Climate related changes in the distribution and abundance of pelagic fish in the eastern Bering Sea

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Eastern Bering Sea

Eastern Bering Sea

A transition zone between Pacific and Arctic ecosystems

A large, highly productive shallow (100 m) shelf

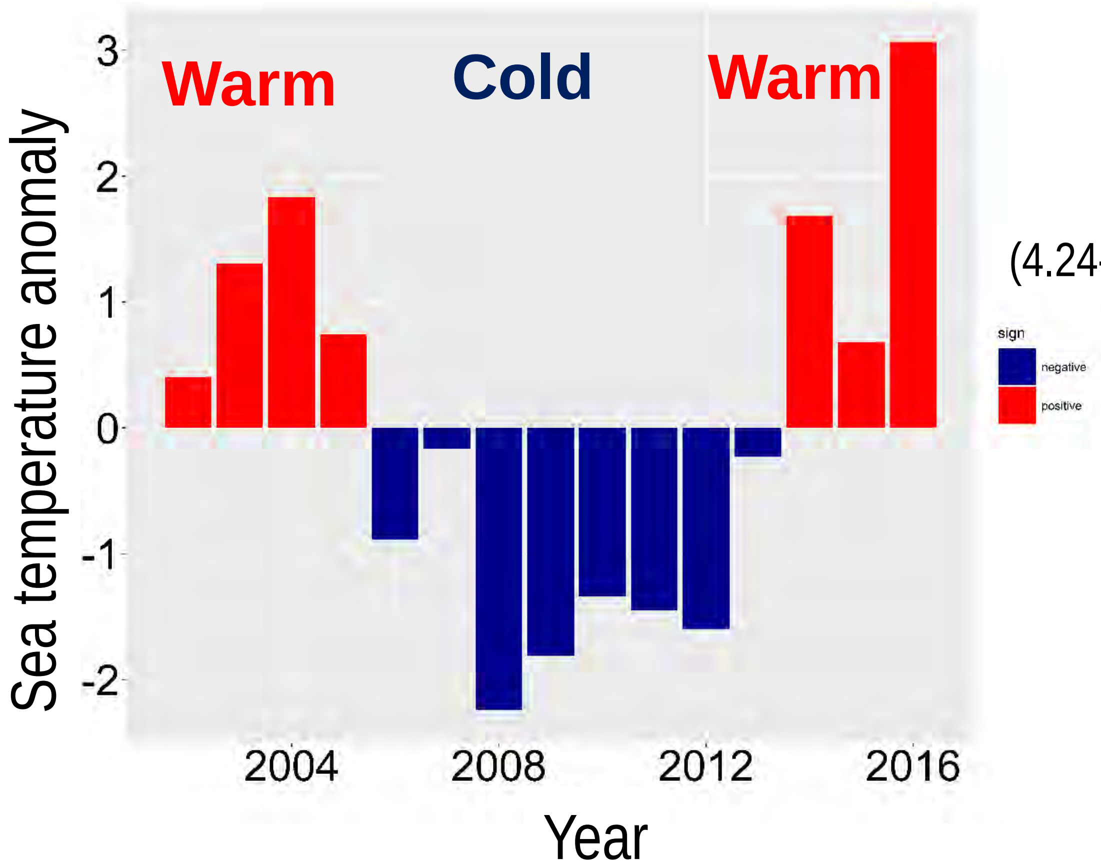
An important rearing habitat for forage fish and juvenile fish

What will happen to pelagic fish with warming?

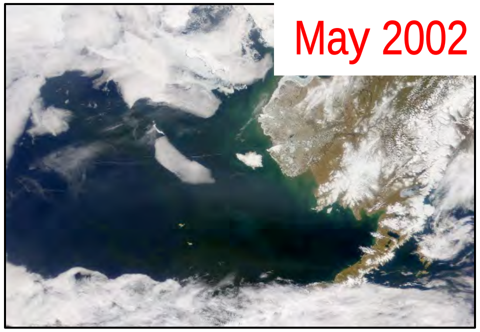
Hypotheses

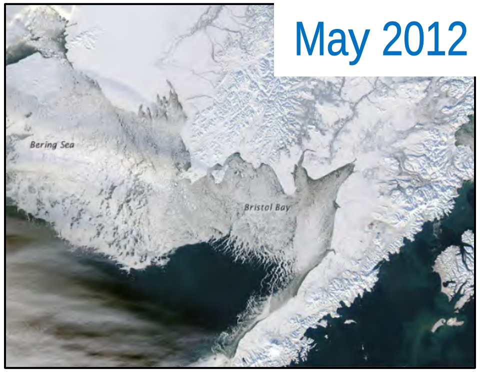
1. Pelagic fish will decrease in abundance during warm years due to reduced prey quality (⬇**Abundance**).
2. Pelagic fish will expand their range during warm years to search for food (⬆**Area occupied**).
3. Pelagic fish will distribute farther north during warm years to search for large zooplankton, closer to the ice “footprint” (⬆**Northward shift**).

Sea ice and temperature are important in establishing feeding conditions for pelagic species in the eastern Bering Sea



(4.24-9.56 °C)





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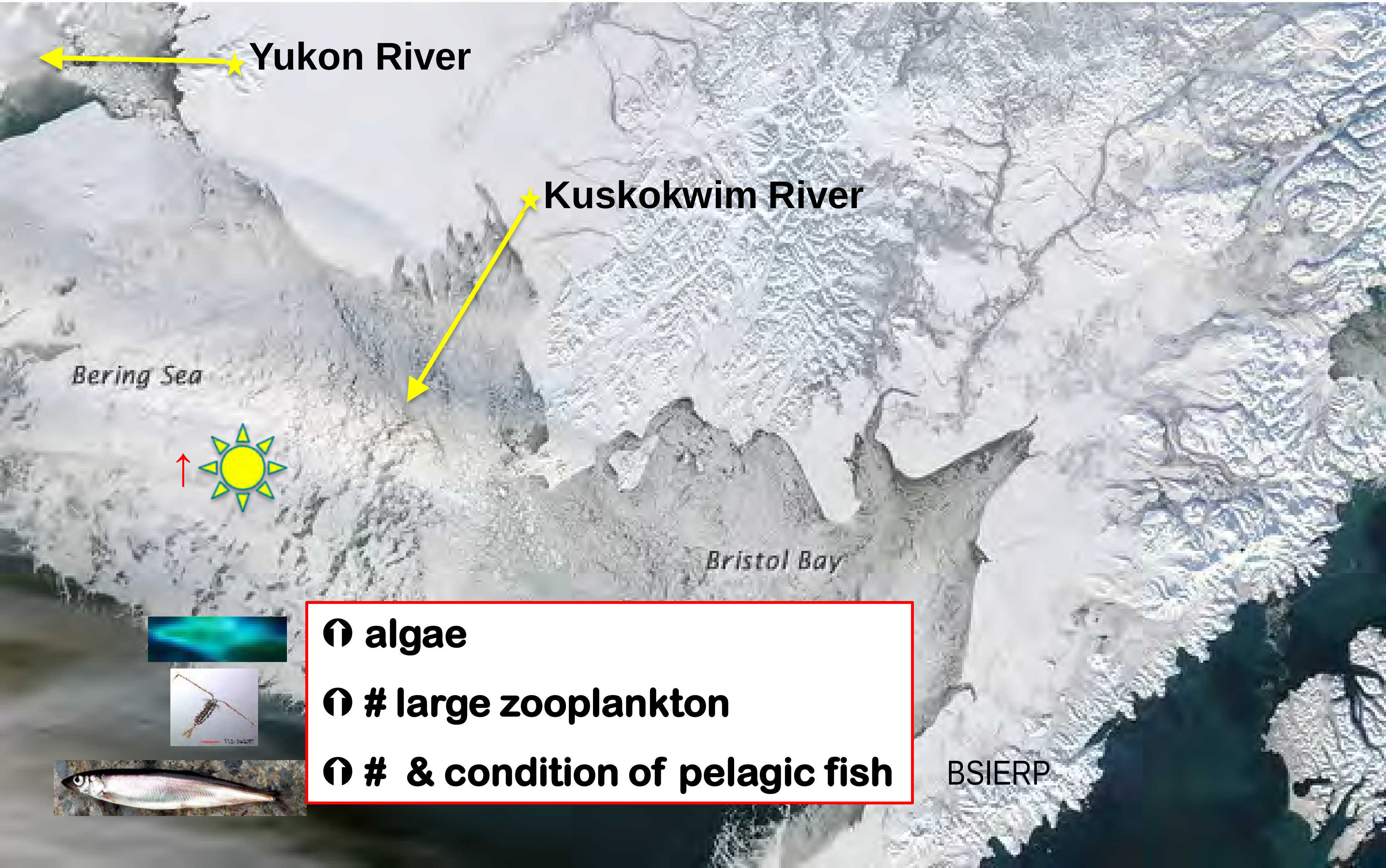
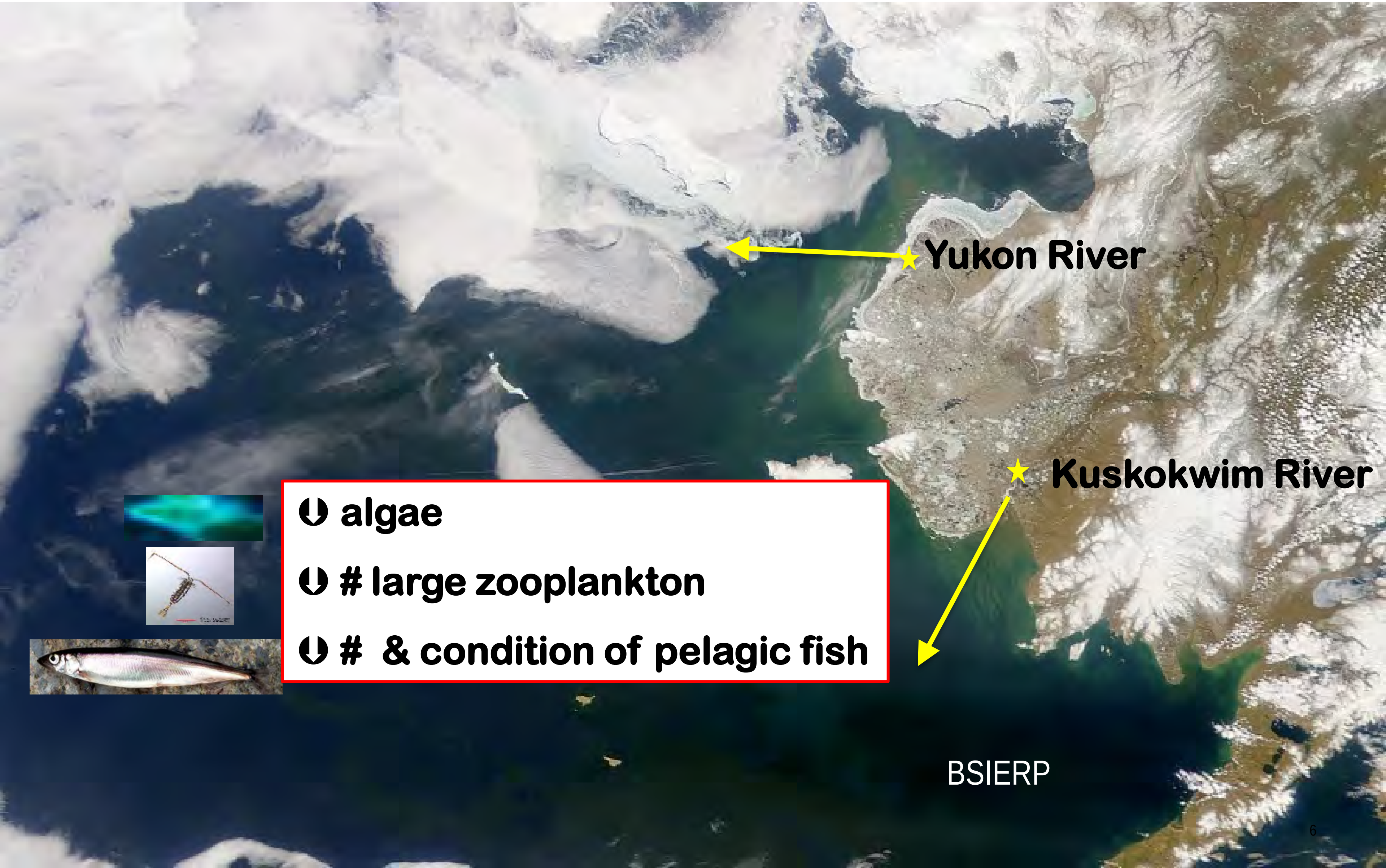
High inter-annual variability in sea temperatures (Connor & Lauth 2017)

Cold years: Increased zooplankton production

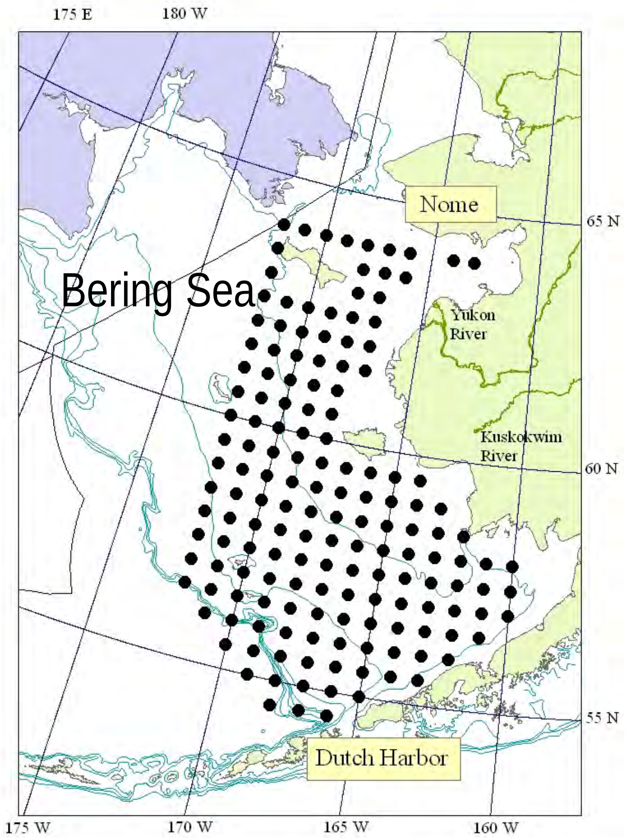


Warm years: Decreased zooplankton production



AFSC pelagic trawl survey in eastern Bering Sea

Survey grid



2002-2016
Late summer
Surface trawl catches (0-20 m)
Juvenile salmon, age-0 gadids, forage fish

Pelagic fish of interest: most abundant

Capelin

Pacific herring

Sand lance

Pacific cod (age-0)

Pollock (age-0)

Oncorhynchus spp.

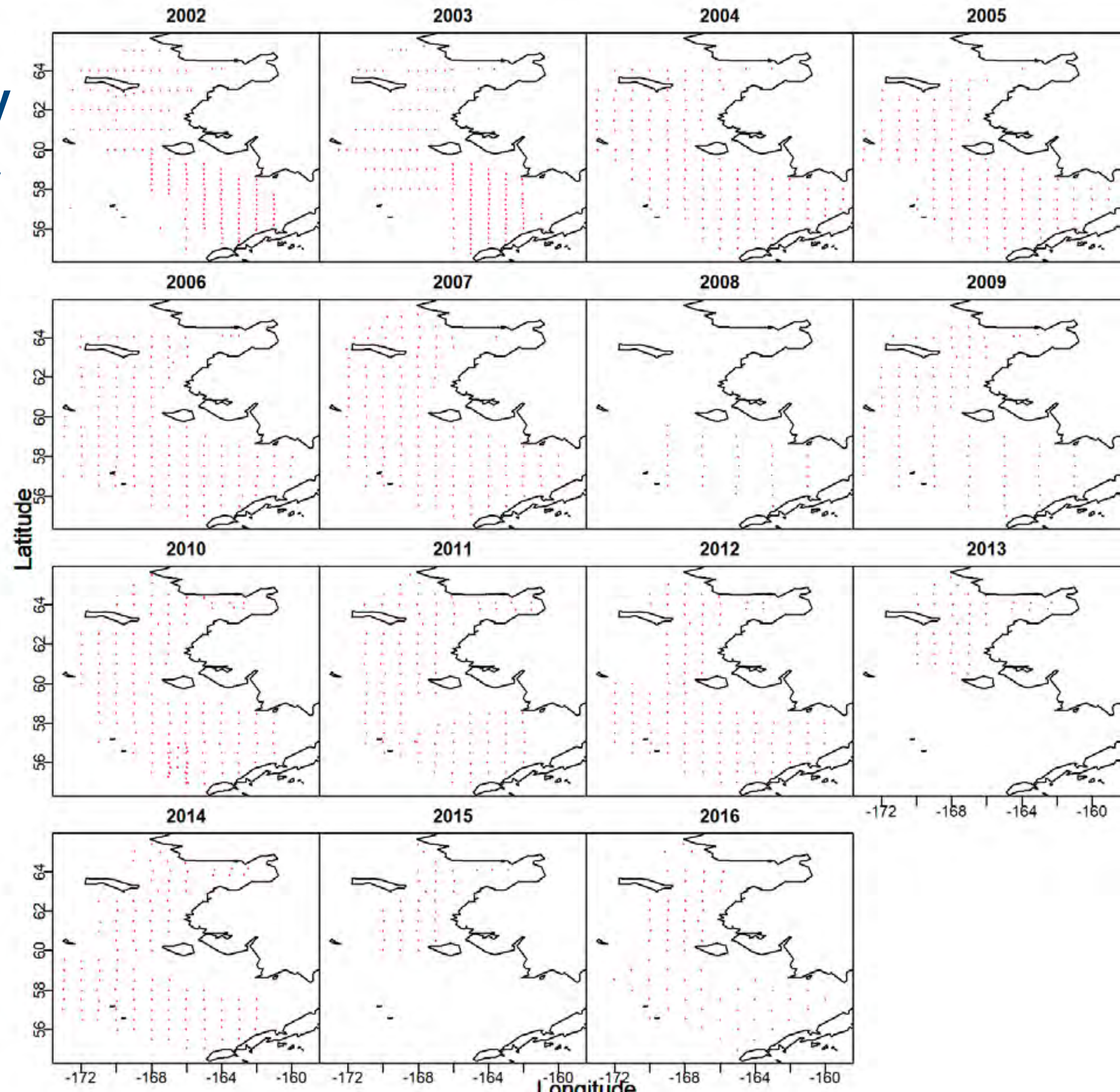
- Pink salmon
- Chum salmon
- Sockeye salmon
- Chinook salmon

http://www.dimensionsinfo.com/herring-sizes/

Survey stations in the eastern Bering Sea

However, the survey data are not directly comparable across years due to:

- Inconsistent design
- Skipped longitudes
- Missing regions



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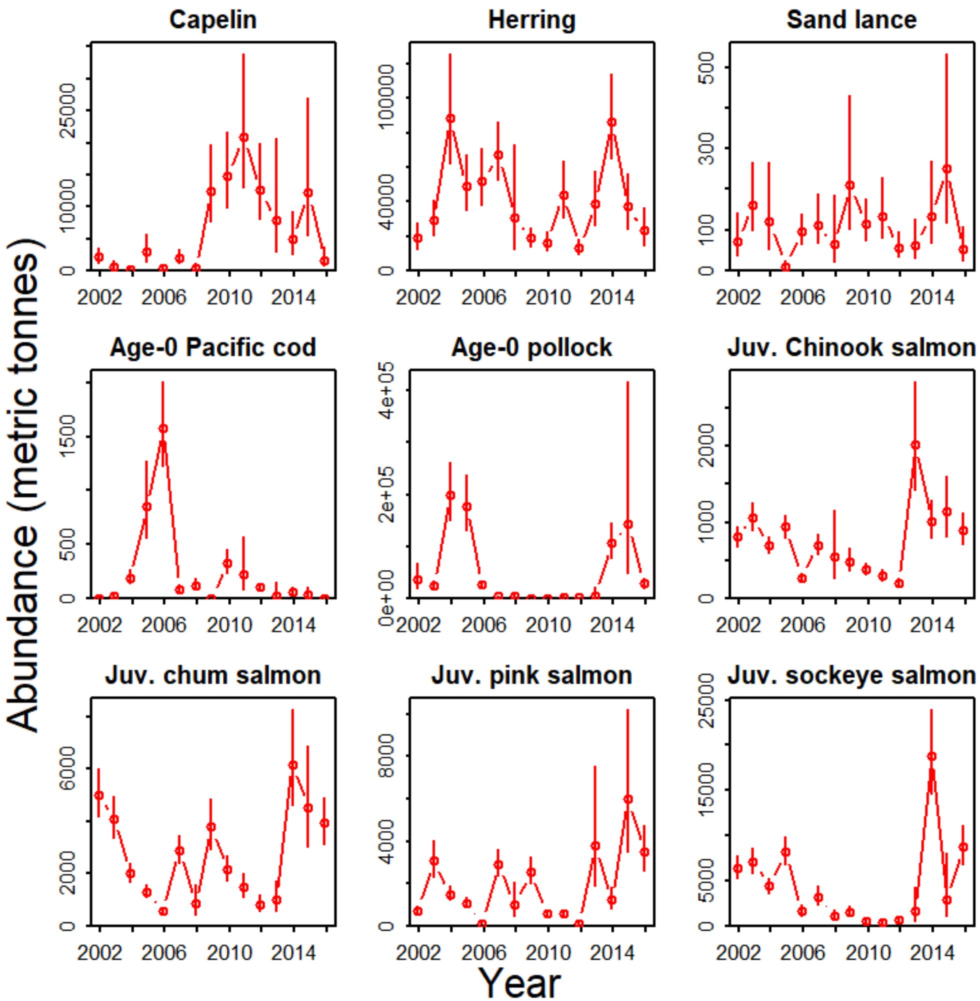
Apply geostatistical multispecies model for data limited surveys

- Vector-Autoregression Spatio-Temporal (VAST) package in R (Thorson et al. 2015, 2016, 2017) Github: nwfsc-assess/geostatistical_delta-GLMM
- Follow “best practices” for model selection
- Delta model: Estimates probability of encounter at each station and catch rate, given an encounter

Indices estimated in VAST for this project

1. Spatiotemporal correlations in catch rate (given an encounter) among species
2. Abundance index
   - Biomass (metric tons)
3. Range expansion (contraction) index
   - Area occupied ($\boldsymbol{ln}(\text{km}^2)$)
4. Center of gravity (distribution) index
   - Distance north from equator (km)

Estimated biomass for survey area



Species	Mean biomass (mt)
Sand lance	110
Pacific cod	241
Chinook salmon	765
Pink salmon	1925
Chum salmon	2713
Sockeye salmon	4522
Capelin	6383
Herring	40802
Pollock	50665

Spatiotemporal correlation for Catch Rate

Positive catch rate

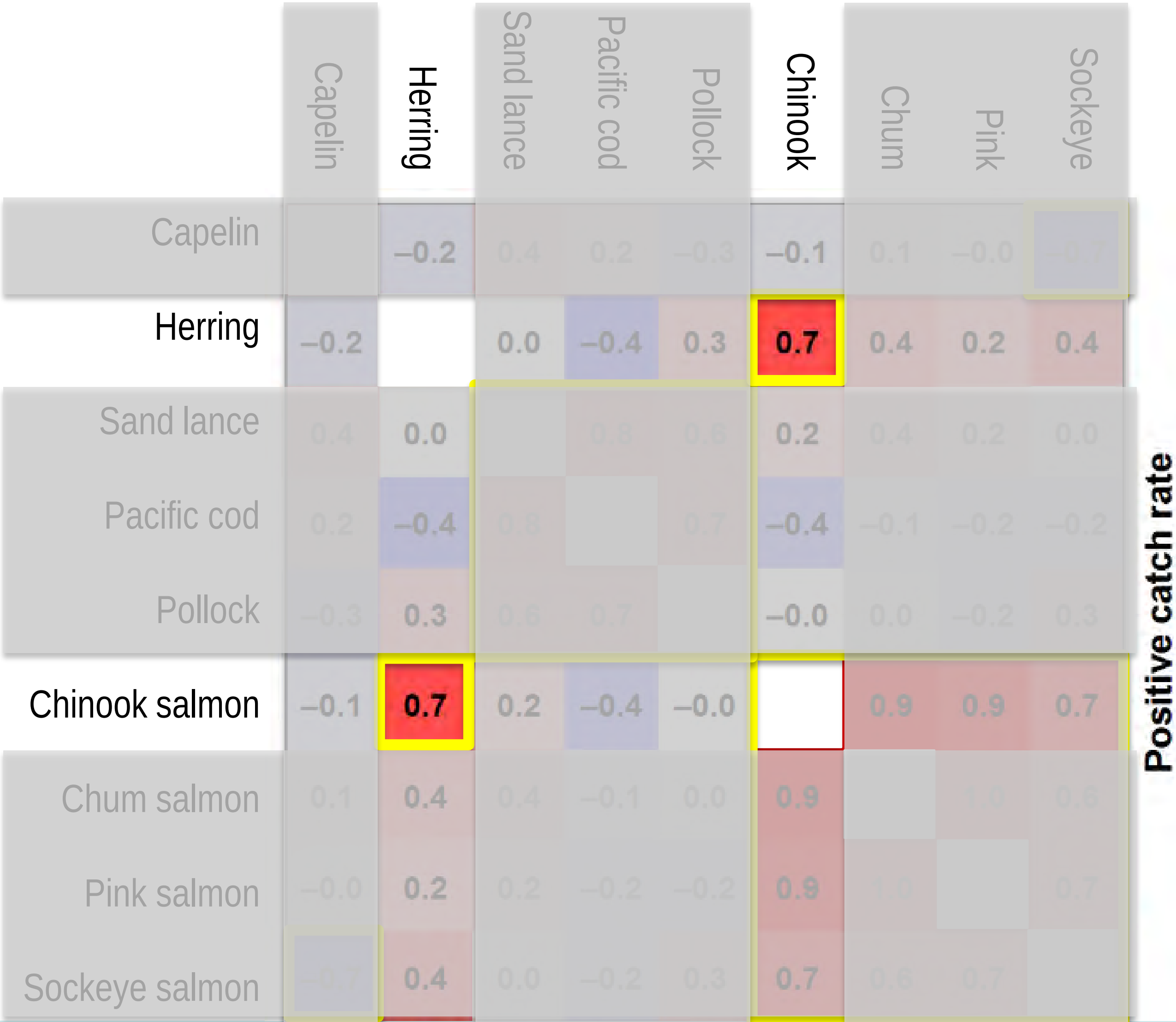
	Capelin	Herring	Sand lance	Pacific cod	Pollock	Chinook	Chum	Pink	Sockeye
Capelin		–0.2	0.4	0.2	–0.3	–0.1	0.1	–0.0	–0.7
Herring	–0.2		0.0	–0.4	0.3	0.7	0.4	0.2	0.4
Sand lance	0.4	0.0		0.8	0.6	0.2	0.4	0.2	0.0
Pacific cod	0.2	–0.4	0.8		0.7	–0.4	–0.1	–0.2	–0.2
Pollock	–0.3	0.3	0.6	0.7		–0.0	0.0	–0.2	0.3
Chinook salmon	–0.1	0.7	0.2	–0.4	–0.0		0.9	0.9	0.7
Chum salmon	0.1	0.4	0.4	–0.1	0.0	0.9		1.0	0.6
Pink salmon	–0.0	0.2	0.2	–0.2	–0.2	0.9	1.0		0.7
Sockeye salmon	–0.7	0.4	0.0	–0.2	0.3	0.7	0.6	0.7	

Four groupings:

1. Chinook & herring (+)
2. Pollock, cod, sandlance (+)
3. Salmon (+)
4. Capelin & sockeye (-)

Significant at $r \geq 0.5$

Spatiotemporal correlation for Catch Rate



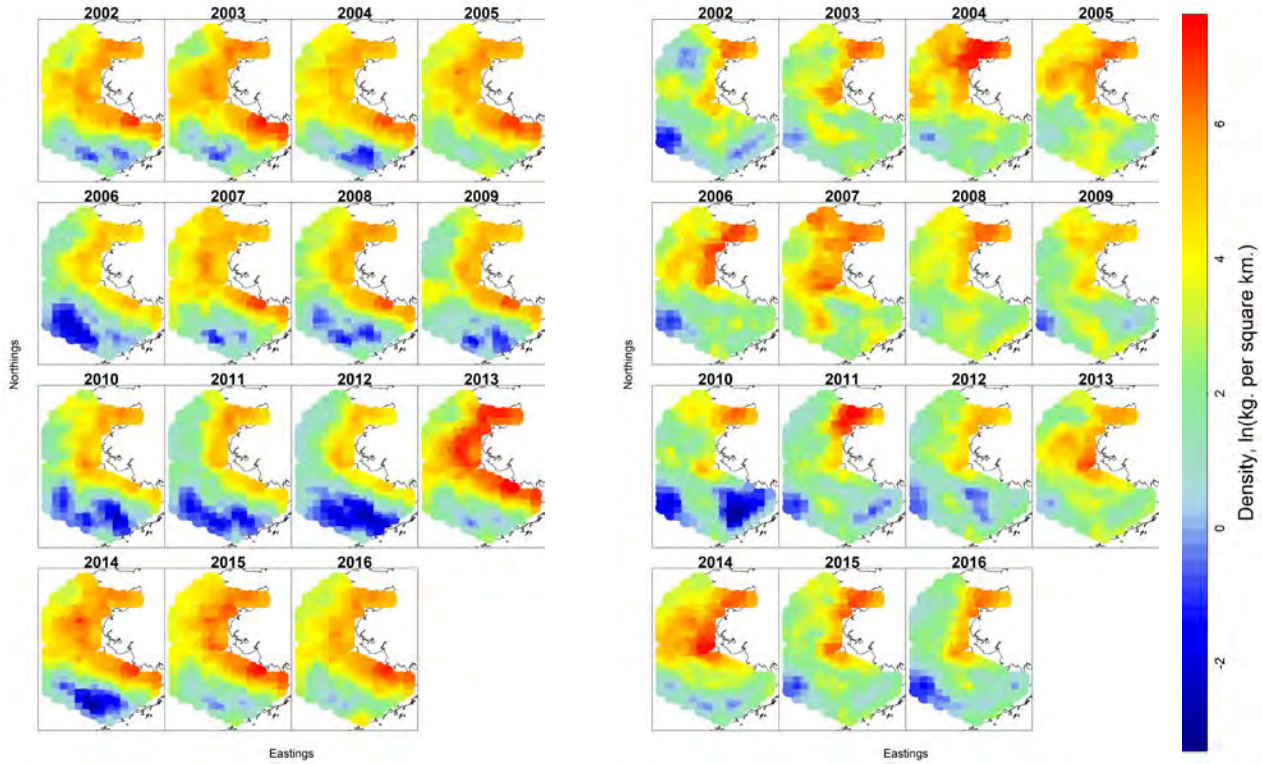
Four groupings:

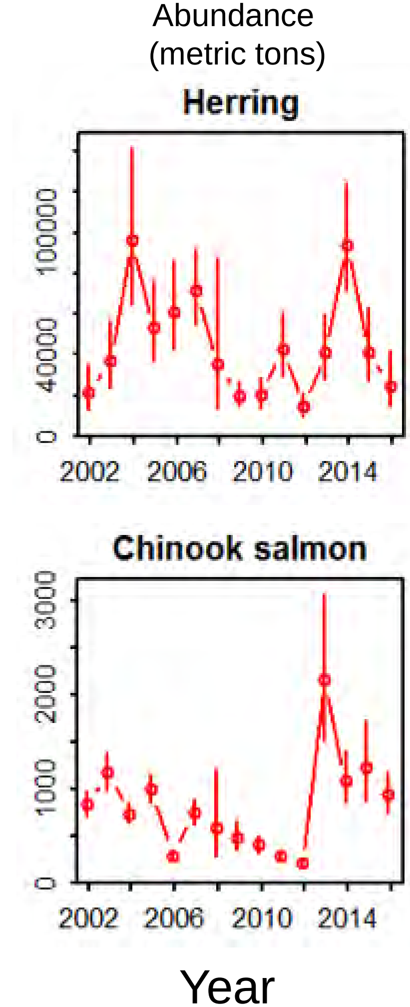
1. Chinook & herring (+)
2. Pollock, P. cod, sandlance (+)
3. Salmon (+)
4. Capelin & sockeye (-)

Significant at r ≥ 0.5

Group 1—Chinook Salmon and Herring

Juvenile Chinook salmon **Herring**

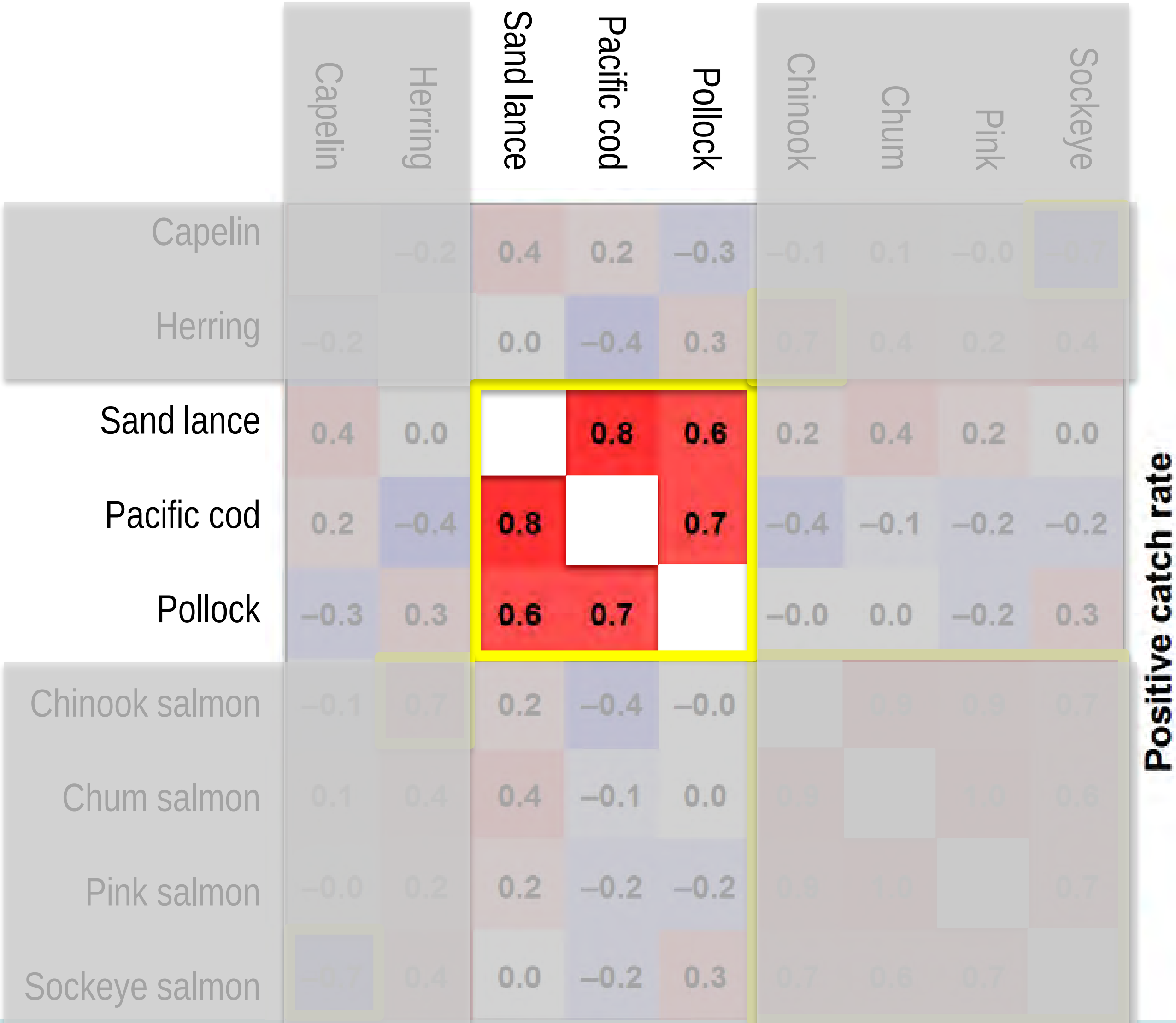




Distributed northwards and more nearshore during cold years

More abundant during warm years

Spatiotemporal correlation for Catch Rate



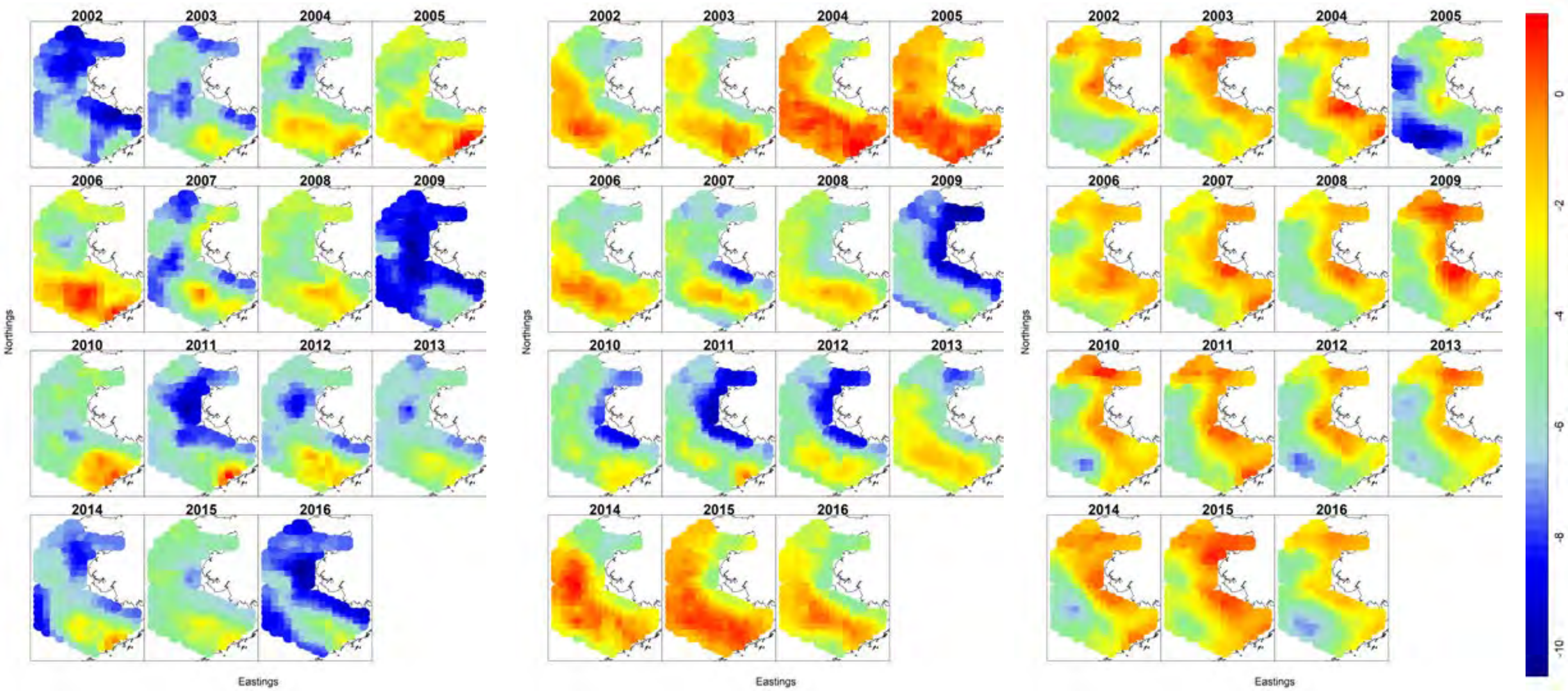
Four groupings:

1. Chinook & herring (+)
2. Pollock, P. cod, sandlance (+)
3. Salmon (+)
4. Capelin & sockeye (-)

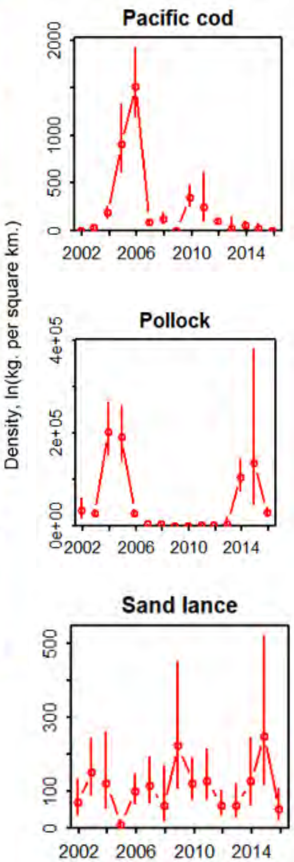
Significant at $r \geq 0.5$

Group 2—P. cod, Pollock, and Sand lance

Pacific cod (age-0) **Pollock (age-0)** **Sand lance**



Abundance (metric tons)



Year

Distributed southwards and onto the middle shelf during cold years
Often abundant during warm periods

Spatiotemporal correlation for Catch Rate

	Capelin	Herring	Sand lance	Pacific cod	Pollock	Chinook	Chum	Pink	Sockeye
Capelin		–0.2	0.4	0.2	–0.3	–0.1	0.1	–0.0	–0.7
Herring	–0.2		0.0	–0.4	0.3	0.7	0.4	0.2	0.4
Sand lance	0.4	0.0		0.8	0.6	0.2	0.4	0.2	0.0
Pacific cod	0.2	–0.4	0.8		0.7	–0.4	–0.1	–0.2	–0.2
Pollock	–0.3	0.3	0.6	0.7		–0.0	0.0	–0.2	0.3
Chinook salmon	–0.1	0.7	0.2	–0.4	–0.0		0.9	0.9	0.7
Chum salmon	0.1	0.4	0.4	–0.1	0.0	0.9		1.0	0.6
Pink salmon	–0.0	0.2	0.2	–0.2	–0.2	0.9	1.0		0.7
Sockeye salmon	–0.7	0.4	0.0	–0.2	0.3	0.7	0.6	0.7	

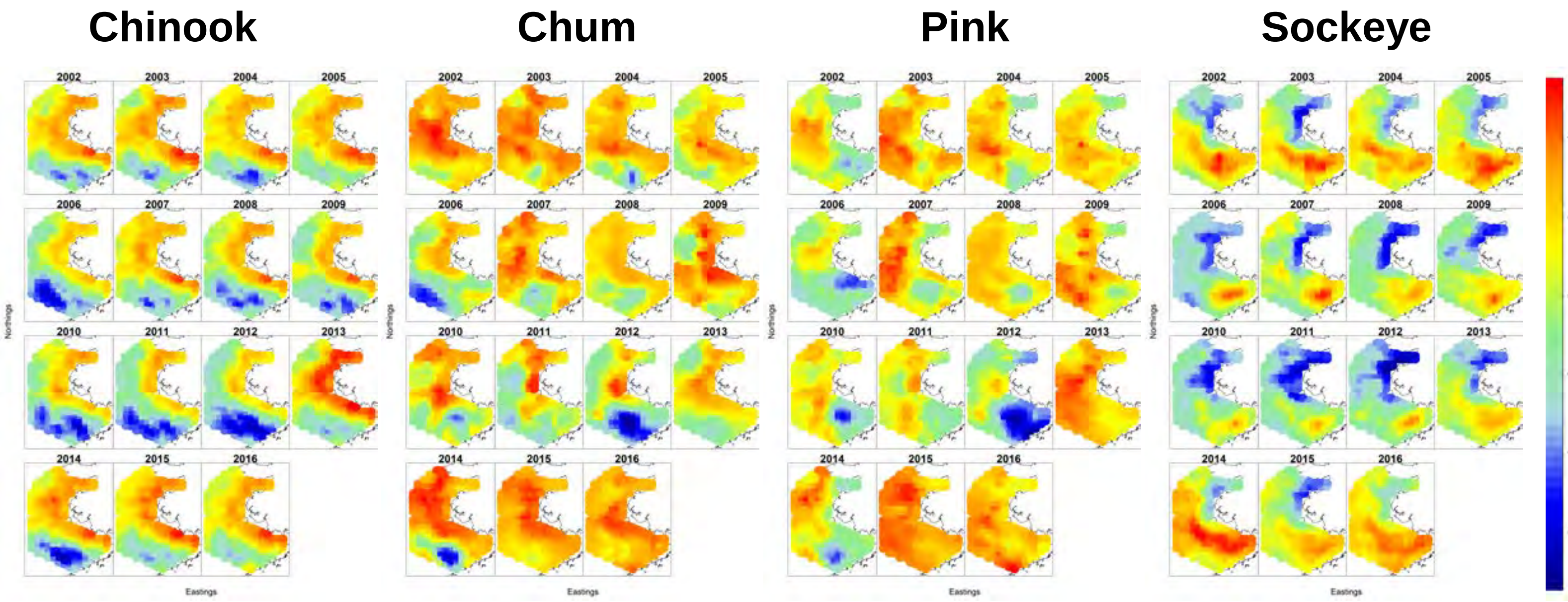
Positive catch rate

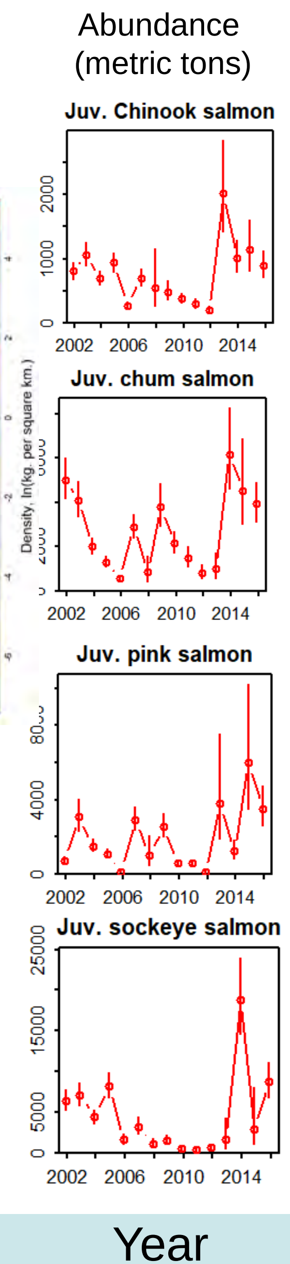
Four groupings:

1. Chinook & herring (+)
2. Pollock, P. cod, sand lance (+)
3. Salmon (+)
4. Capelin & sockeye (-)

Significant at r ≥ 0.5

Group 3—Juvenile Salmon





Distributed north and south across the shelf
Often abundant during warm periods

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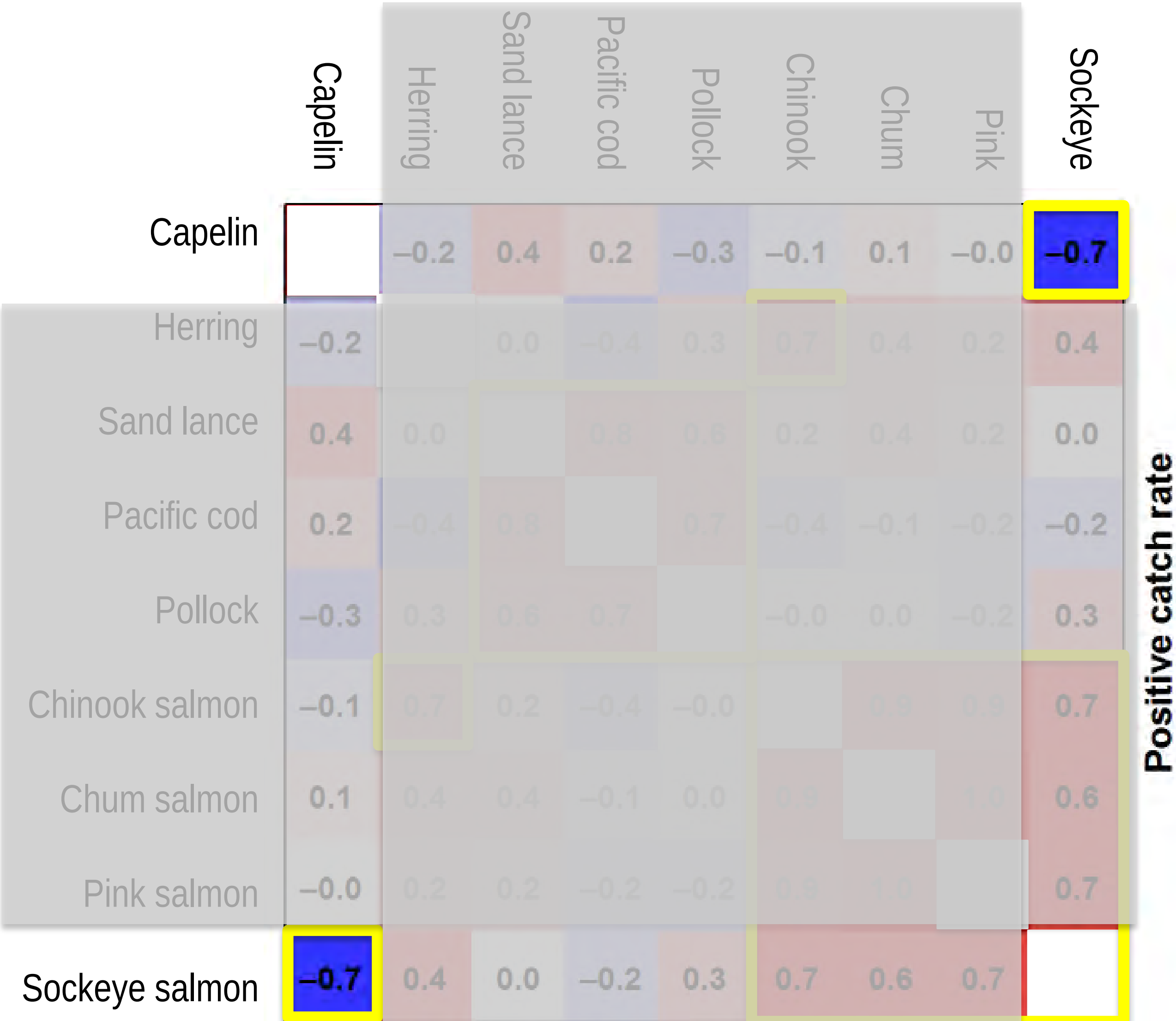
Spatiotemporal correlation for Catch Rate



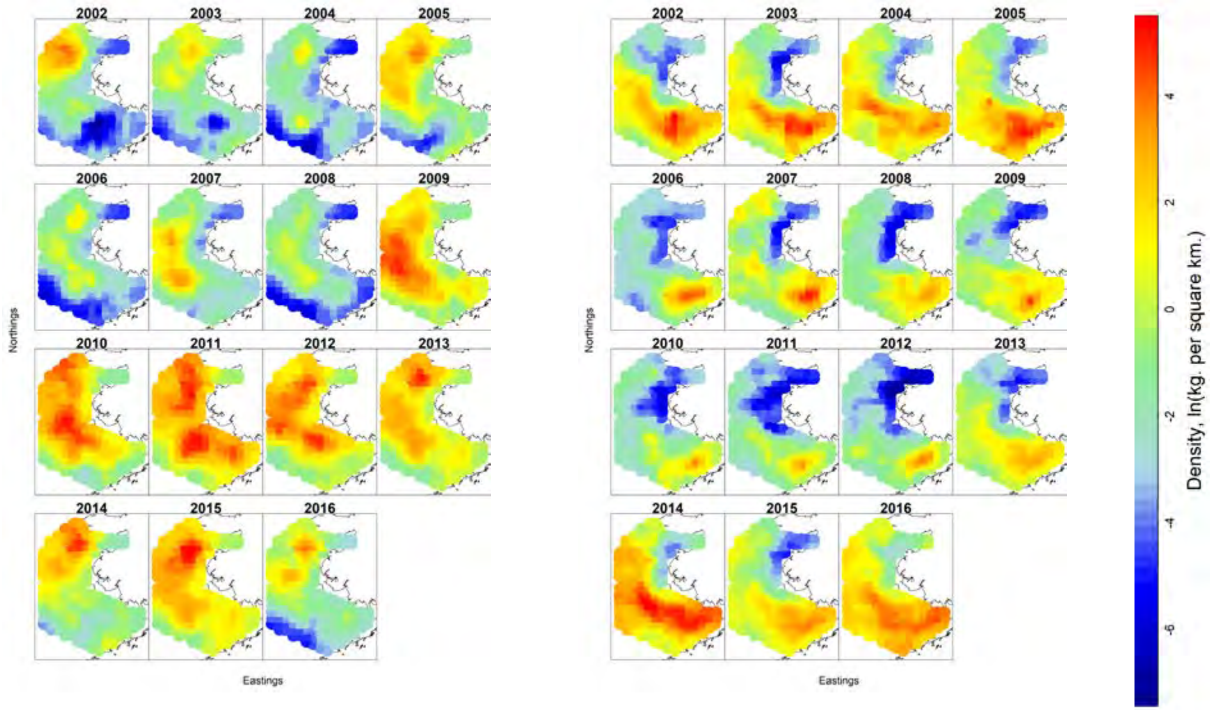
Four groupings:

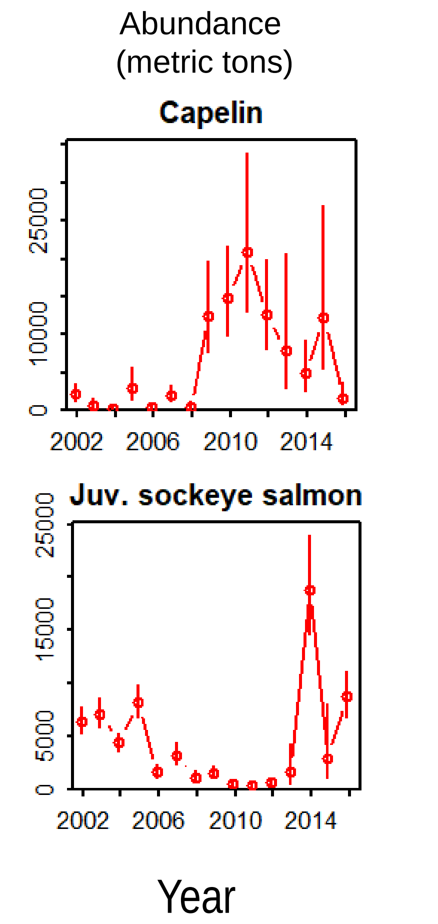
1. Chinook & herring (+)
2. Pollock, P. cod, sandlance (+)
3. Salmon (+)
4. Capelin & sockeye (-)

Significant at r ≥ 0.5

Group 4—Capelin and Juvenile Sockeye Salmon (inverse patterns)

Capelin | **Juvenile sockeye salmon**

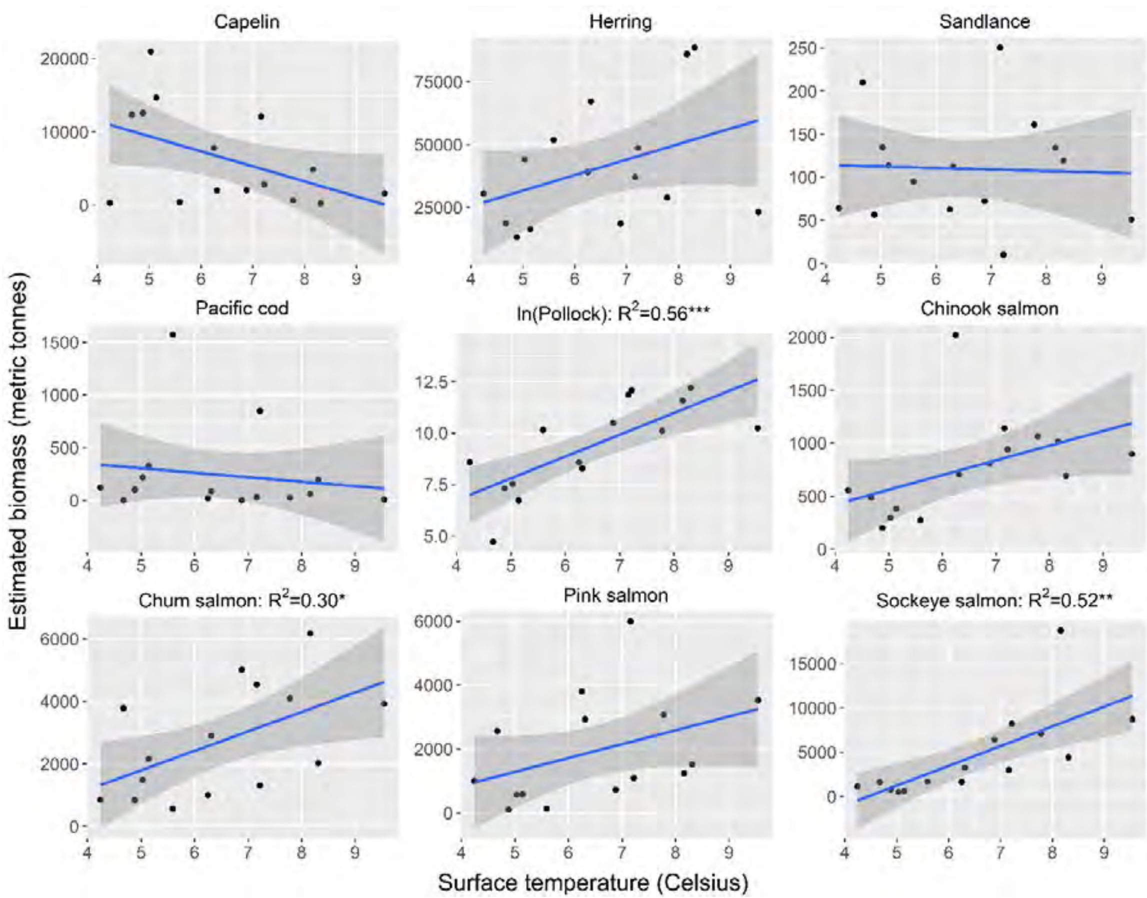




Capelin distributed north. More abundant during colder periods (with a possible lag)

Juvenile sockeye distributed south. More abundant during warm periods

Changes in biomass with warming



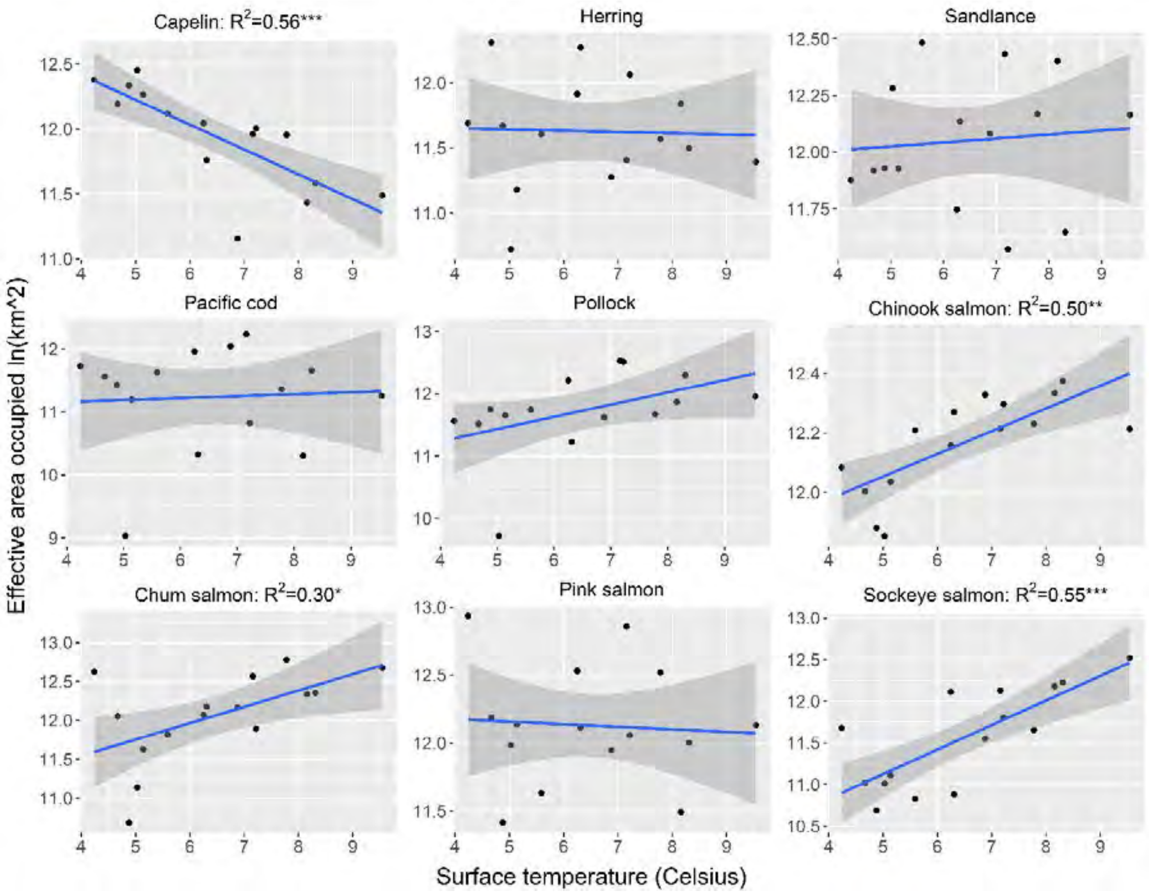
H1: Expected to observe decreases in biomass

- **Observed increases**

Δ Biomass

↑ pollock (age-0)
↑ juvenile chum salmon
↑ juvenile sockeye salmon

Range expansion/contraction with warming



H2: Expected to observe expansion

- **Observed expansion and contraction**

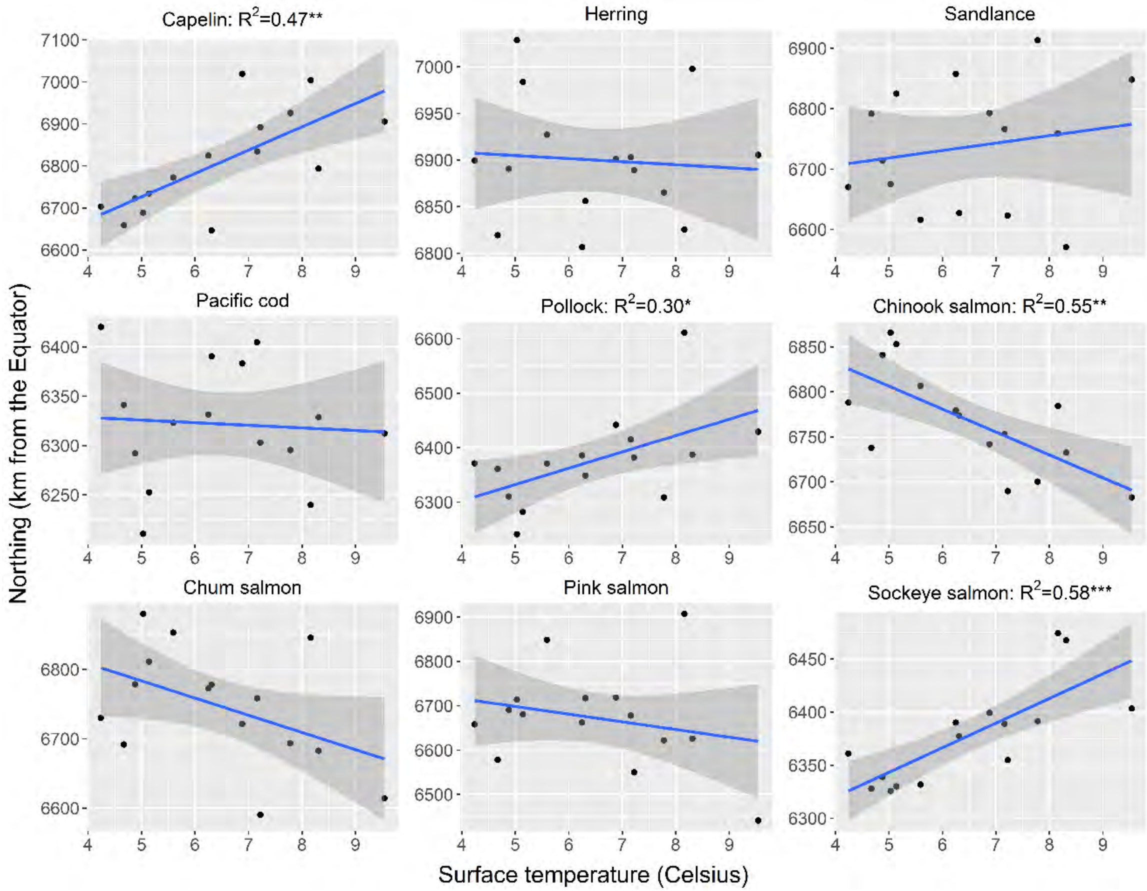
Range expansion

- ⇑ juvenile Chinook salmon
- ⇑ juvenile chum salmon
- ⇑ juvenile sockeye salmon

Range contraction

- ⇓ capelin

Northward movement with warming



H3: Expected to observe northward movement

- **Observed northward and southward movement**

Northward movement

- ⇧ capelin
- ⇧ pollock (age-0)
- ⇧ juvenile sockeye salmon

Southward movement

- ⇩ juvenile Chinook salmon

Implications of warming

- **Biomass ↑ with warming (age-0 pollock, juvenile sockeye salmon, juvenile chum salmon)**
  - Currently, food for pelagic fish may not be limited by warming on the EBS shelf.
- **Fish appear to adapt to warming**
  - Southern abundant planktivores moved north (juvenile sockeye salmon, age-0 pollock) possibly searching of food.
  - Capelin moved north during warm years (also contracted)
  - Range expansions with warming by juvenile salmon indicate possibly searching for food.
- **Warming appears to alter the distribution and abundance of some pelagic fish species in the eastern Bering Sea.**
- No consistent impact of warming by fish group.

Por su atención, muchas gracias

Coming next: Examination of spatial overlap of species with prey and oceanography using VAST

Appreciation for assistance from:

- AFSC BASIS survey crew and scientists
- James Thorson (NWFSC)

Questions to:
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The views expressed herein are those of the author and do not necessarily represent those of NOAA