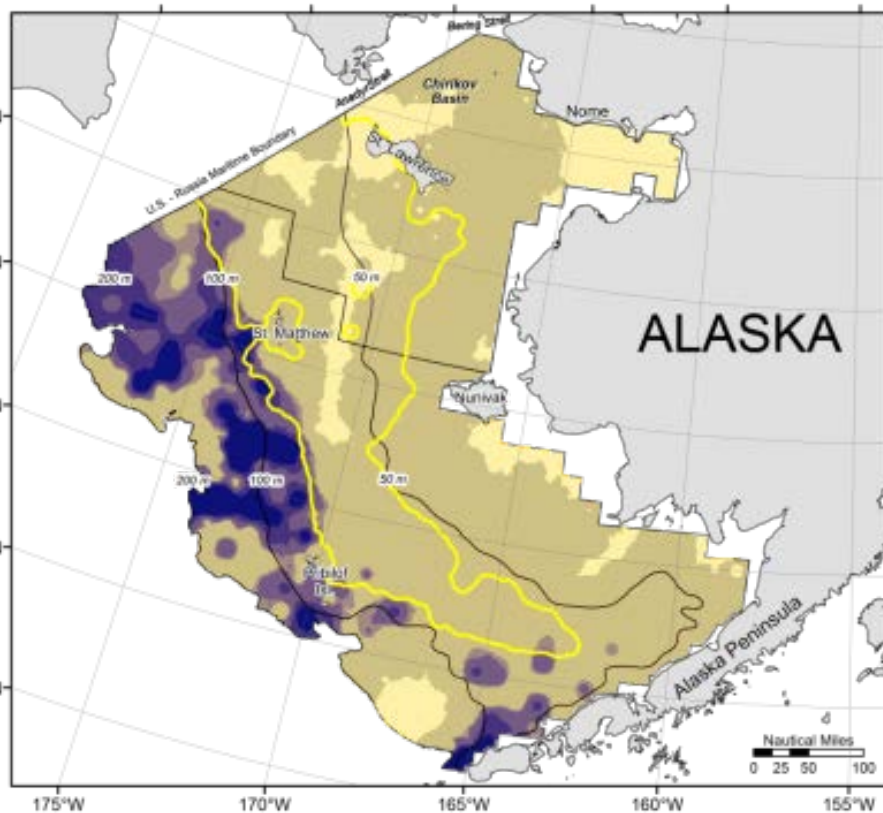## Alaska pollock

2010 surveys
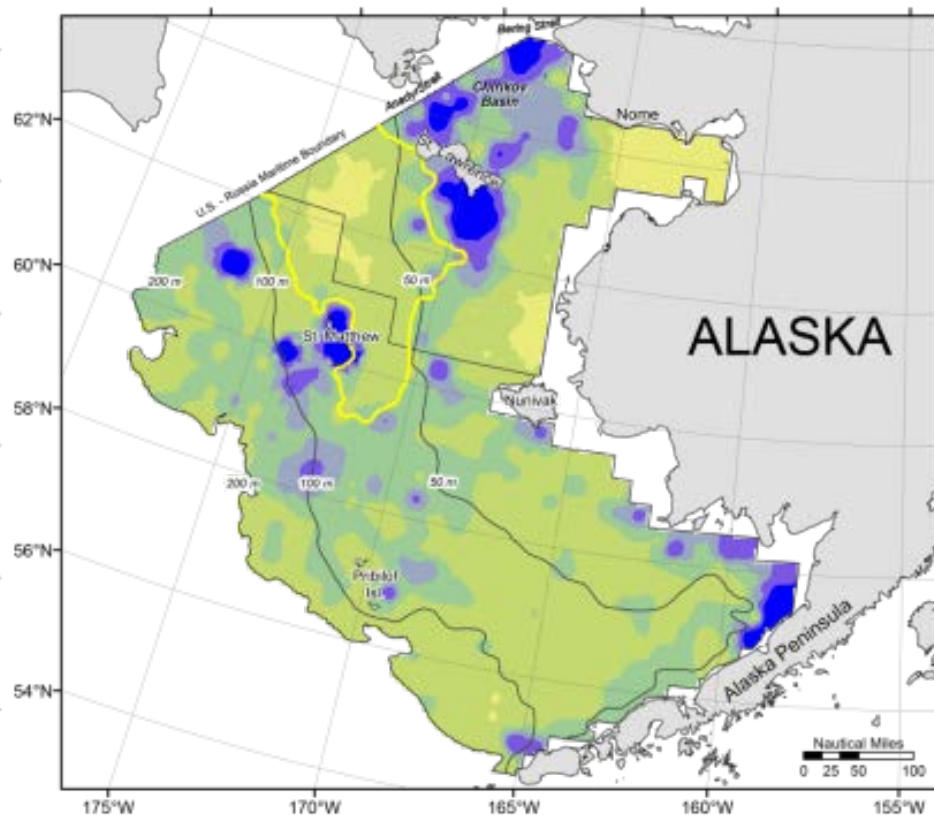
2017 surveys

Image courtesy of Bob Lauth

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Outline

1. What is the evidence for rapid distribution shift worldwide?

2. What research themes are being conducted by AFSC scientists to identify and forecast distribution shifts?

3. What research is needed in the next 2-5 years?

Outline

1. **What is the evidence for rapid distribution shift worldwide?**

   - **Barents Sea**

   - **Gulf of Maine**

   - **Gulf of St. Lawrence**

2. What research themes are being conducted by AFSC scientists to identify and forecast distribution shifts?
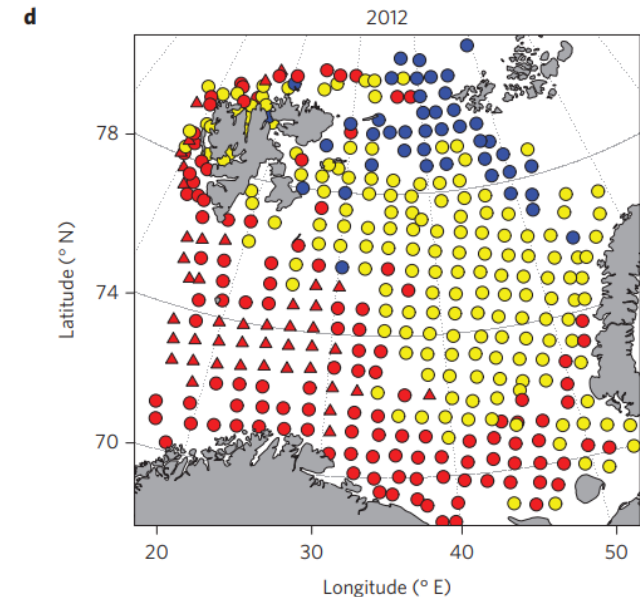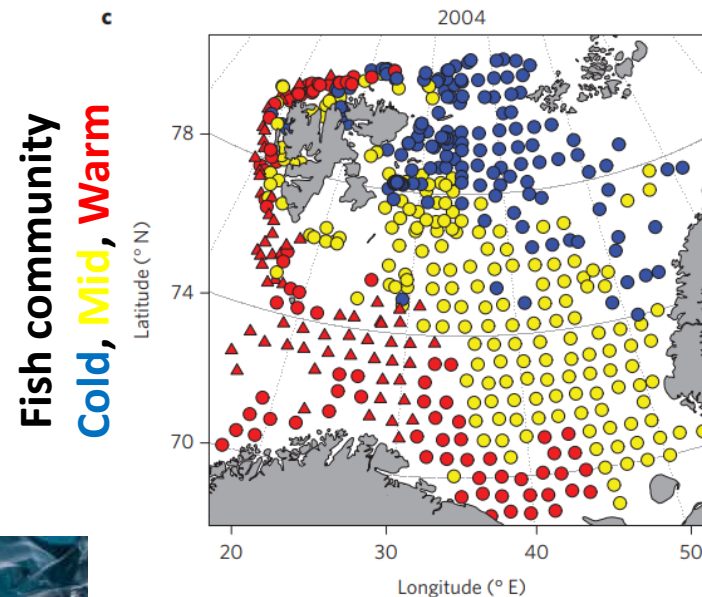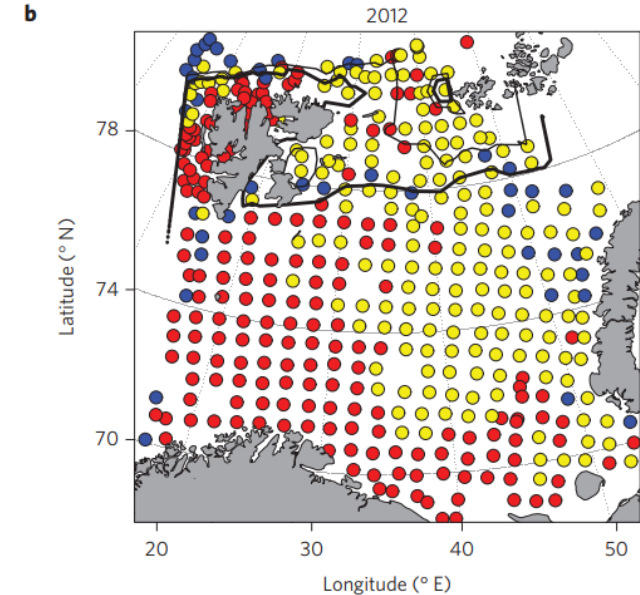
3. What research is needed in the next 2-5 years?

1. Evidence for rapid shifts

Barents Sea

- Fish shifts follow temperature drivers

- Warm-water speces expand North and East

Fossheim, et al. (2015). *Nature Climate Change* 5, 673–677.

1. Evidence for rapid shifts

Gulf of Maine

Kleisner, et al. (2016). *PLOS ONE* **11**, e0149220.

A. FALL, South, Average Bearing = 38

B. FALL, North, Average Bearing = 238
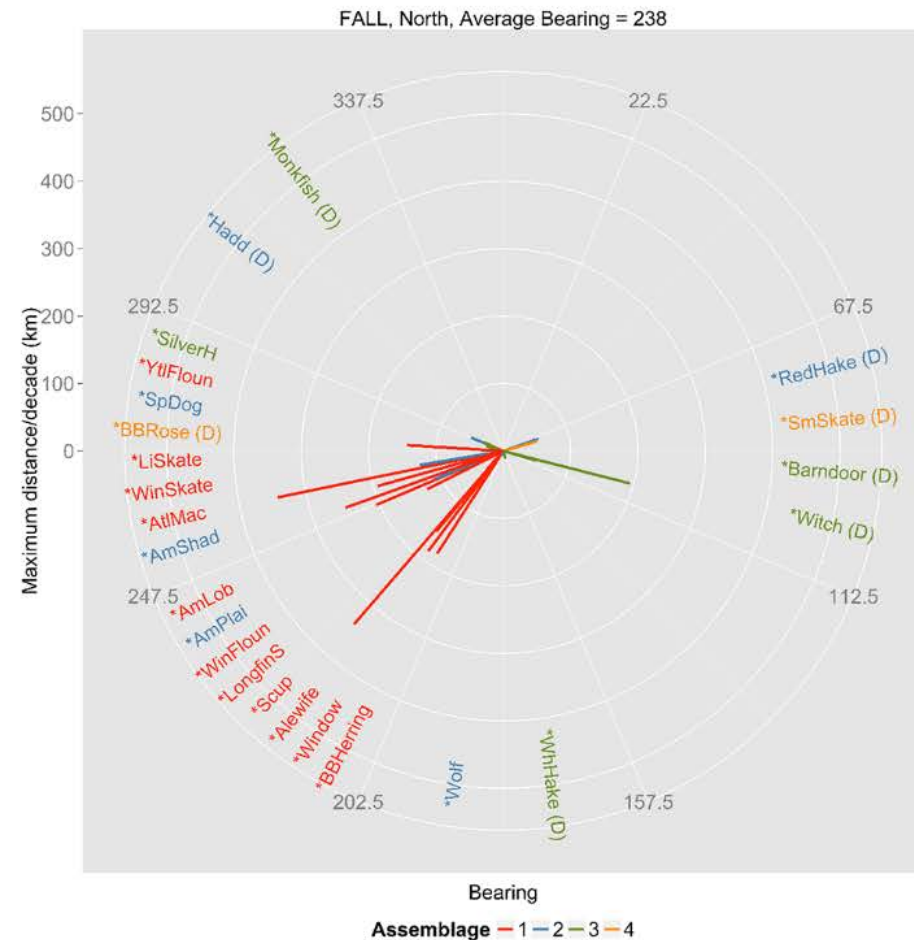
1. Evidence for rapid shifts

Gulf of St. Lawrence

- Steady northward shift for fishes (skate and hake)

- Likely top-down driver

Thorson, Munch, Swain, (2017)
Ecology **98**, 1277–1289.

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Outline

1. What is the evidence for rapid distribution shift worldwide?

2. **What research themes are being conducted by AFSC scientists to identify and forecast distribution shifts?**
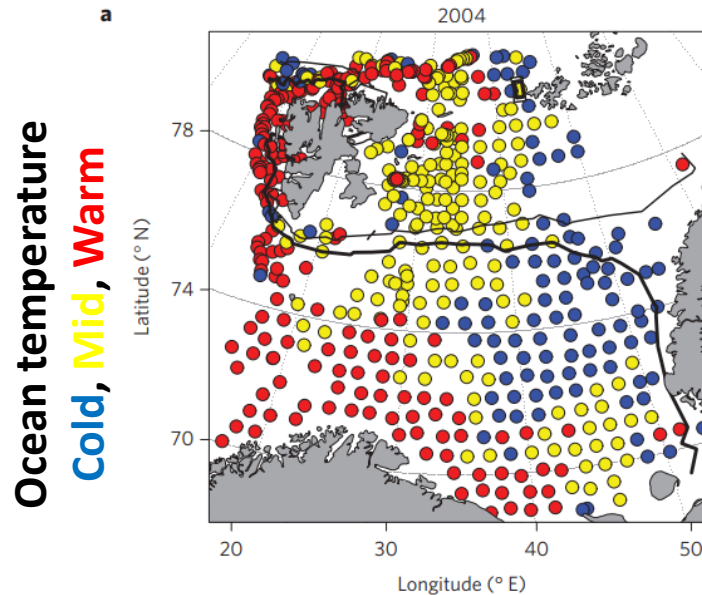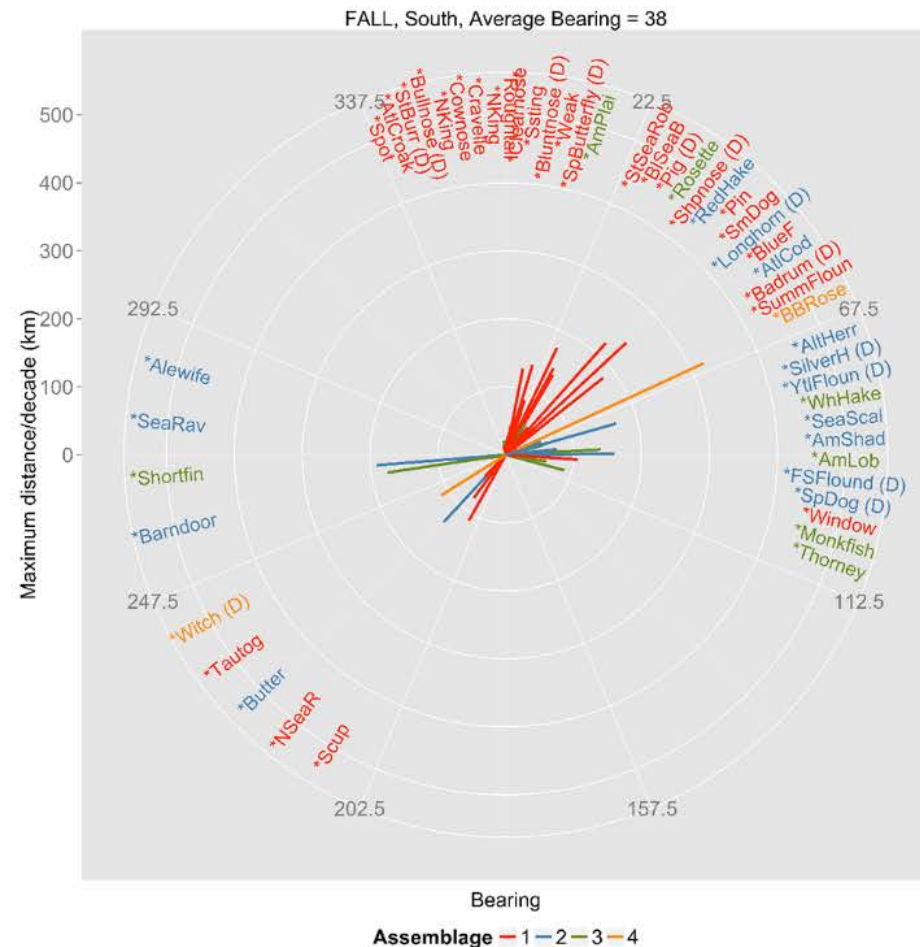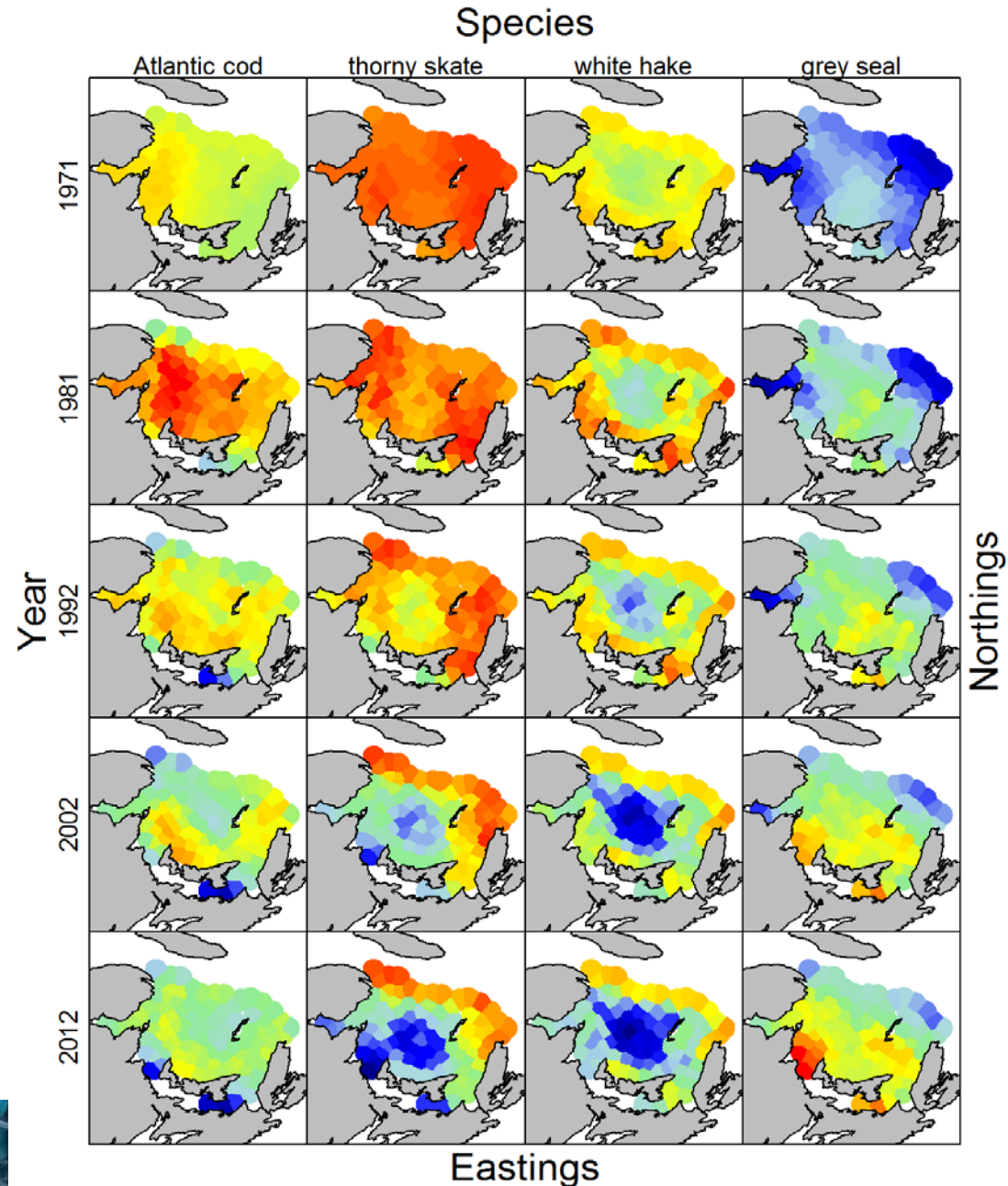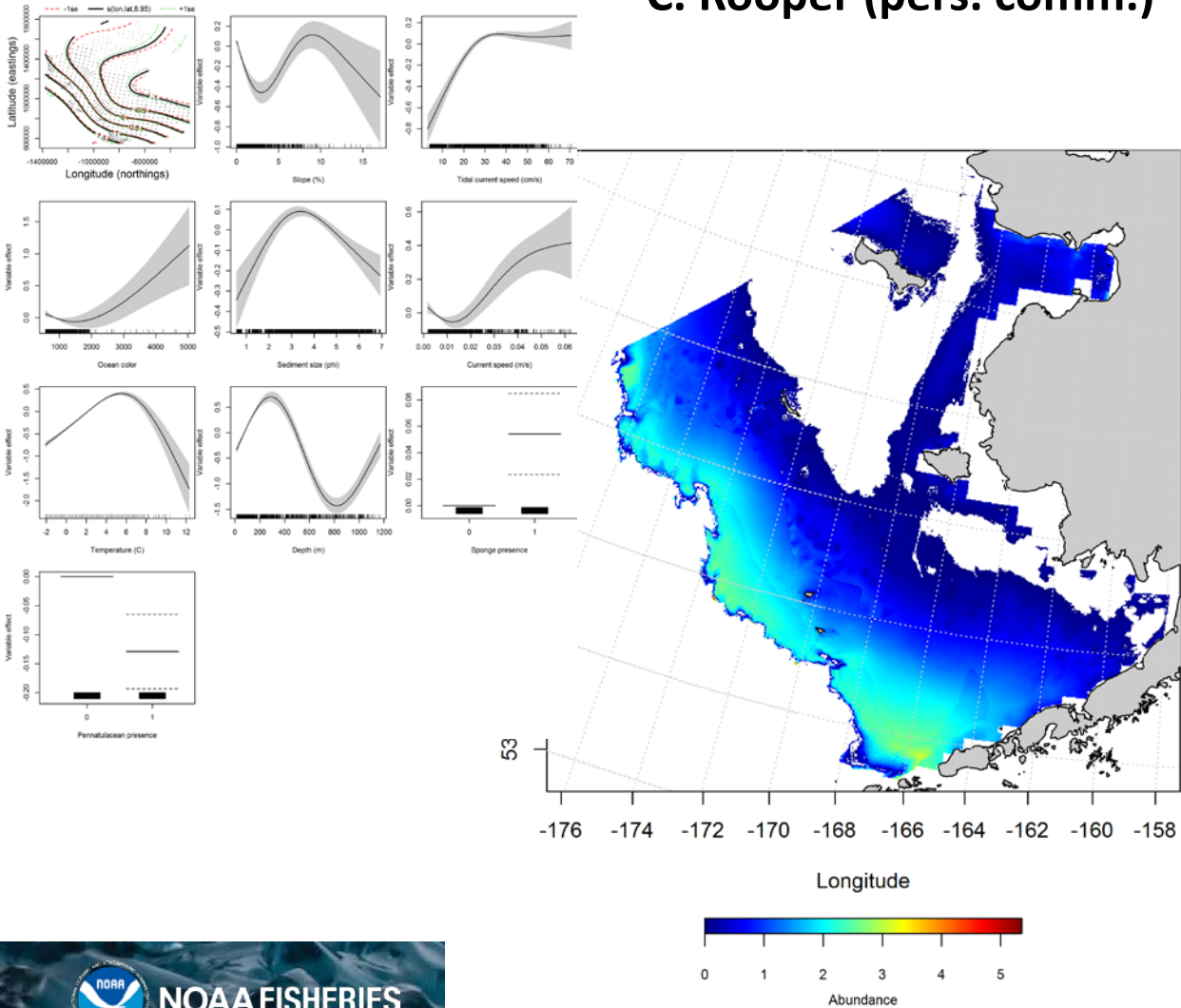
   - Models for essential fish habitat

   - Combining data from multiple surveys

   - Larvaculture experiments

   - Size-structured spatio-temporal models

3. What research is needed in the next 2-5 years?

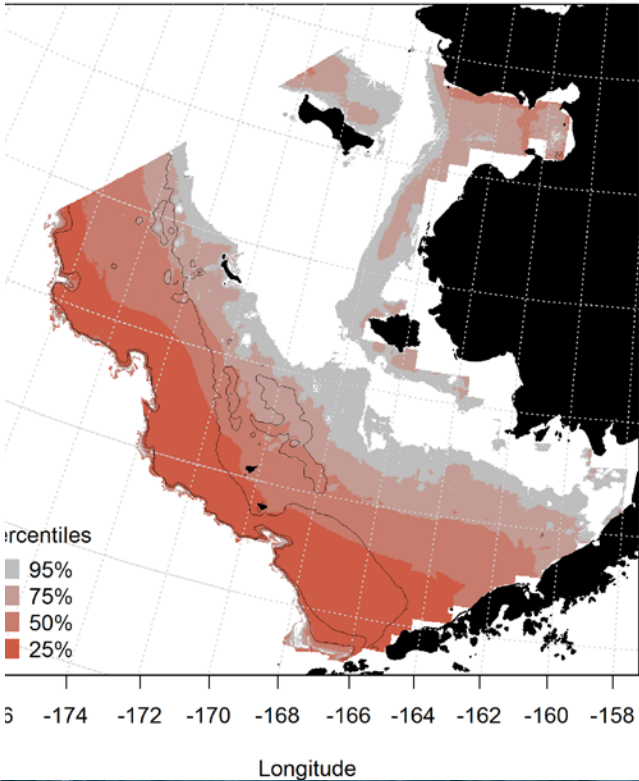# 2. Research themes at AFSC (a sampler...)

Model-based essential fish habitat

C. Rooper (pers. comm.)

Arrowtooth flounder

2. Research themes at AFSC (a sampler...)

Model-based essential fish habitat

C. Rooper (pers. comm.)
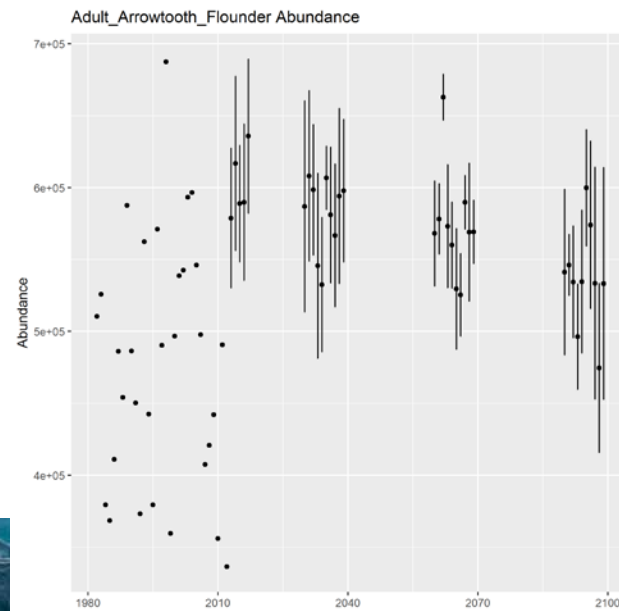
2. Research themes at AFSC (a sampler...)
Combining data from multiple surveys

- Fish shift vertical distribution
  - Changes in light levels
  - Changes in temperature
- Sampling will be biased if we cannot integrate across vertical distribution
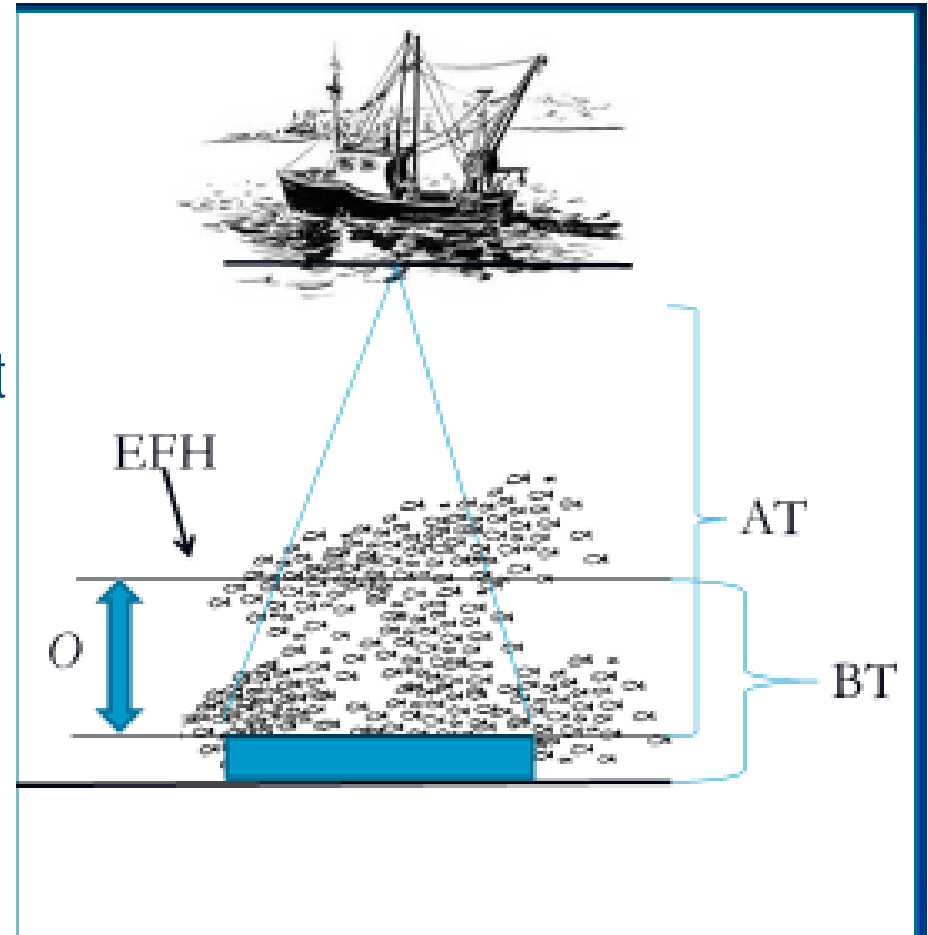
S. Kotwicki (pers. comm.)

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2. Research themes at AFSC (a sampler...)

Combining data from multiple surveys

Example – Pollock

- Changes in vertical distribution among years
  - Light levels
- Correction available from paired sampling

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Larvaculture experiments

Temperature impacts on early life-history

- Temp. drives metabolism
- Used in ROMS to project changes in growth rates
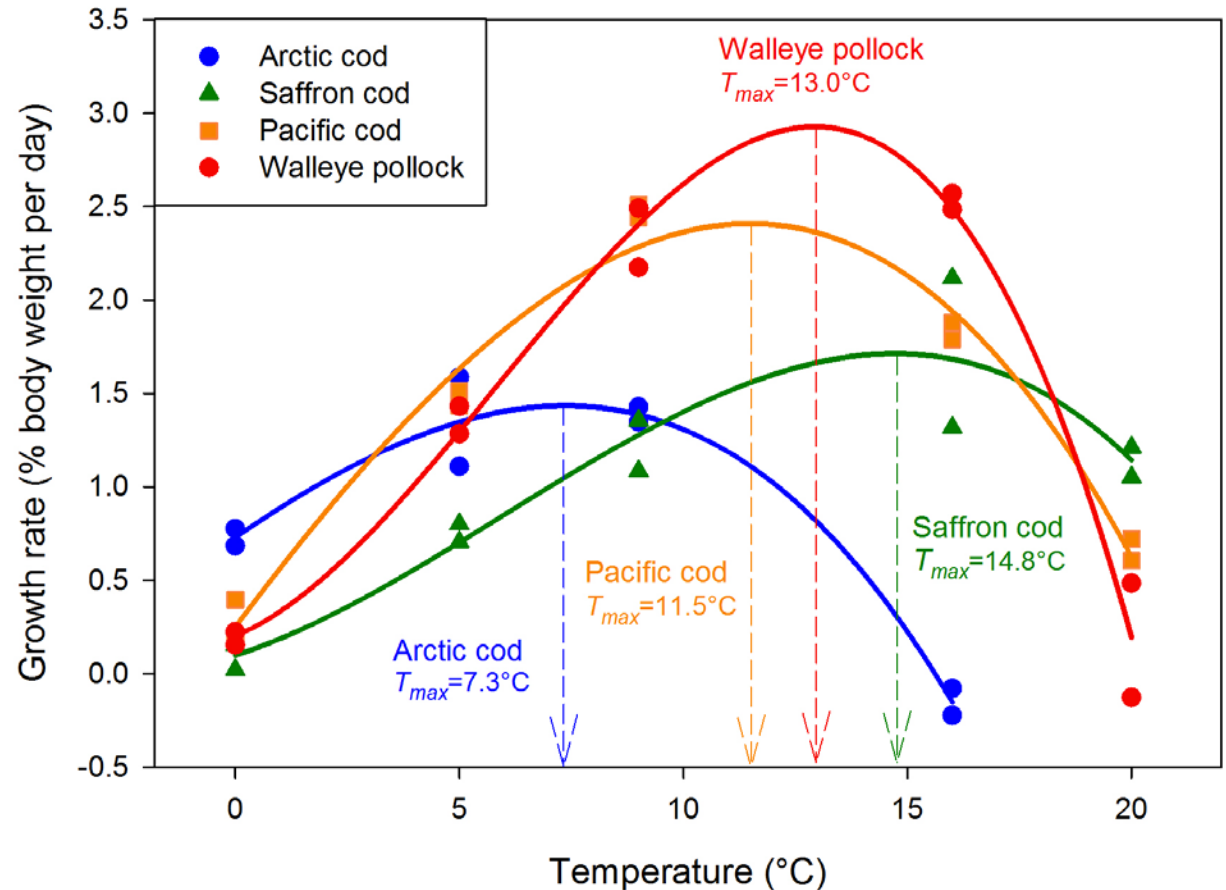
Laurel et al. (2016) *Polar Biology* **39**, 1127–1135.

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2. Research themes at AFSC (a sampler…)

Larvaculture experiments

Decrease in growth rate with food availability

- Stronger impact of prey on arctic cod than pollock

Laurel (pers. comm.)
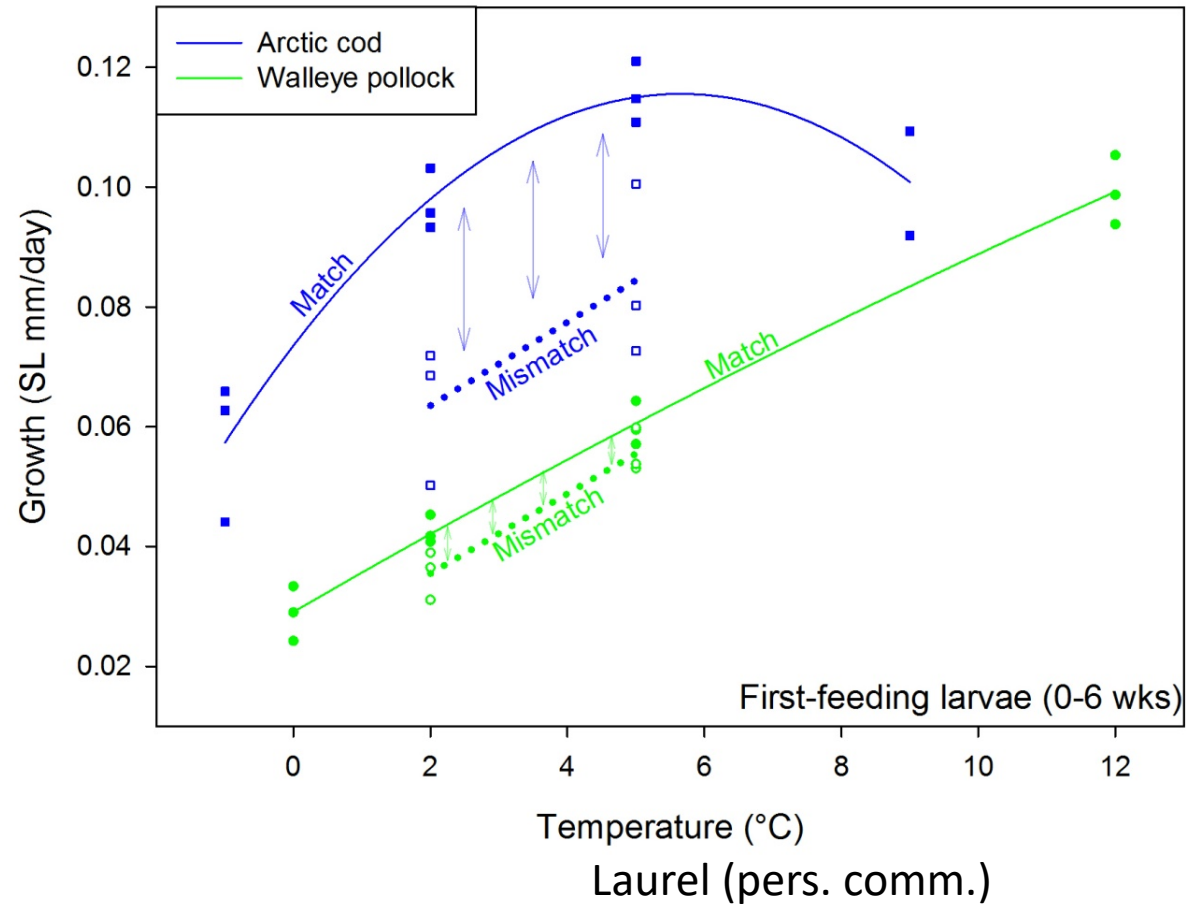
2. Research themes at AFSC (a sampler…)

Spatio-temporal models

Kai et al. (2017) *CJFAS*. 74(11): 1765-1780

Shortfin mako shark in the Western Pacific

Can model distribution for different sizes

- Show changes in distribution by size class
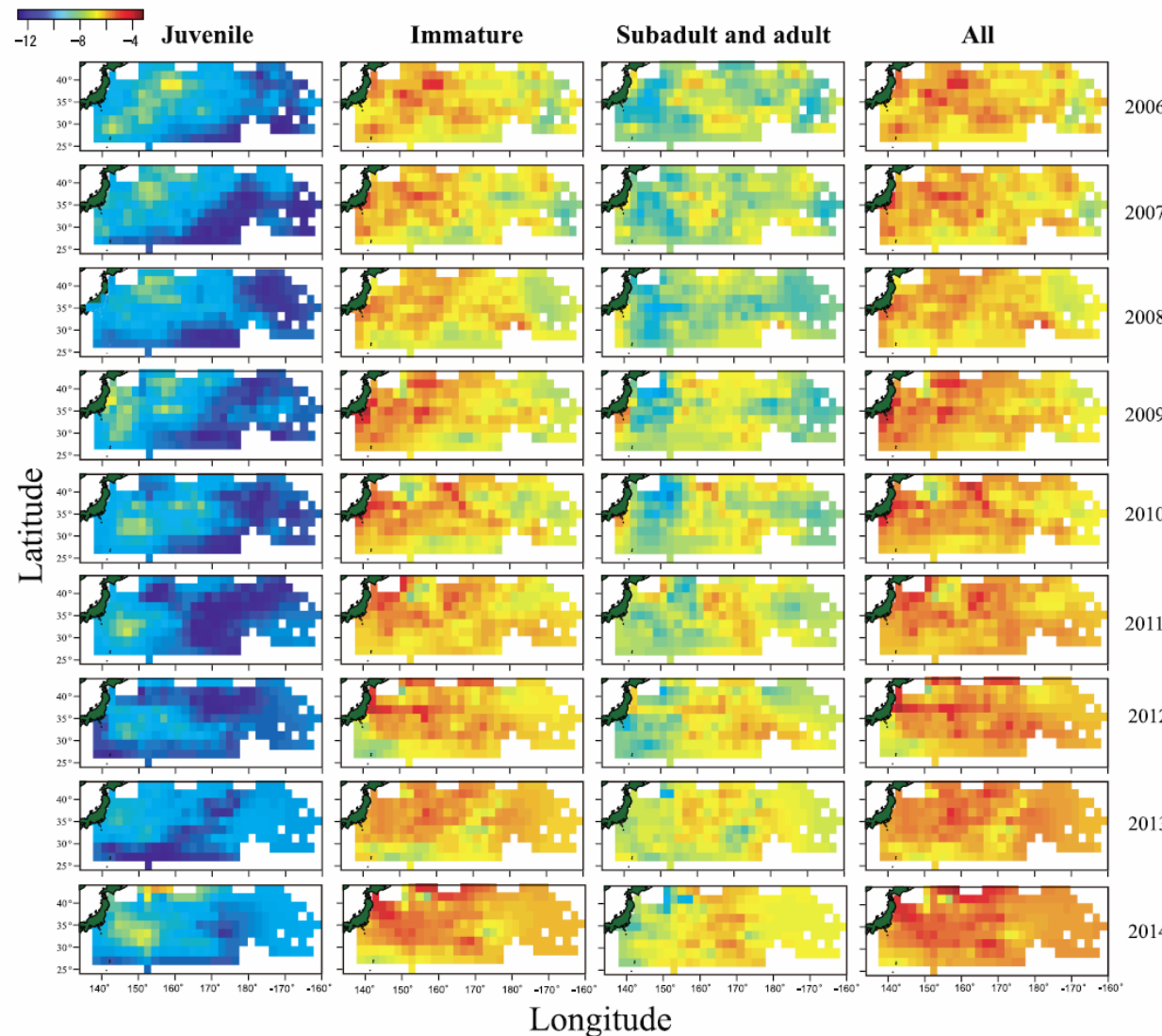
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2. Research themes at AFSC (a sampler…)

Spatio-temporal models

Used to attribute observed shifts to different drivers

- E.g., Pollock distribution shift is not sufficiently explained by temperature in isolation

Thorson et al. (In press) *Fish and Fisheries*.
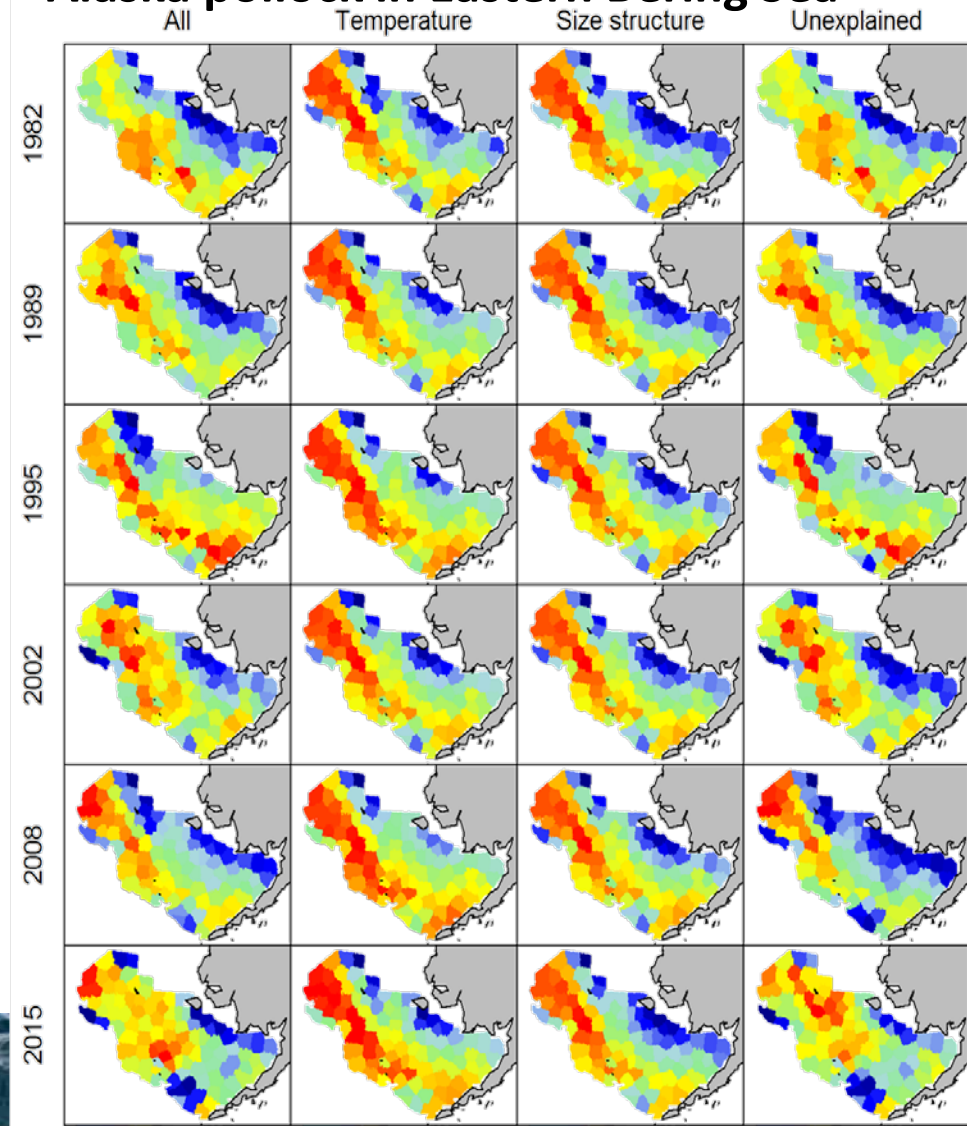
Alaska pollock in Eastern Bering Sea

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Outline

1. What is the evidence for rapid distribution shift worldwide?

2. What research themes are being conducted by AFSC scientists to identify and forecast distribution shifts?

3. What research is needed in the next 2-5 years?

- Skill testing

- Attribution

- Comparative analyses

- Combining data

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3. Research for coming years

Skill testing

We need to learn what models work best for predicting distribution shifts

Different models have better/worse skill

- Some good at long-term forecasts
- Others good at short-term

Example: 1-3 year forecasts

- Local bottom temperature is not sufficient to forecast distribution
- Spatio-temporal model works well

Pacific cod in Eastern Bering Sea

Climate envelope

VAST

VAST with temperature

Annual regression

Fitted to data through year...
- 2015
- 2011
- 2007
- 2003
- 1999
- 1995

Centroid (km north of equator)

Year

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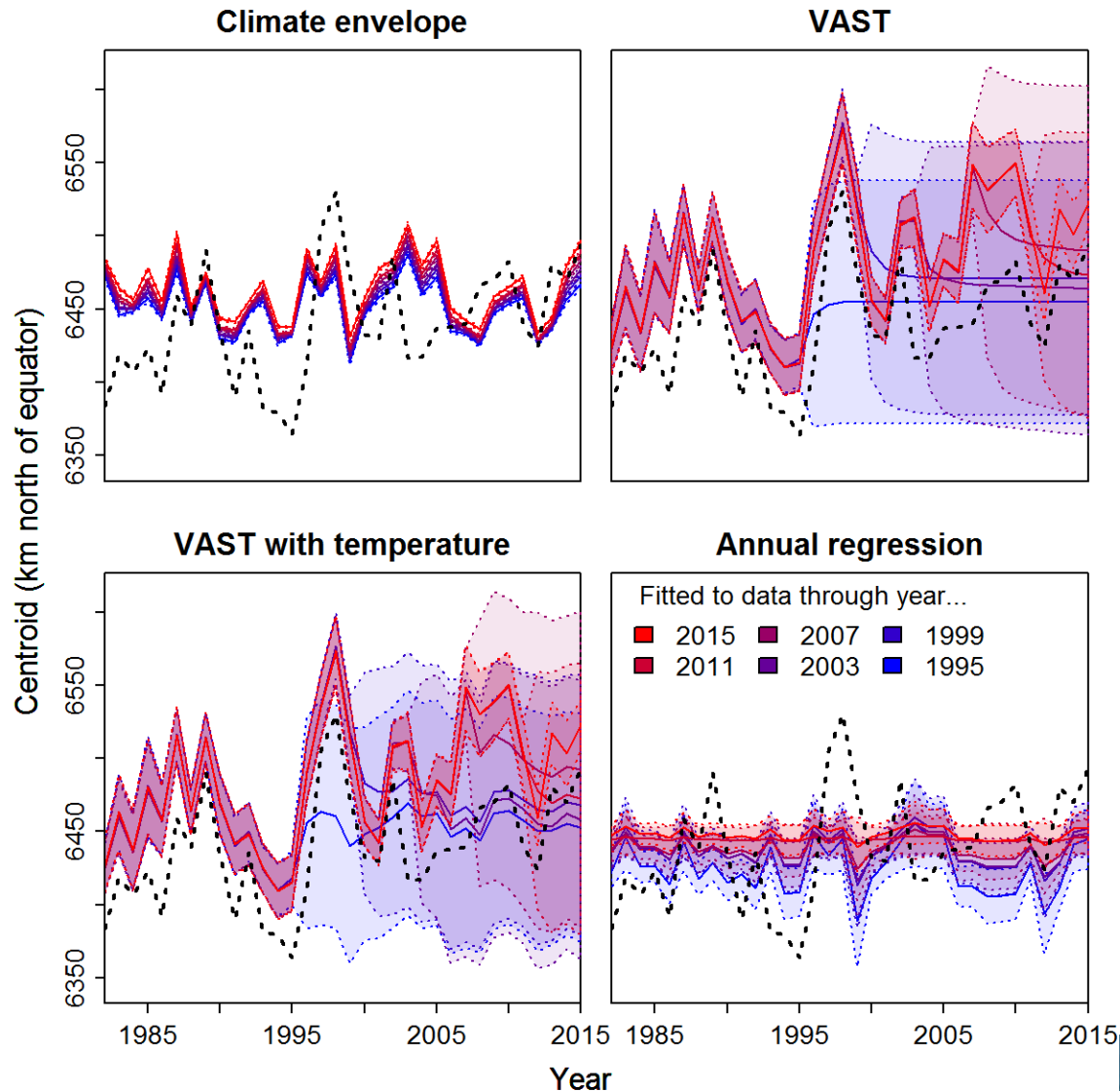
3. Research for coming years

Attribution

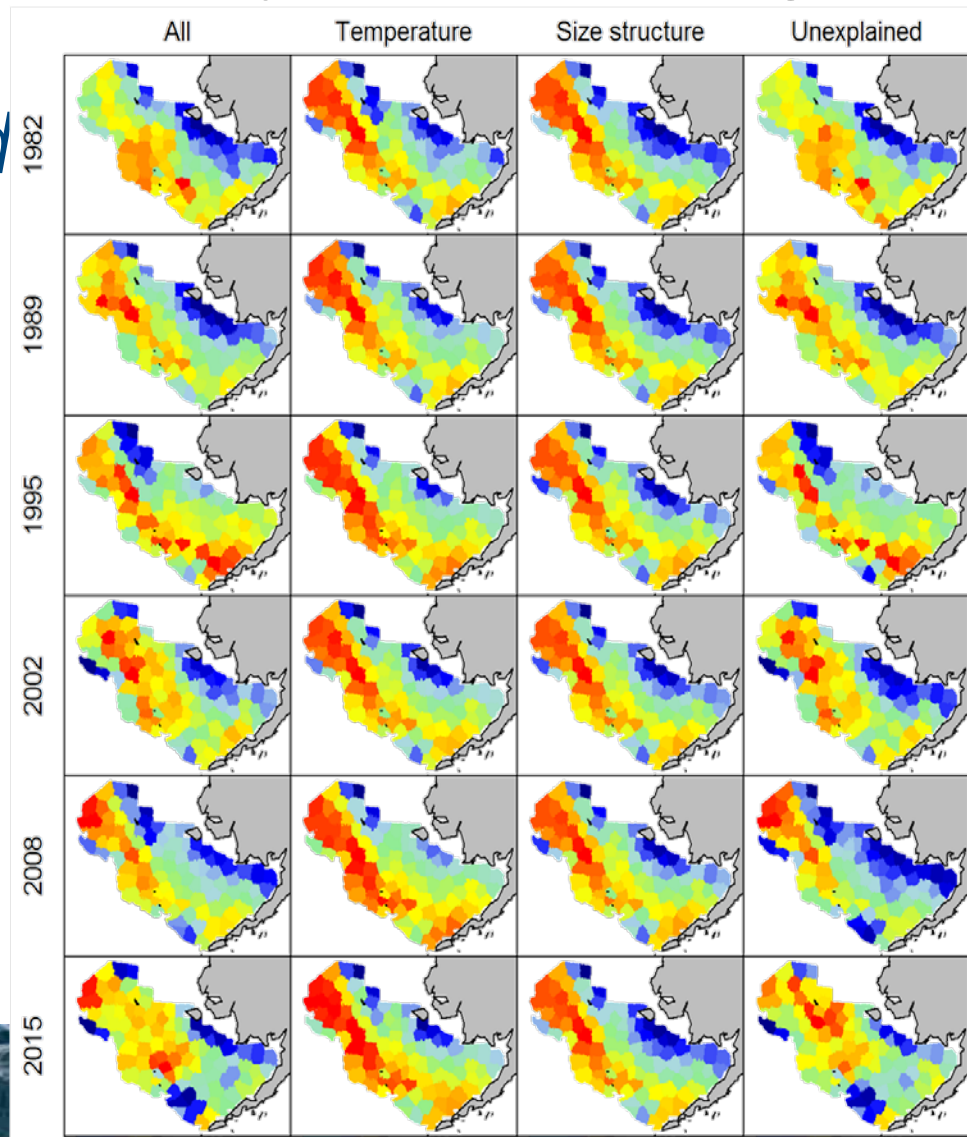*We need to understand why observed patterns happened*

- Structural models include multiple drivers
  - Bottom-up (temperature)
  - Top-down (predation)
  - Human (fishing)
- Can attribute observed shifts to different drivers

Thorson et al. (In press) *Fish and Fisheries*.
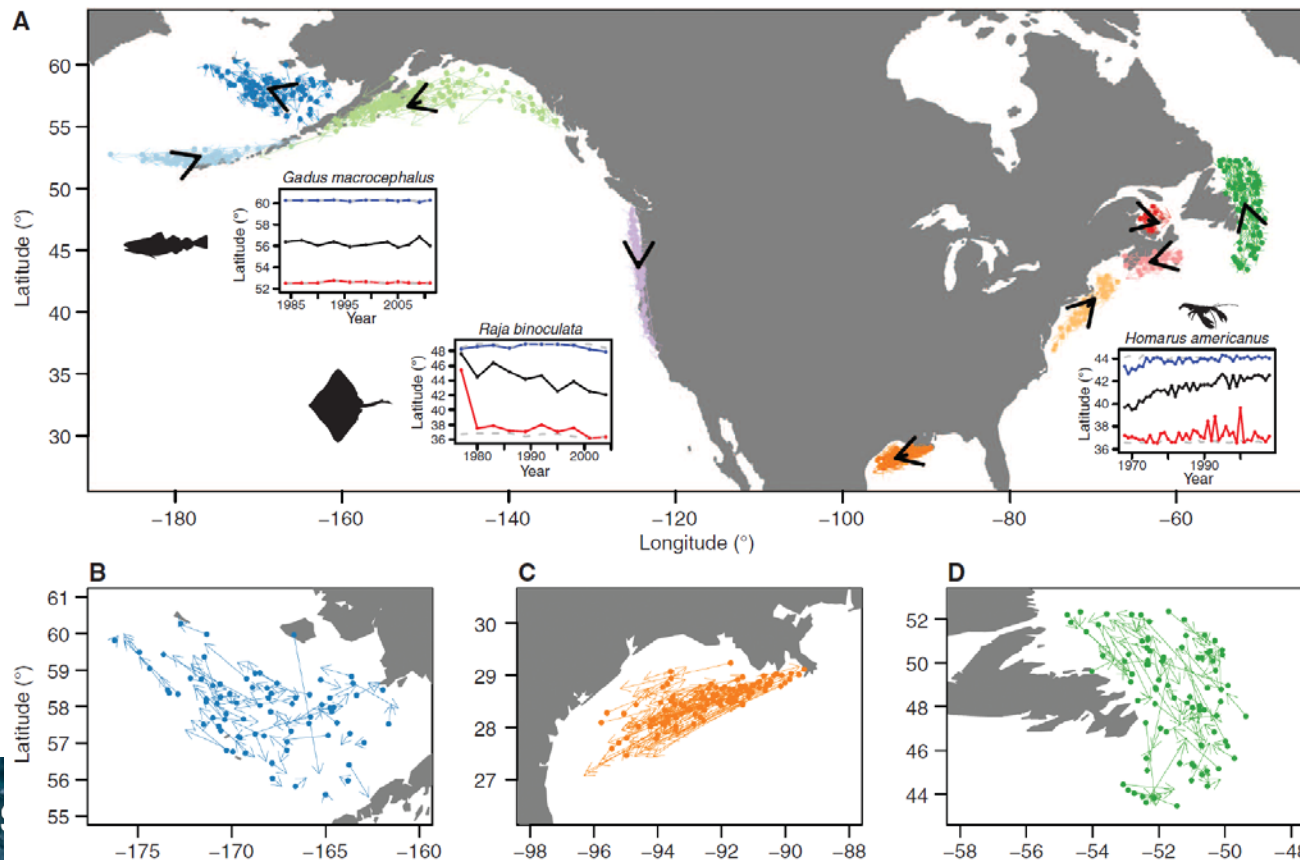**Alaska pollock in Eastern Bering Sea**

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3. Research for coming years

Comparative analysis

We can learn faster by testing methods on changes in other regions

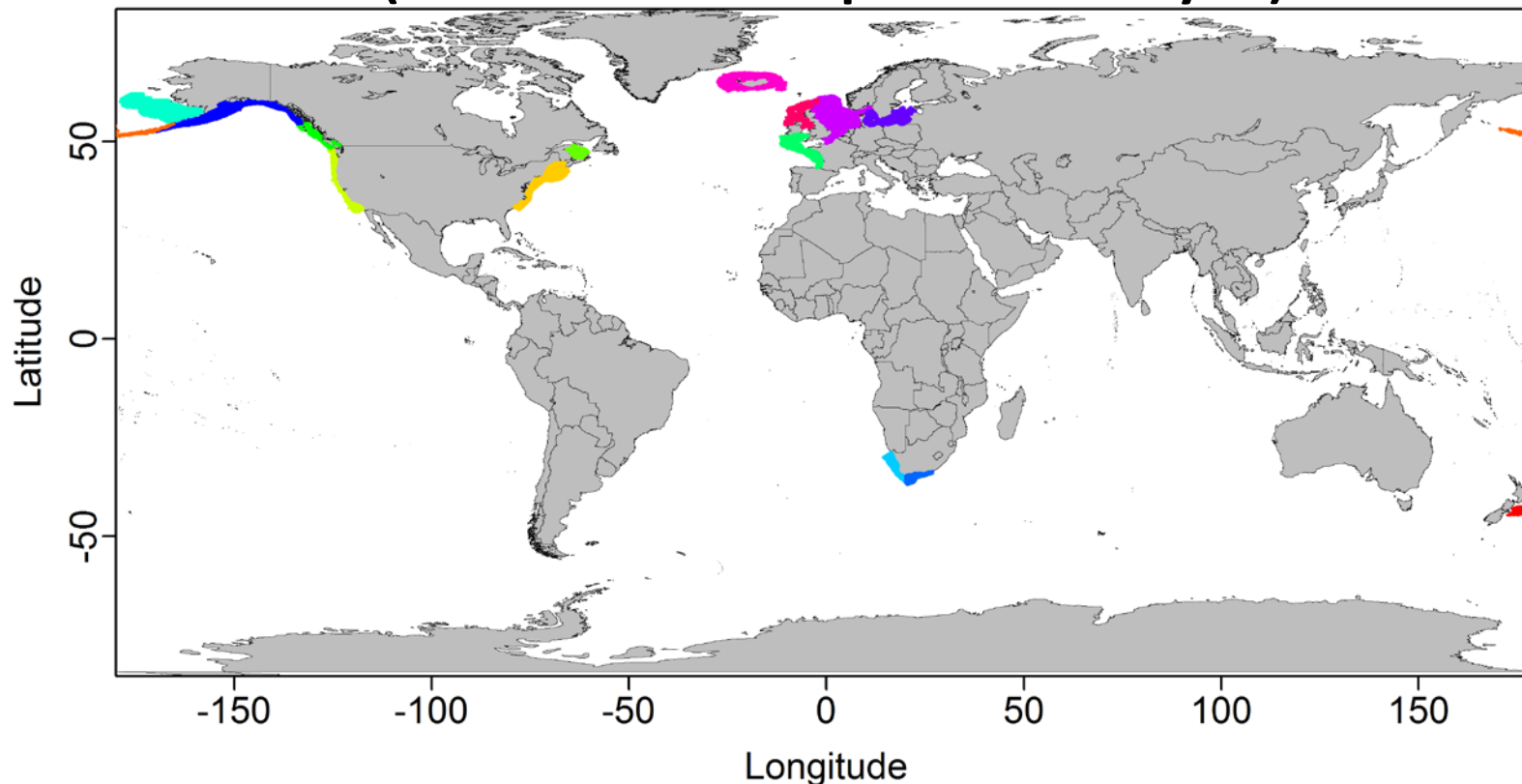Pinsky et al. (2013) *Science* **341**, 1239–1242.

3. Research for coming years

Combining data

We need to look at basin scales to distinguish changes in abundance vs. distribution

**Public bottom trawl surveys
(available for comparative analysis)**

NOAA FIS

Conclusions

1. What is the evidence for rapid distribution shift worldwide?

Many regions show strong evidence worldwide!

2. What research themes are being conducted by AFSC scientists to identify and forecast distribution shifts?

Diverse portfolio is showing success for many species

3. What research is needed in the next 2-5 years?

New approaches are evolving quickly and need additional efforts

Acknowledgements

- Mike Sigler
- Discussions and slides
  - Stan Kotwicki
  - Ben Laurel
  - Steve Barbeaux
  - Chris Rooper
  - Jie Cao
  - Kirstin Holsman
- Researchers noted in slides
- Decades of research and data collection at AFSC!

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