Opening the Black Box: Advances in Understanding the Marine Phase of the Salmon Lifecycle

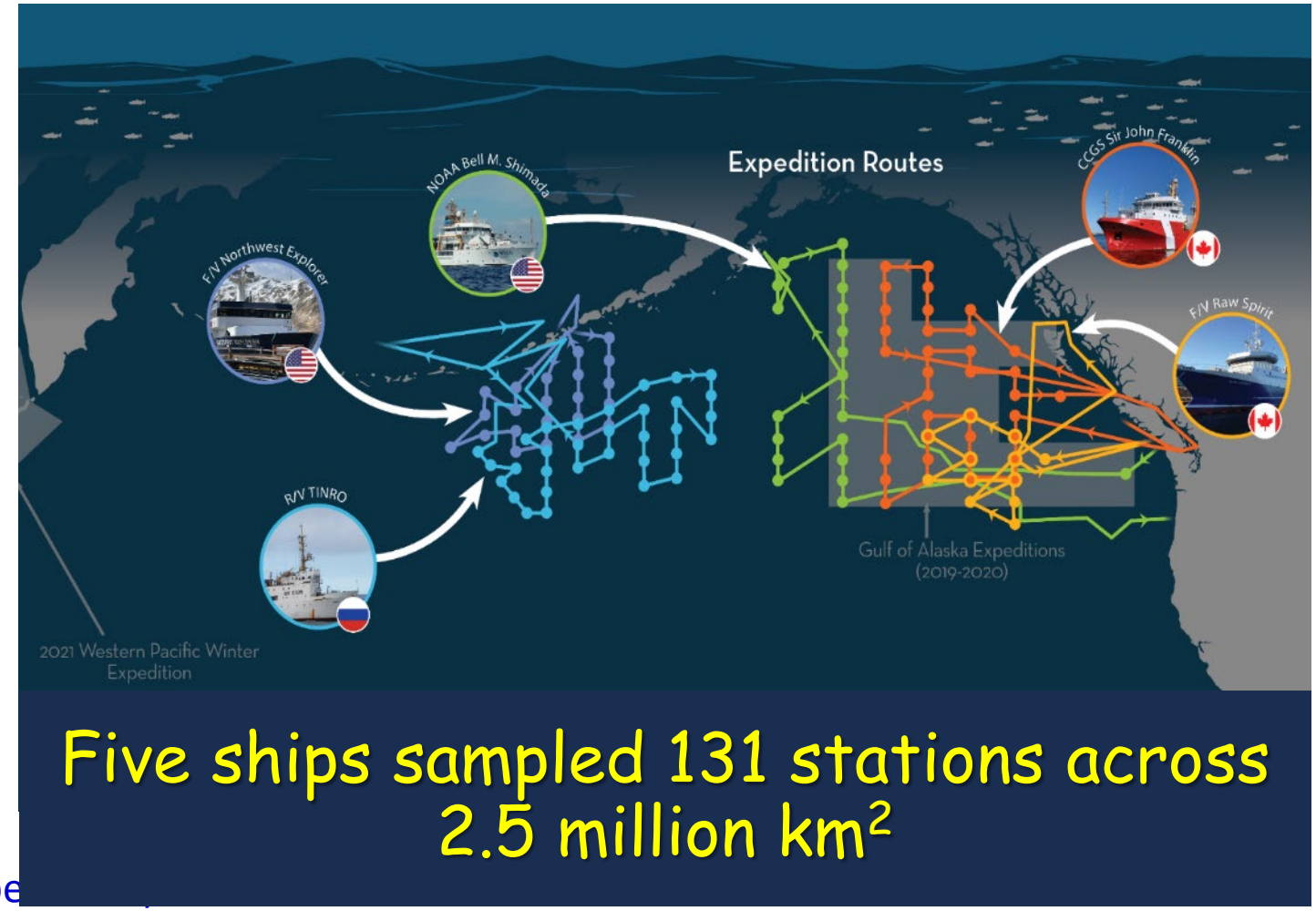
The 2022 IYS Pan Pacific Winter High Seas Expedition

Laurie Weitkamp and Ed Farley: U.S. NOAA Fisheries
Evgeny Pakhomov: University of British Columbia
Jackie King and Cam Freshwater: Fisheries & Oceans Canada
Aleksey Somov: Russian Res Inst Fisheries & Oceanography-Pacific
Mark Saunders, Caroline Graham, Aidan Schubert: IYS/NPAFC
Vladimir Radchenko: North Pacific Anadromous Fish Commission
Dick Beamish: Independent
Brian Riddell: Pacific Salmon Foundation

Fisheries and Oceans Canada | Pêches et Océans Canada

What is the 2022 IYS Pan Pacific Winter Expedition?

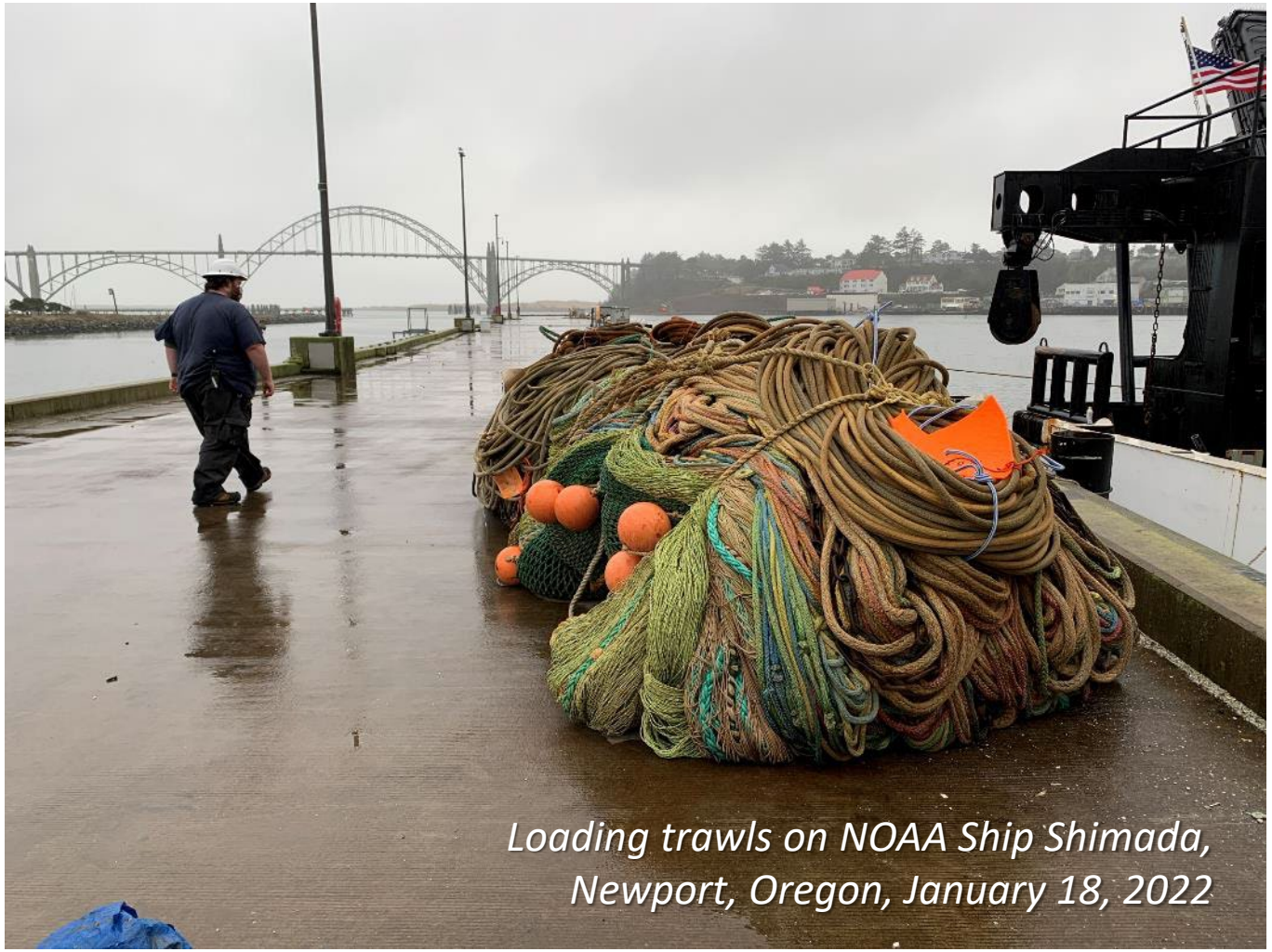
A well-publicized international multi-ship survey of high seas Pacific salmon habitats across the North Pacific Ocean conducted in winter 2022.



https://yearofthesalmon.org/high-seas-expe

Today's talk

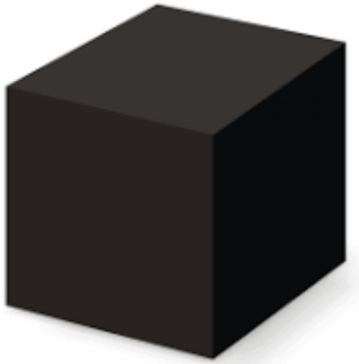
- Why the survey?
- Methods
- Initial result
- Looking forward



Loading trawls on NOAA Ship Shimada, Newport, Oregon, January 18, 2022

Little is know about salmon on the high seas in winter

- Least understood period of salmon life cycle. Poor understanding of:
  - Stock-specific distributions (and why distributed as they are)
  - Prey field and food habits
  - Competitors (salmon and non-salmon)
  - Predators
- Proposed role as critical period due to low prey availability
  - High mortality if low salmon energy reserves entering winter?
- If mortality is high, what is the source of mortality?
  - Starvation or predation?
- Builds on winter high seas expeditions to Gulf of Alaska in 2019, 2020



Management questions

- Can winter surveys improve forecasts of Pacific salmon returns?
- Have changes to salmon winter ecology contributed to long term declines in some salmon populations (especially in Pacific Northwest)?
- Is changing winter ecology responsible for unexpectedly high or low returns of salmon associated with marine heat waves, now or in the future?
- Which stocks may be impacted by IUU Fishing?

IYS 2022 Pan Pacific Survey objective

Demonstrate the utility of an international pan-Pacific winter ecosystem survey to understand how **increasingly extreme climate variability** in the North Pacific Ocean and the associated changes in the physical environment influence the abundance, distribution, migration, growth, fitness and survival of **Pacific salmon and surrounding species**.

Pakhomov et al. 2021. Preliminary Cruise Plan for the NPAFC International Year of the Salmon (IYS) 2022 Pan-Pacific Winter High Seas Expedition. NPAFC Doc 1995.

What is known about Pacific salmon winter ecology

North Pacific Anadromous Fish Commission
Bulletin No. 6: 113–138, 2016

Pacific Salmon and Steelhead: Life in a Changing Winter Ocean

Katherine W. Myers[1], James R. Irvine[2], Elizabeth A. Logerwell[3], Shigehiko Urawa[4], Svetlana V. Naydenko[5], Alexander V. Zavolokin[5, 6], and Nancy D. Davis[7]

Skip McKinnell's database of historic high seas catches

*"The most important **lesson** to be learned from **past winter research** is that **spatial and temporal scales** are important to understanding the relationships between **salmon distribution and their environment**"*

Historic winter high seas effort

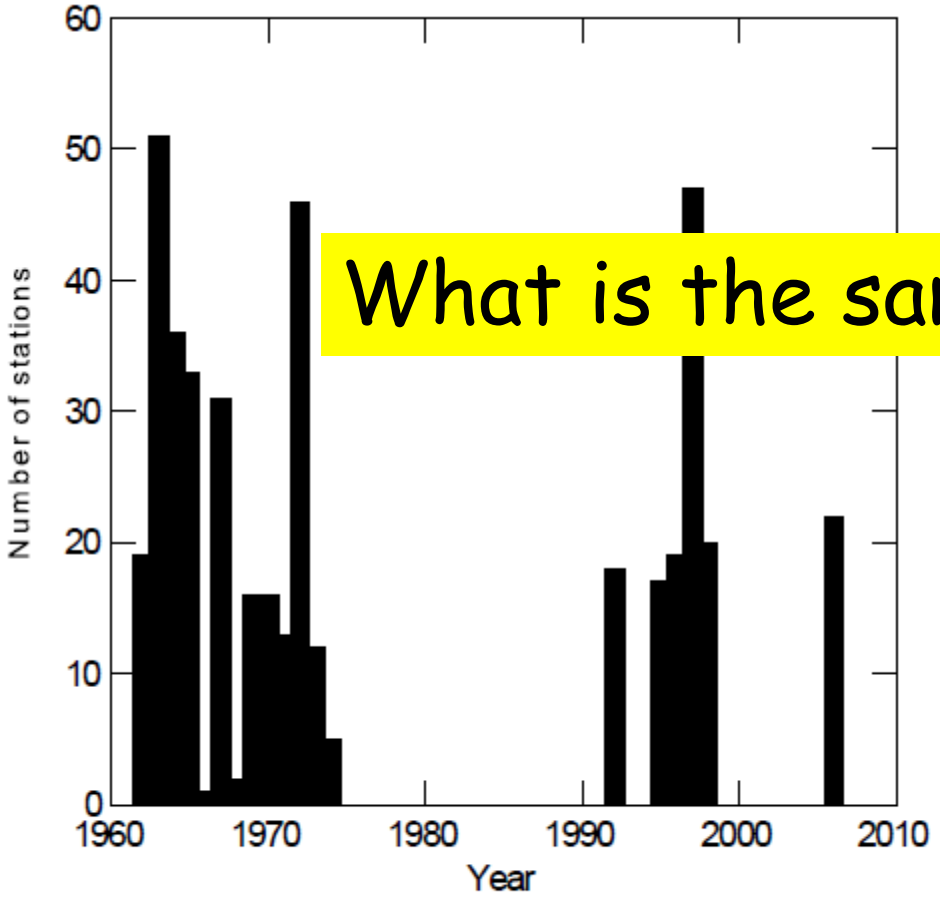


Figure 1: Number of salmon fishing stations in winter in the North Pacific Ocean by year.

What is the same? What is different?

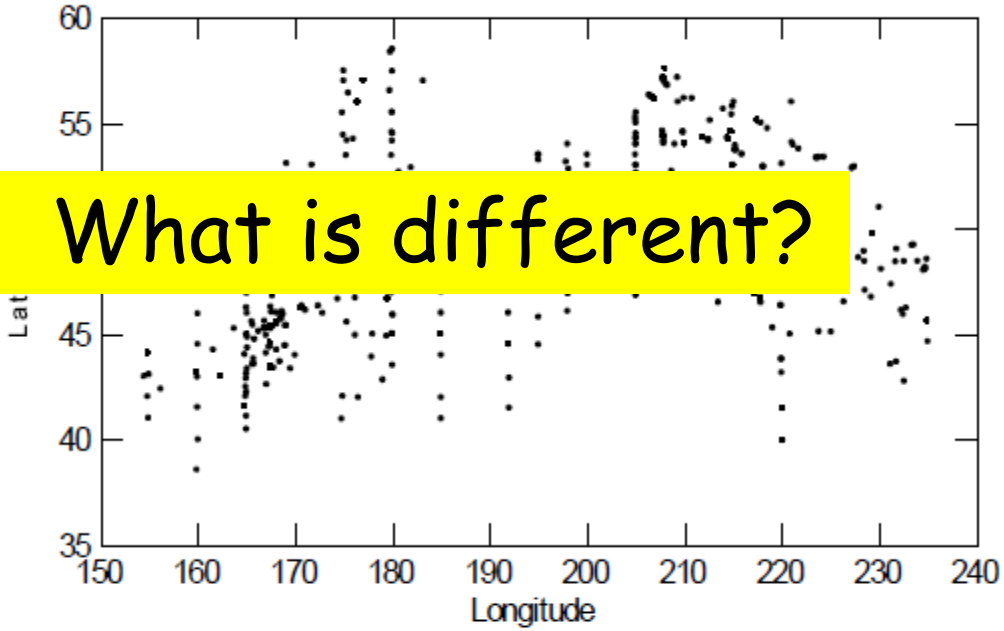
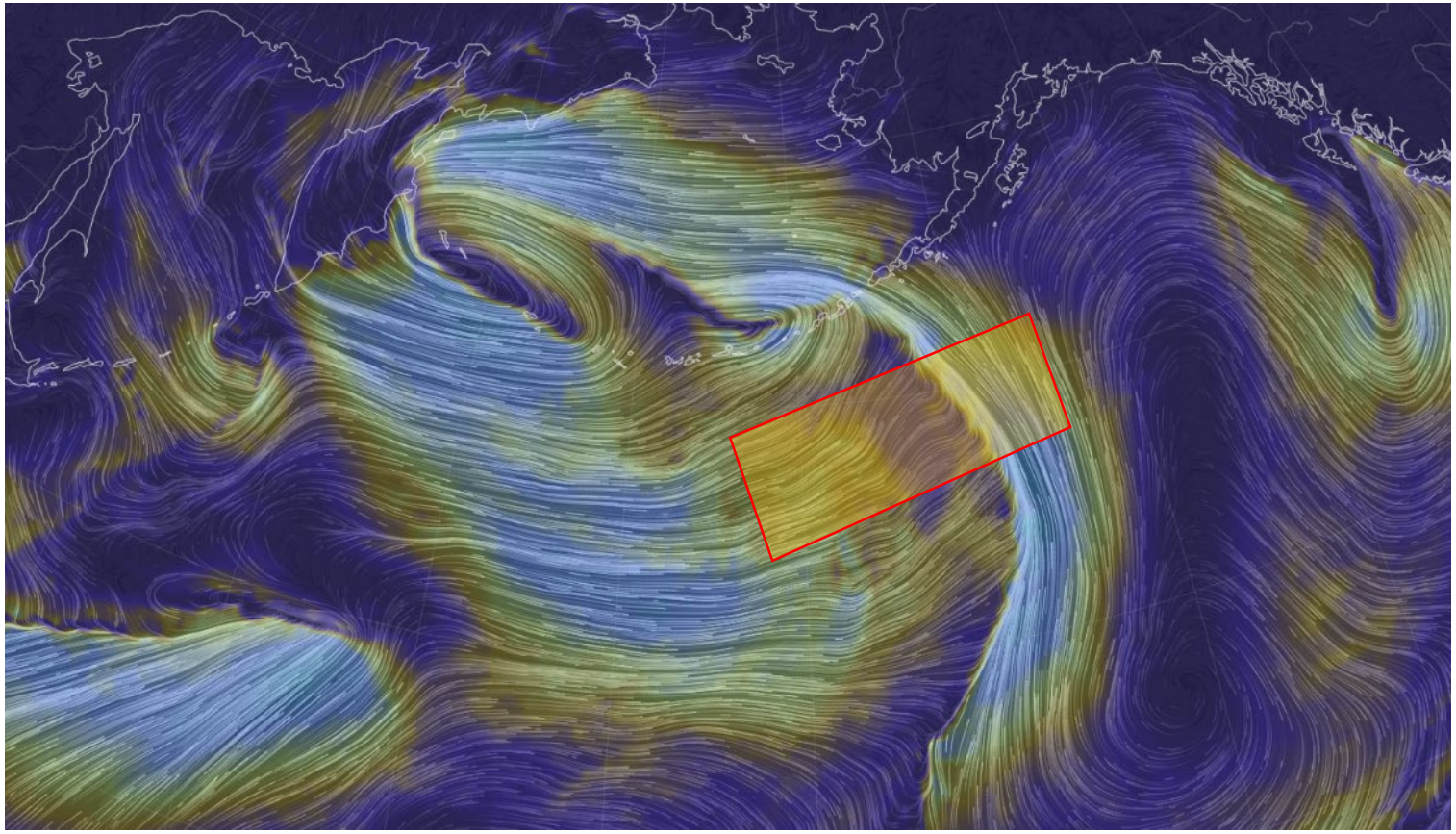


Figure 2: January through March fishing locations in the North Pacific Ocean and Bering Sea prior to IYS and where SST was also measured.

Figures from Skip McKinnell

Challenges



Typical synoptic situation over the NPO during the work period. The area of work is marked. Figure from Aleksey Somov, TINRO

Covid!

Late commitment of ships

Global political climate

Common methods across ships

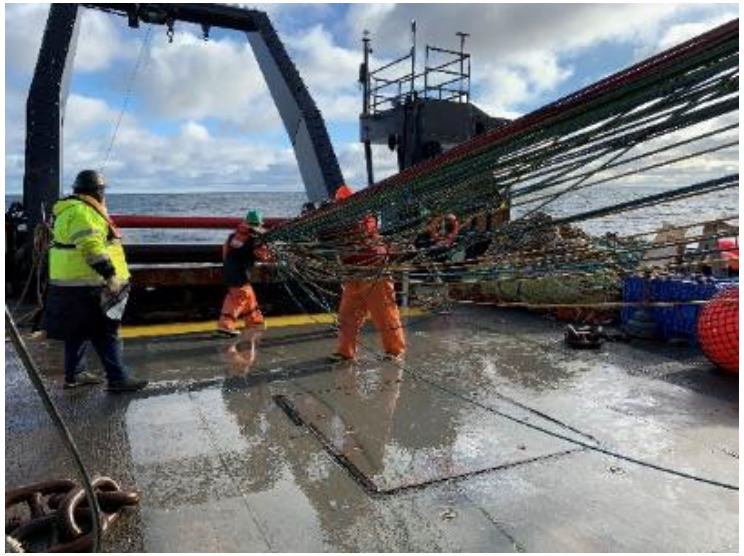
Physical oceanography

CTD casts to 300-2000m
Multi-depth samples for O_2, nutrients, Chl a, flow cytometry, POM, HPLC, environmental DNA

Biological oceanography

Standardized vertical bongo nets (all ships), also Tucker trawls (Shimada, Franklin), Juday net (TINRO)

Fishing (surface trawl or gillnet)



Surface trawls or Japanese-style research gill net (F/V Raw Spirit)

Trawl deployed behind the F/V Northwest Explorer

Courtesy Andrew Dimond, NOAA Fisheries/AFSC

Bongo Tows

Slide from Jackie King, CDFO

Tucker Trawls

Surface Trawls

Measurements & samples collected from trawls catches

Basic biology

- Length, weight
- Scales (age, growth)*
- Otoliths (age, hatchery thermal marks)*
- CWTs (origins, age)*
- External marks (possible predation attacks)
- Gonads (maturation)*

- **Food web linkages/bioenergetics**
- Stomach contents (food habits)
- Muscle, liver, gonads (bioenergetics, fatty acids, stable isotopes, thiamine)

*Salmon only

“Newish” technologies*

Fin clips (Genetic Stock Identification)

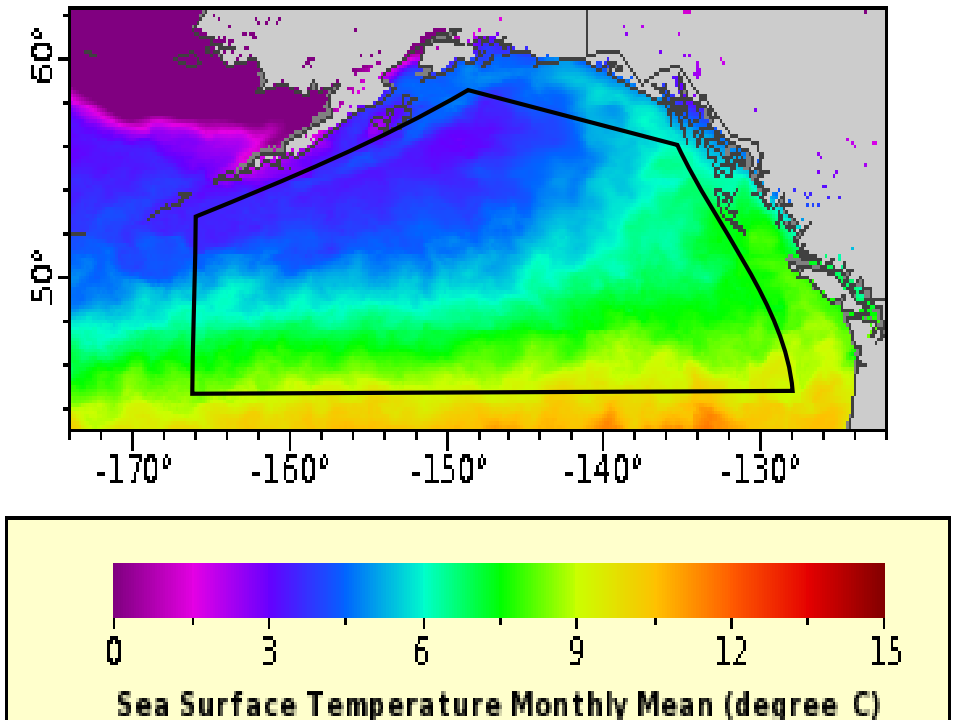
Gill tissue (pathogens, up/down regulation of genes)

Blood (Insulin-like Growth Factor hormone)

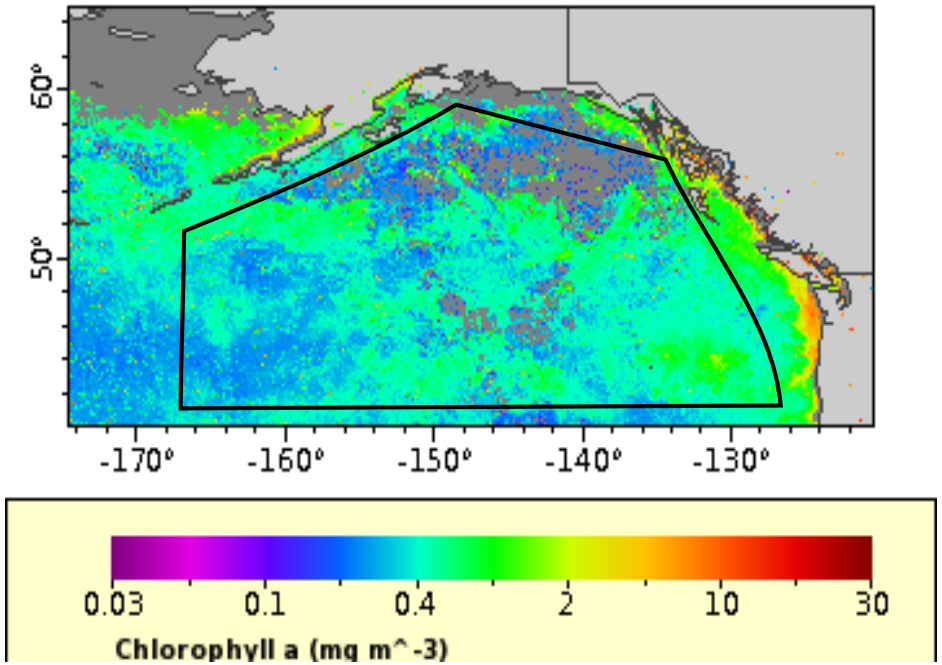
Stomachs (microplastics)

Temperatures and Chl a across the survey area (monthly means for February 2022)

Sea surface temperature

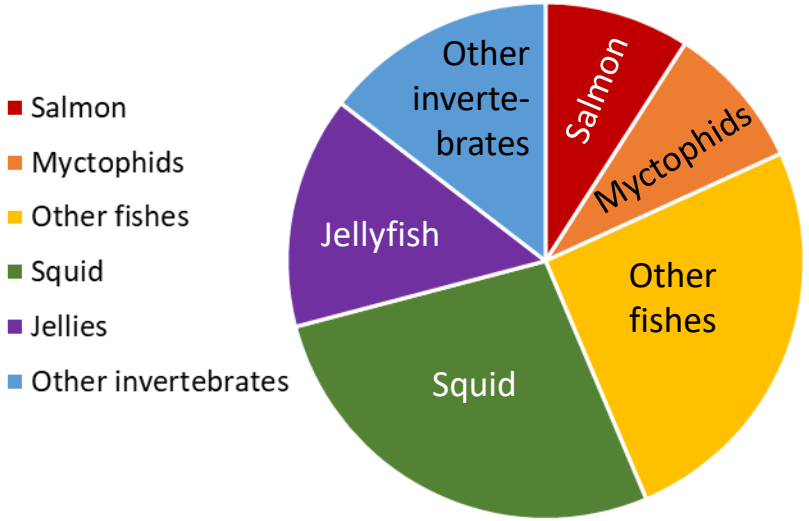


Chlorophyll a

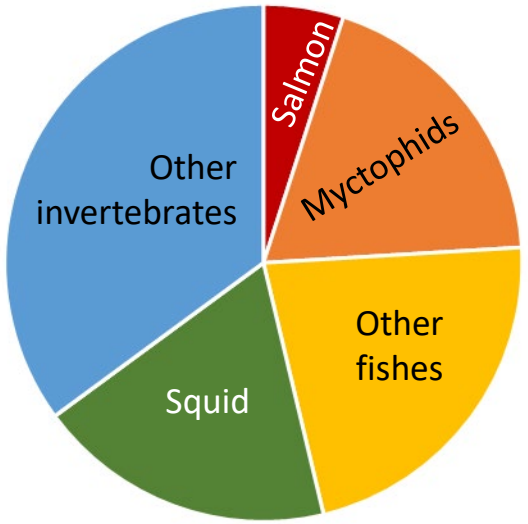


Catches by taxonomic group (all trawls combined)

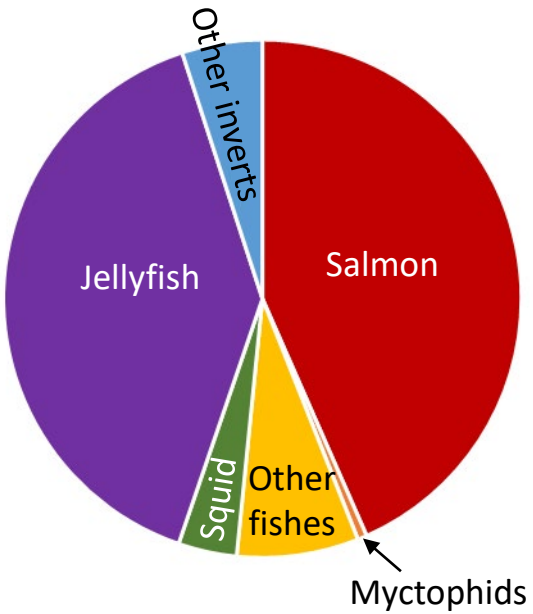
55 taxonomic groups identified



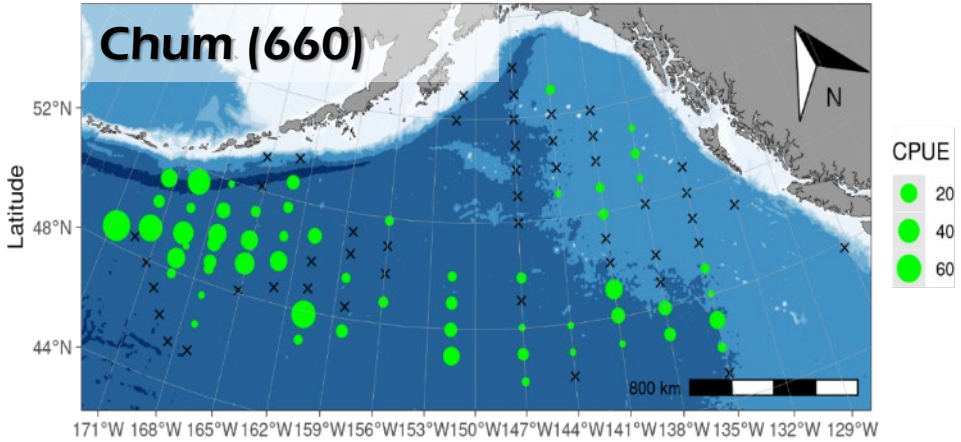
42,567 organisms counted (excludes jellyfish)

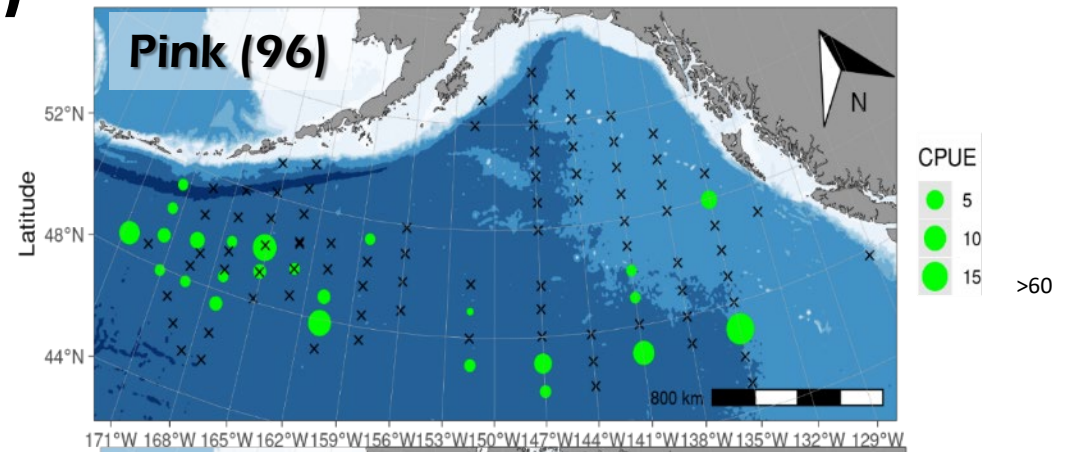


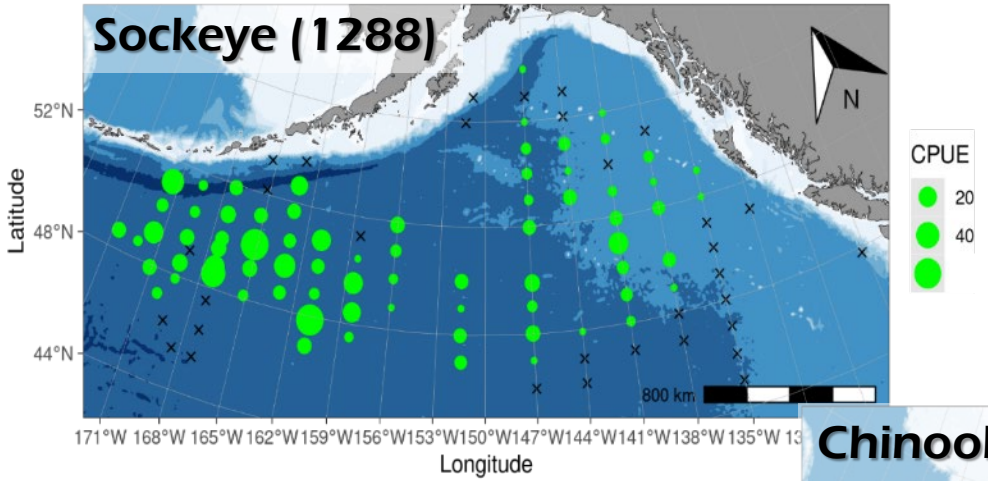
2,932 kg of trawl contents weighed

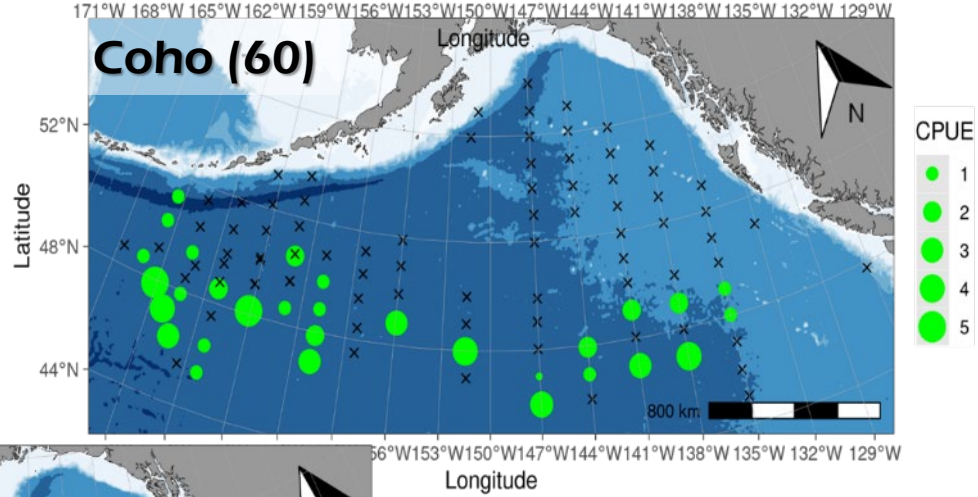


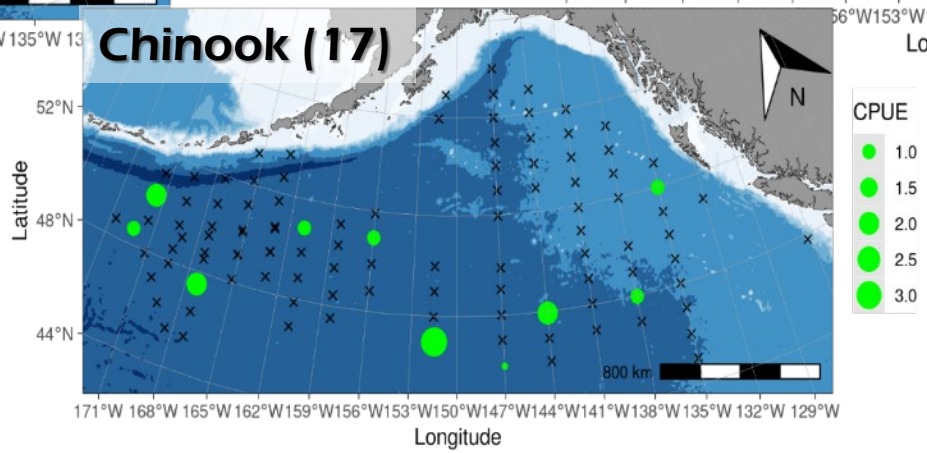
Salmon counts/hour (total)





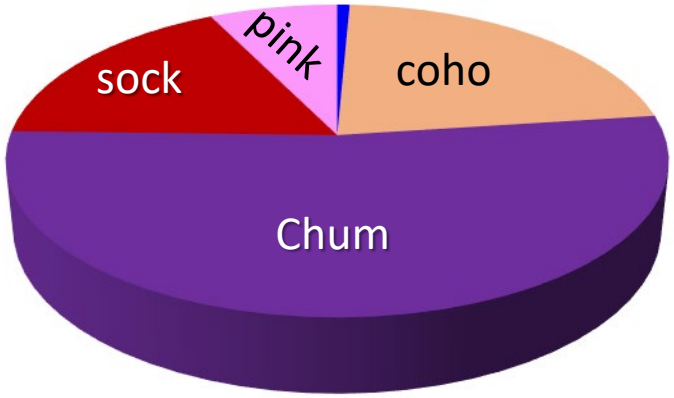




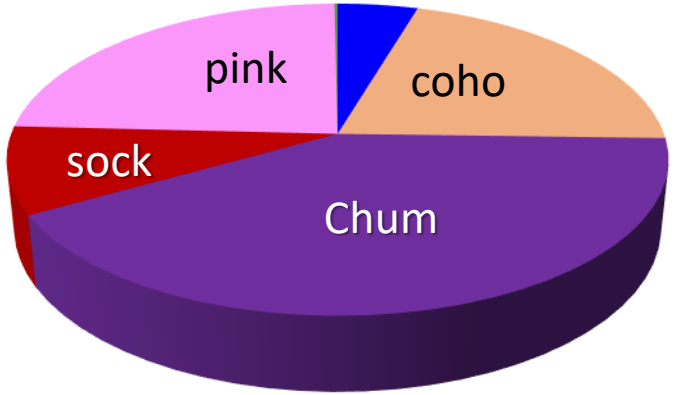


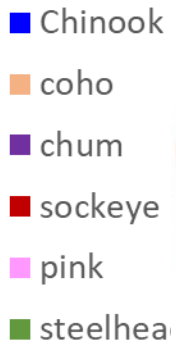
Gulf of Alaska catches by year

2019 (423)

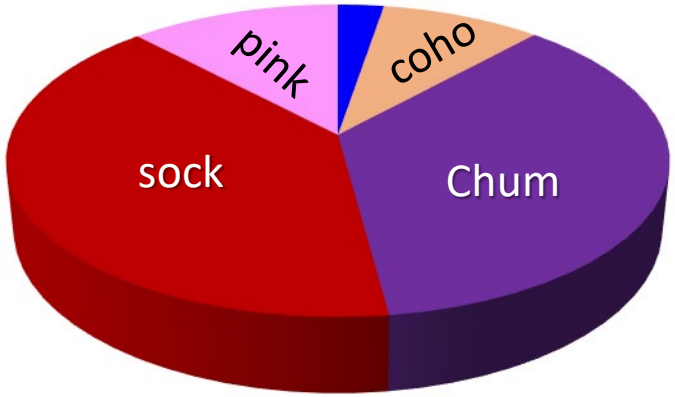


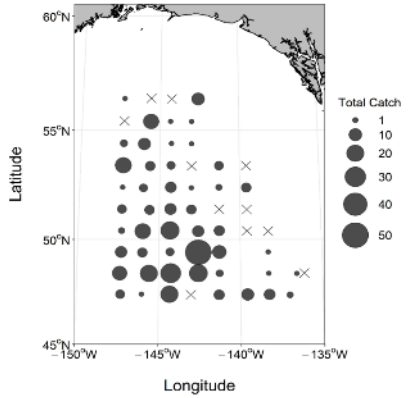
2020 (566)

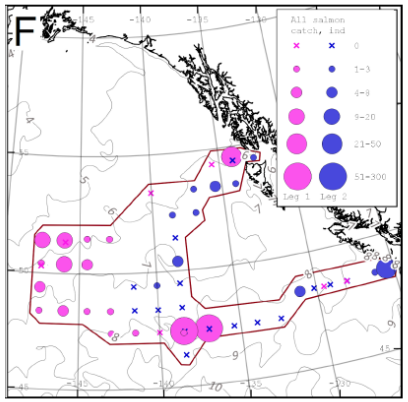


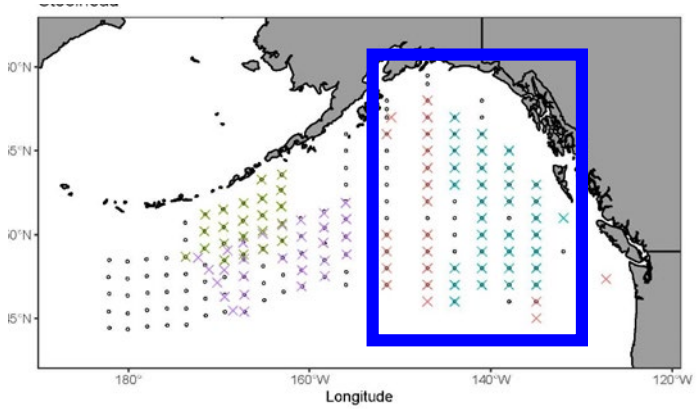


2022
Franklin &
Shimada (383)



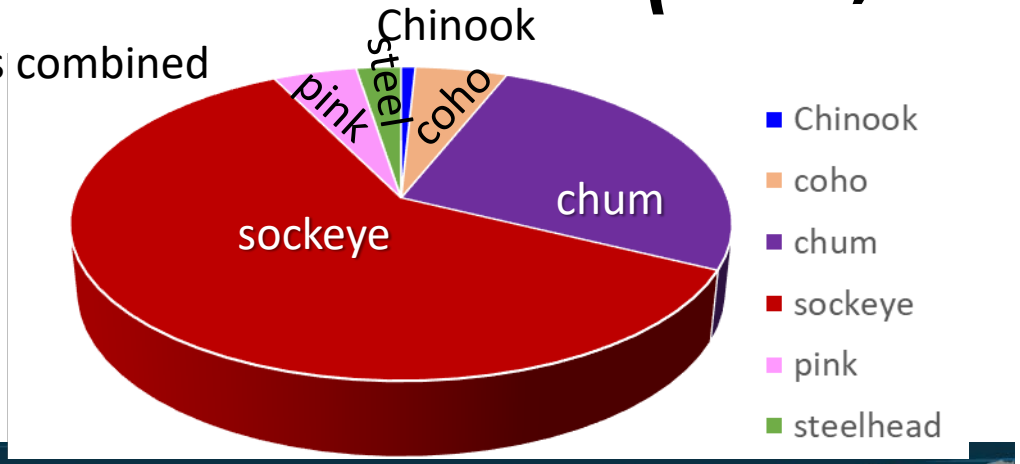




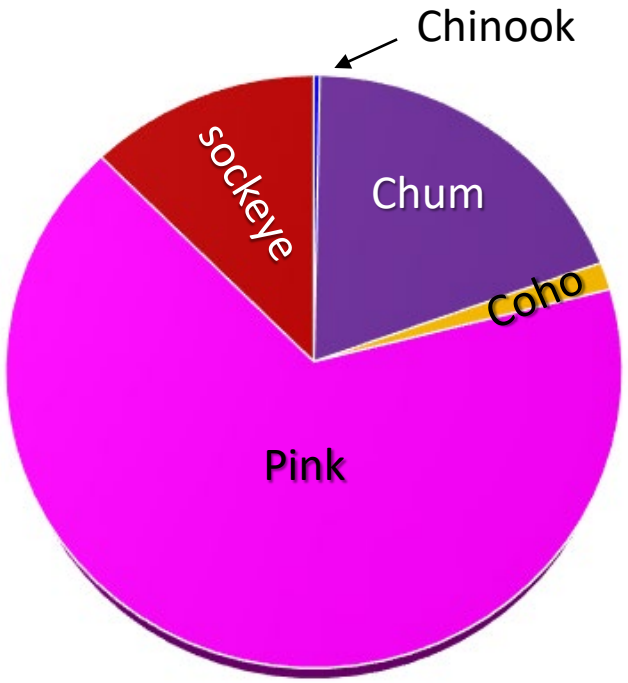


Catch of salmon (n=2,323)

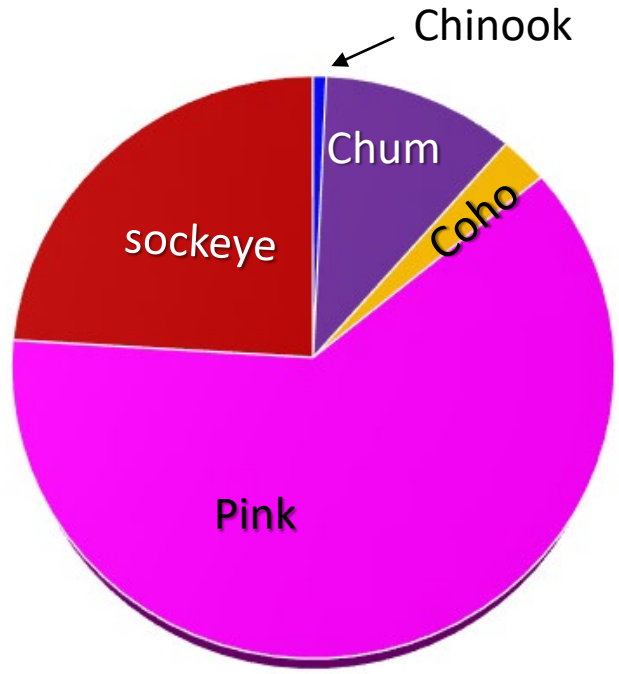
All ships combined

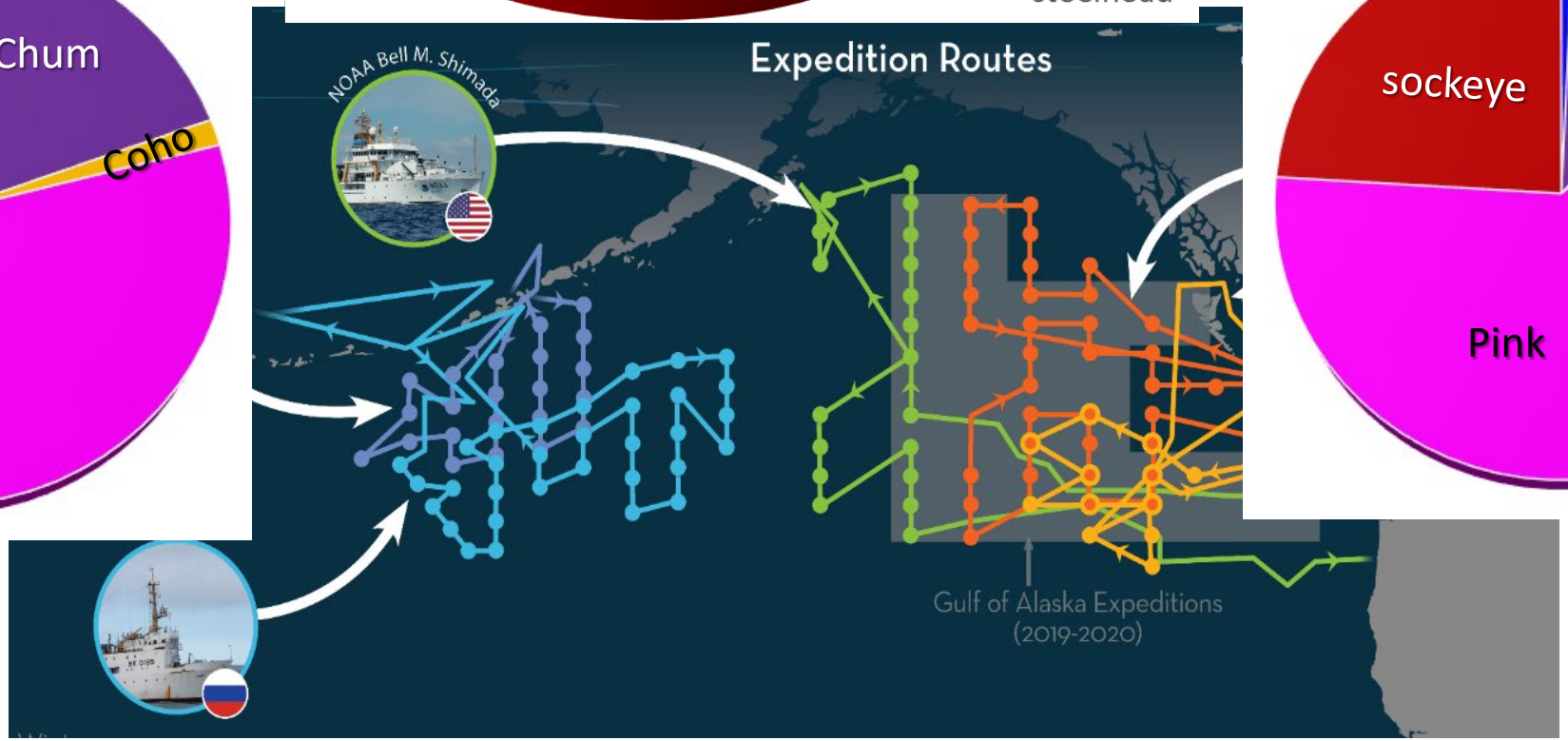


Whole Pacific catch
2000-2021



US & Canada catch
2000-2021

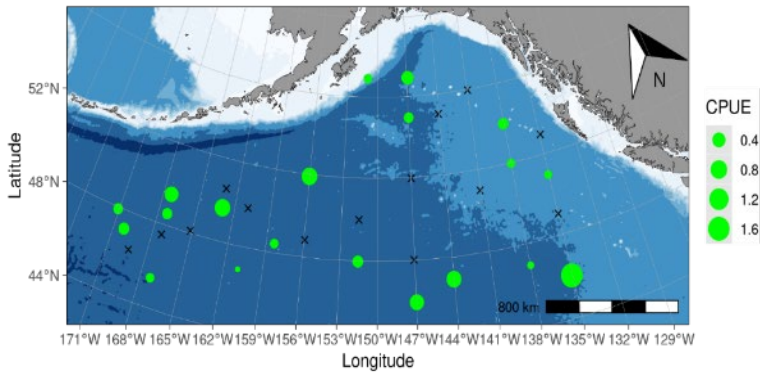




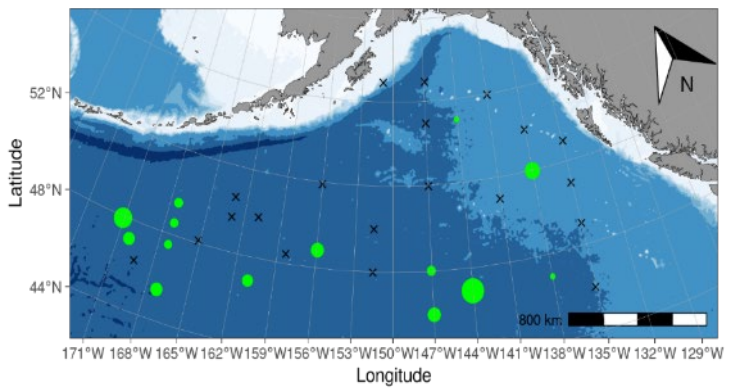
Other frequently caught species: squid, myctophids and jellyfish (kg/hour)

Prey, competitors

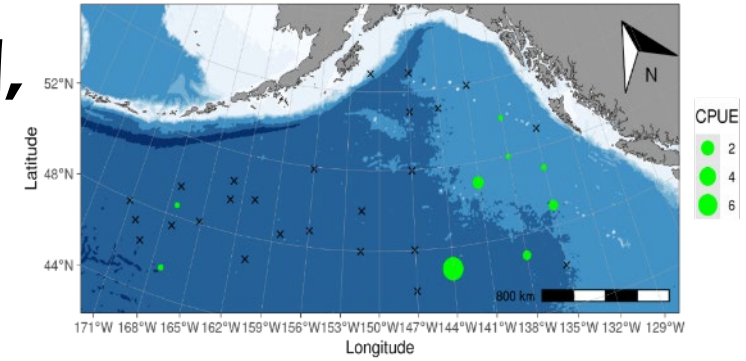
Boreopacific armhook squid



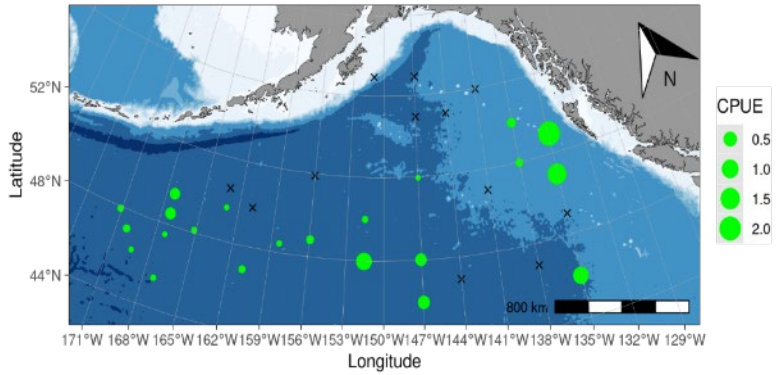
Boreal clubhook squid



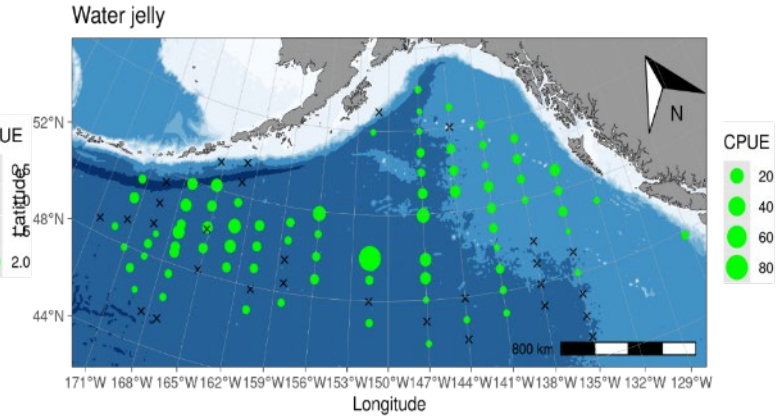
Northern Lampfish



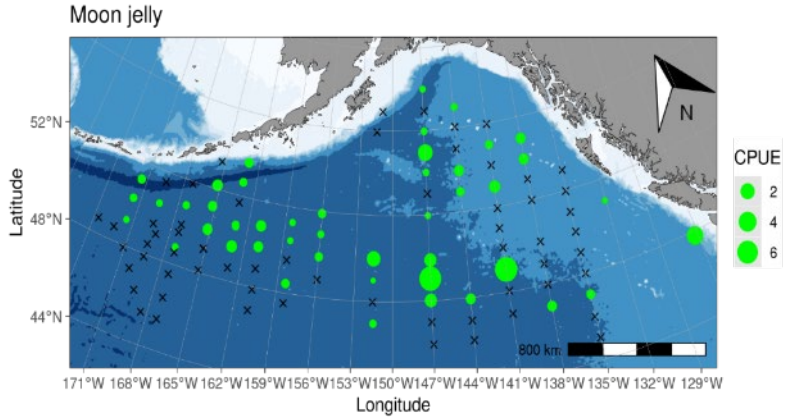
Blue lanternfish



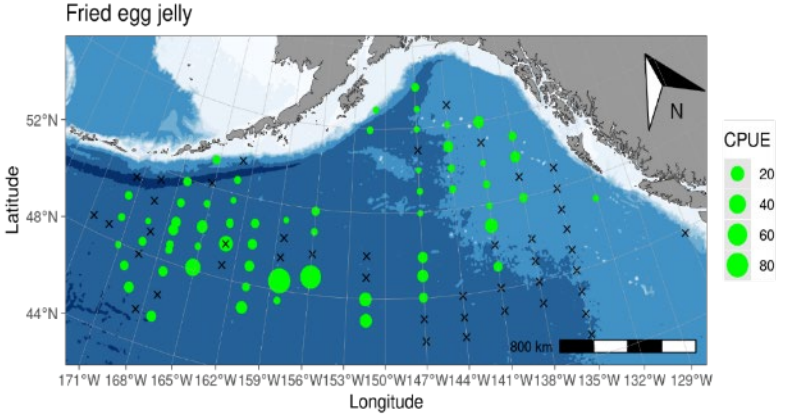
Water jelly



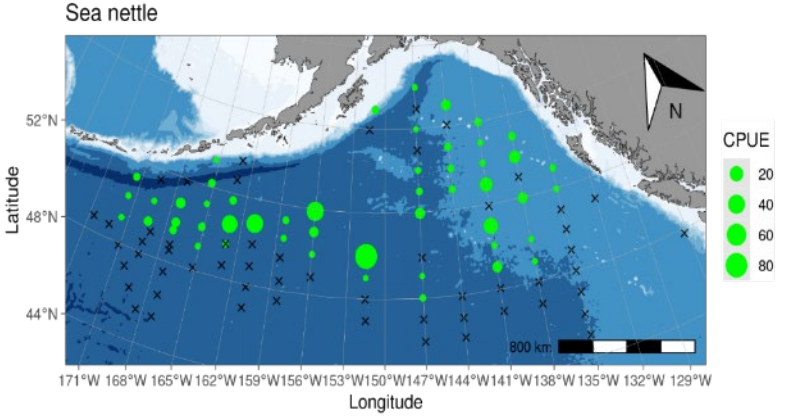
Moon jelly



Fried egg jelly



Sea nettle



So much more to do!

Oceanological environment

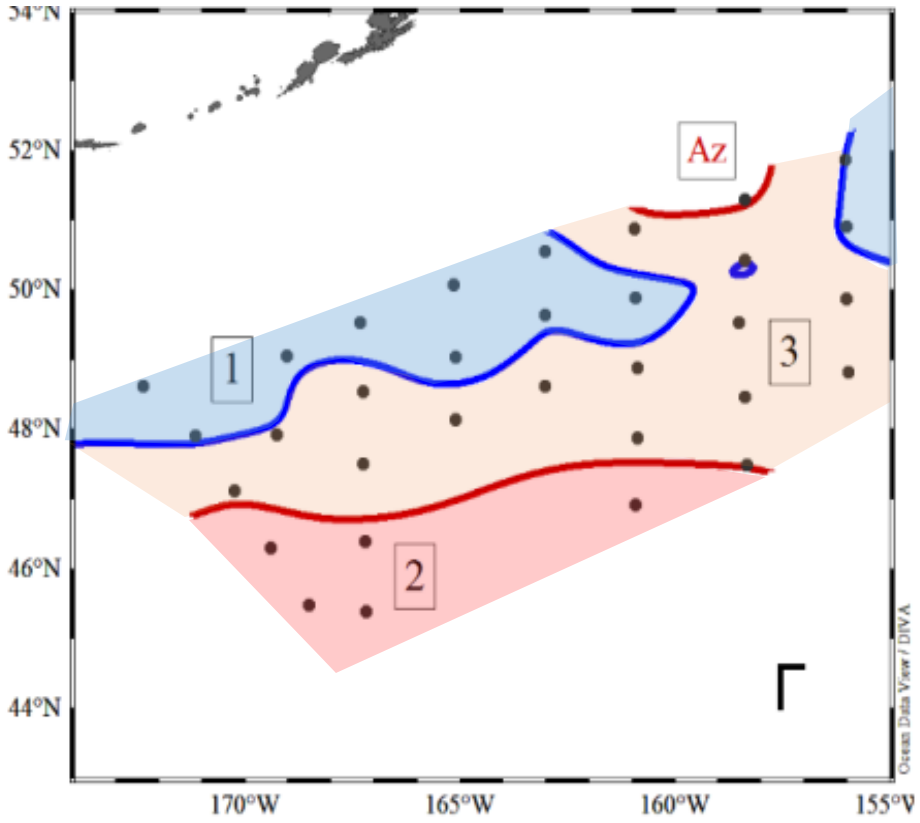


Figure 4 - distribution of water masses (left) and water surfac
subtropical waters, 3 - mixing zone, Az - a

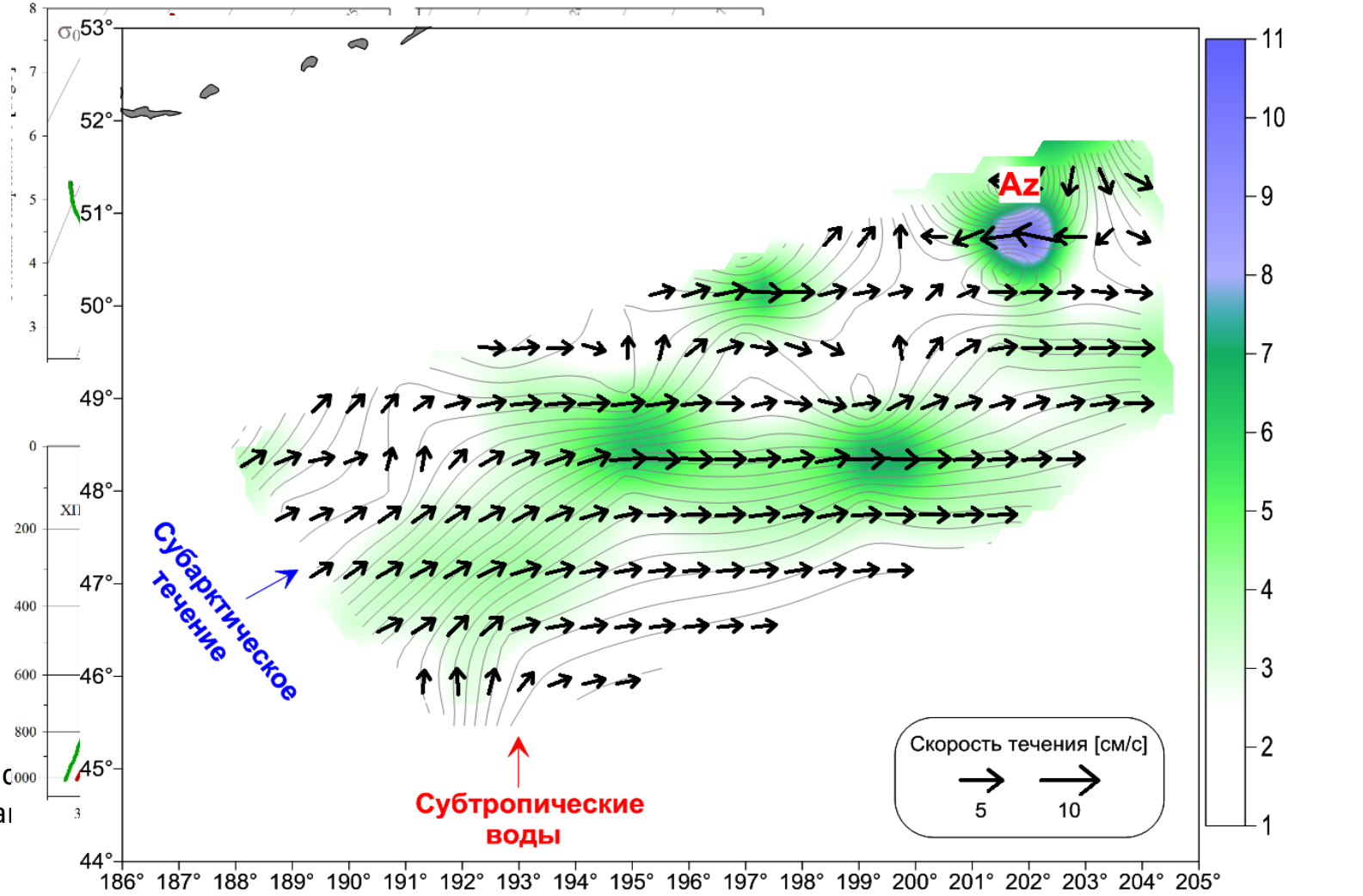
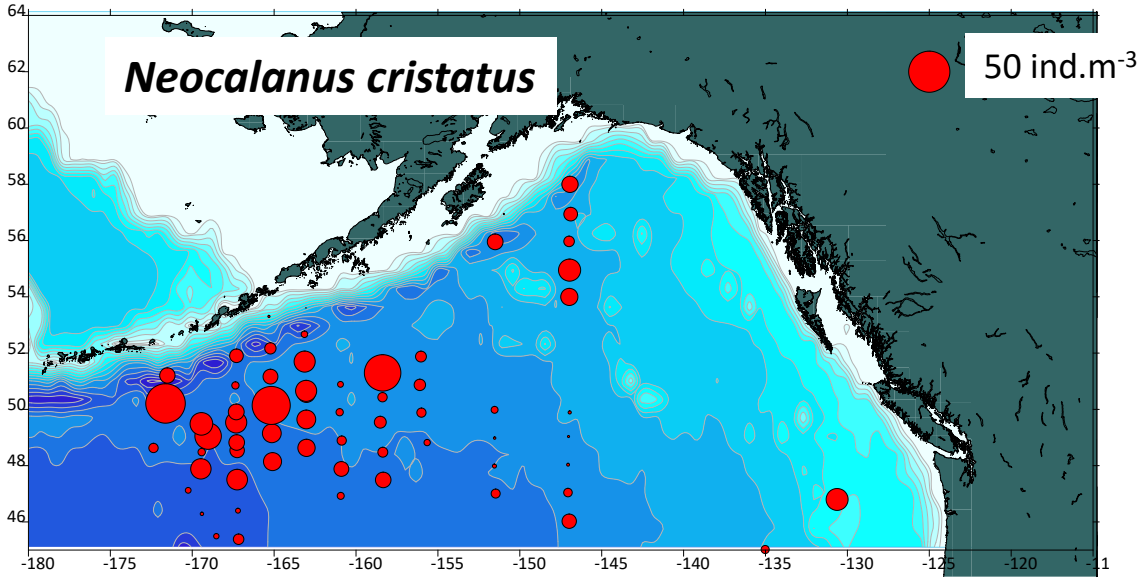
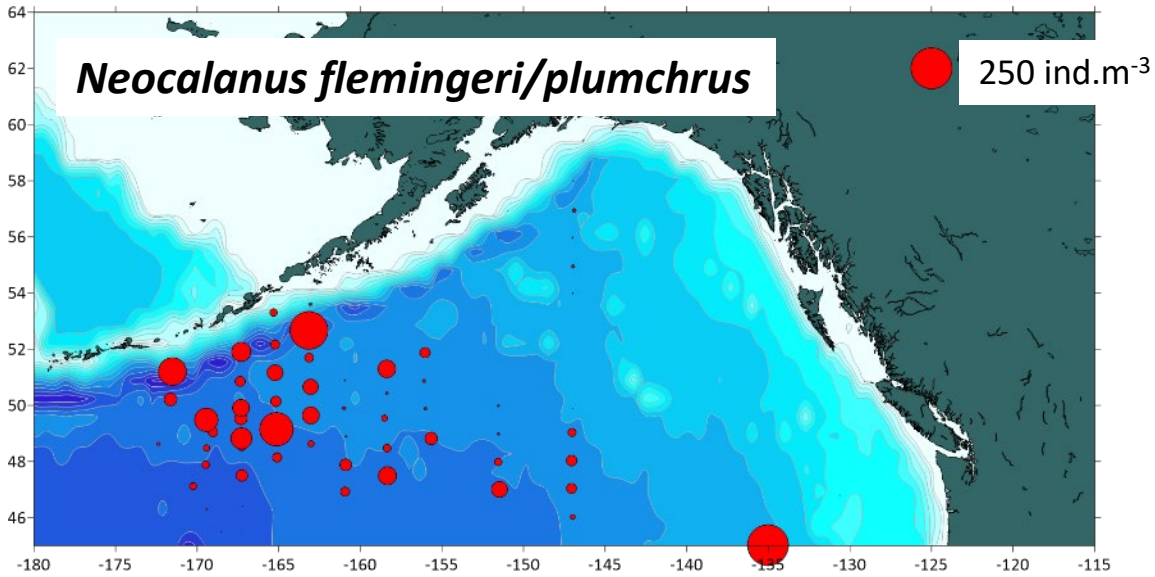


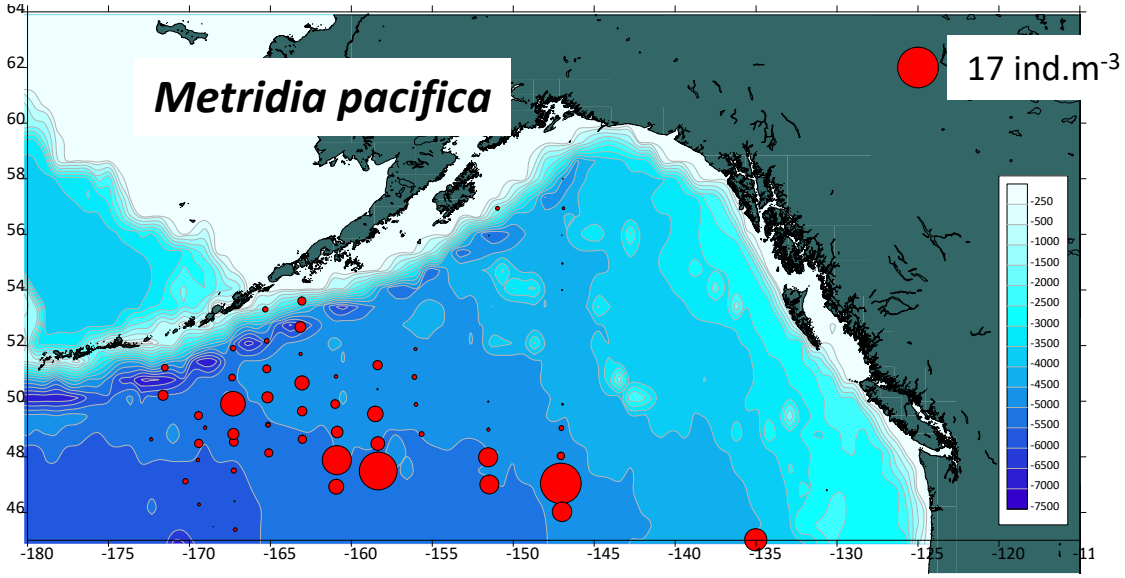
Figure 5 - TS-diagrams and characteristic vertical profiles of different types of water masses within the study area

Figures from Aleksey Somov, TINRO

Preliminary bongo zooplankton results







Figures provided by Alexei Pinchuk, Univ Alaska Fairbanks

Salmon diets from TINRO

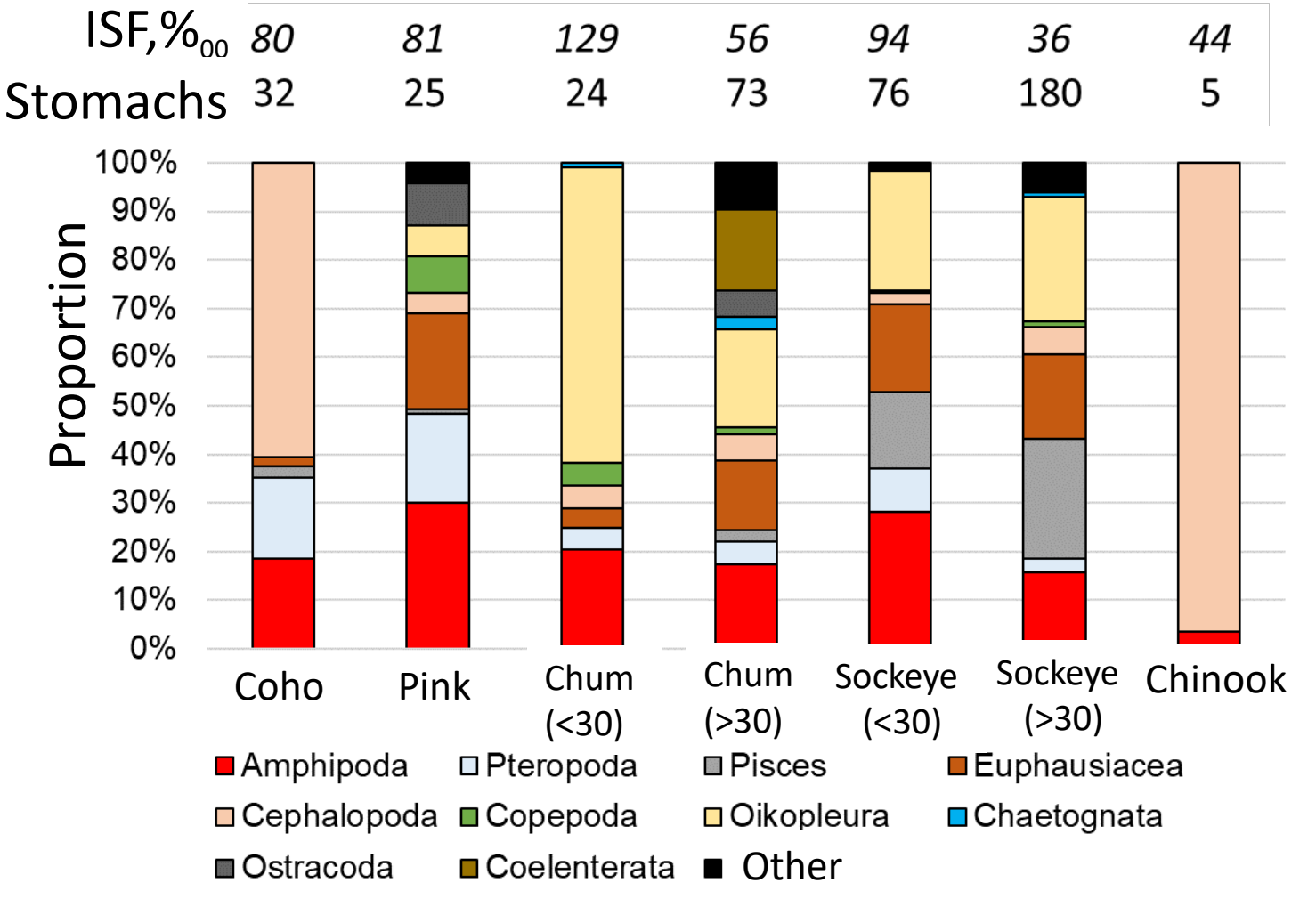
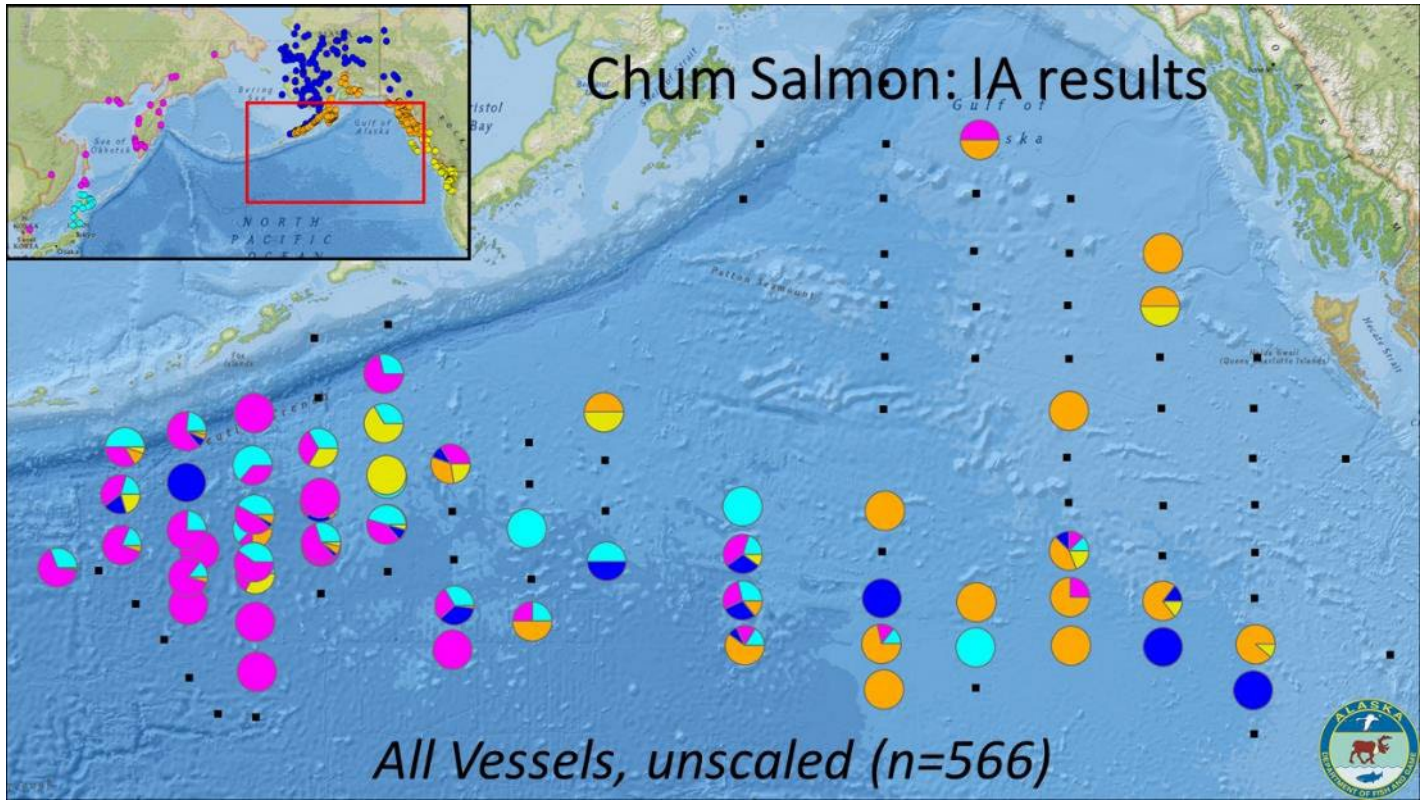
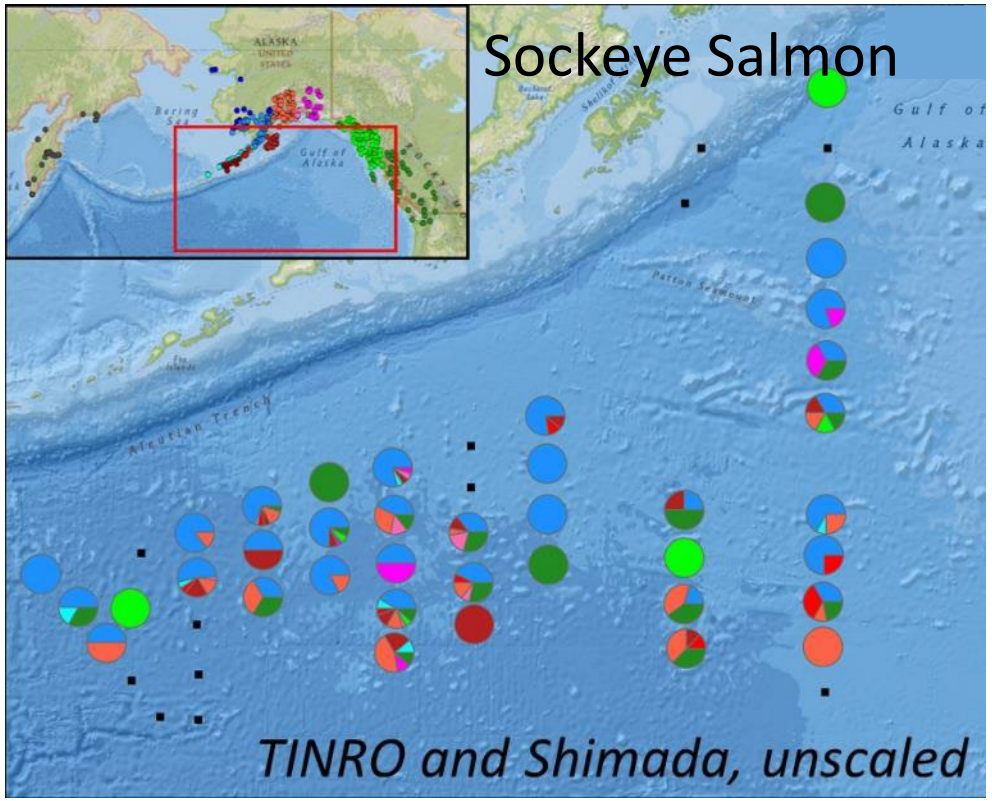


Figure 13 - Ratio of Pacific salmon diet groups in near-Aleutian waters of the NPO in March 2022.

Figure from Aleksey Somov, TINRO

Preliminary genetic stock identification results

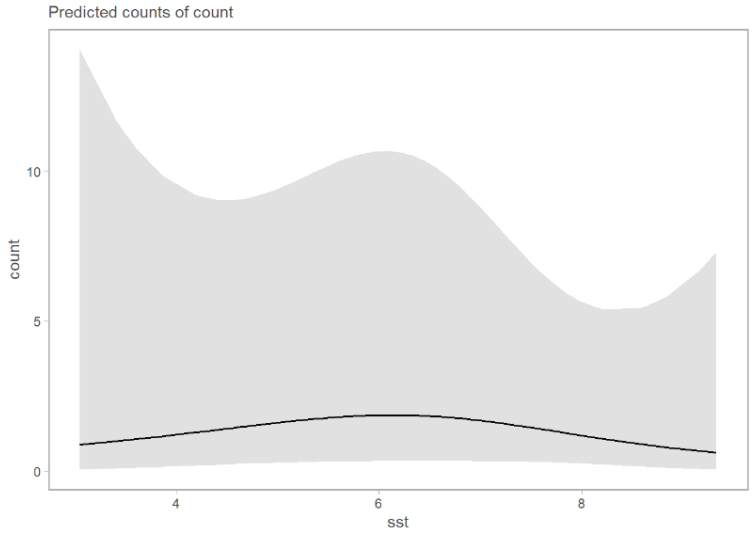


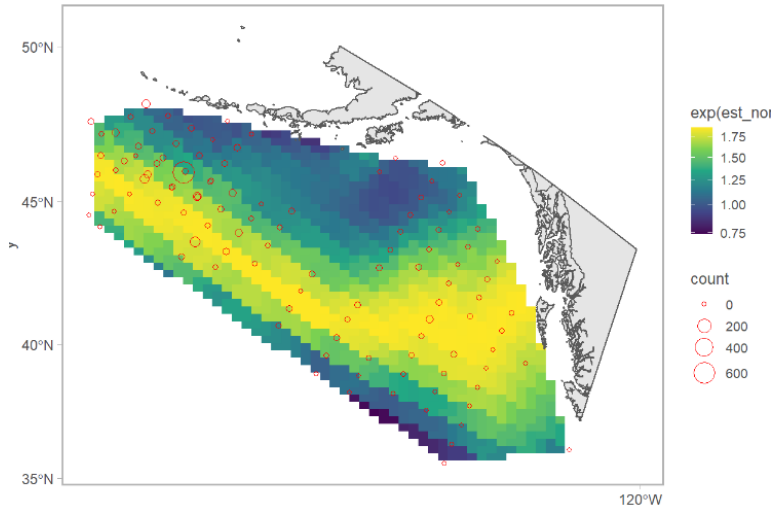


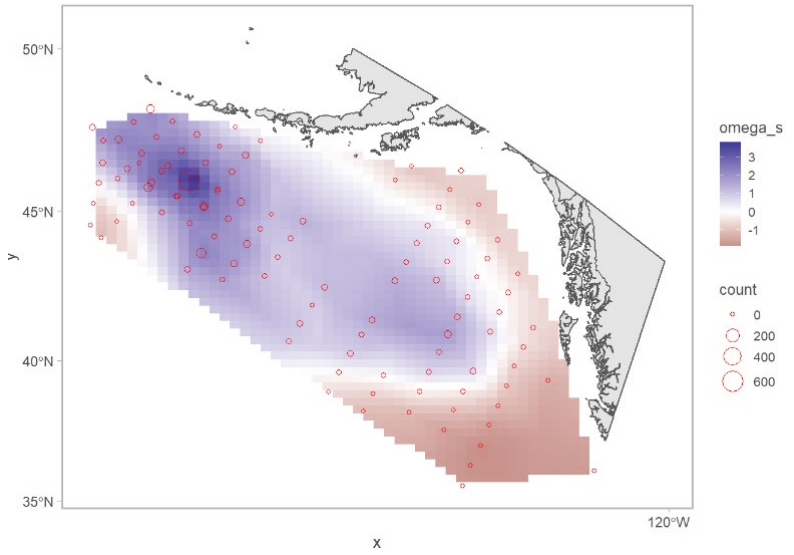
Slide from Liz Lee, Alaska Dep Fish and Game

Geostatistical models

- highlight ecological important spatial processes (e.g. foraging hotspots; migration corridors)
  - disentangle measured effects (e.g. SST) from unmeasured effects
  - allow for more valid statistical inference,
  - improve prediction







2022 Fraser River Sockeye

	Sockeye caught	From Fraser River	Fraser River	
			Summer-run	Late-run
Franklin	88	7%	83%	17%
Raw Spirit	53	28%	86%	16%
Total Eastern	135	16%	85%	15%
Shimada	68	13%	78%	22%
TINRO	313	0.03%	88%	12%
NW Explorer*	207	.005%	100%	0%*
Total Central	588	3.1%	83%	17%
Historic Returns				60%
Pre-Season Forecast based on spawner abundance				30-44%
In-Season Observations				29%

*survey occurred later than other vessels

Table provided by Jackie King, CDFO

2022 catches compared to predictions based on historical catches: ex. Pink salmon.

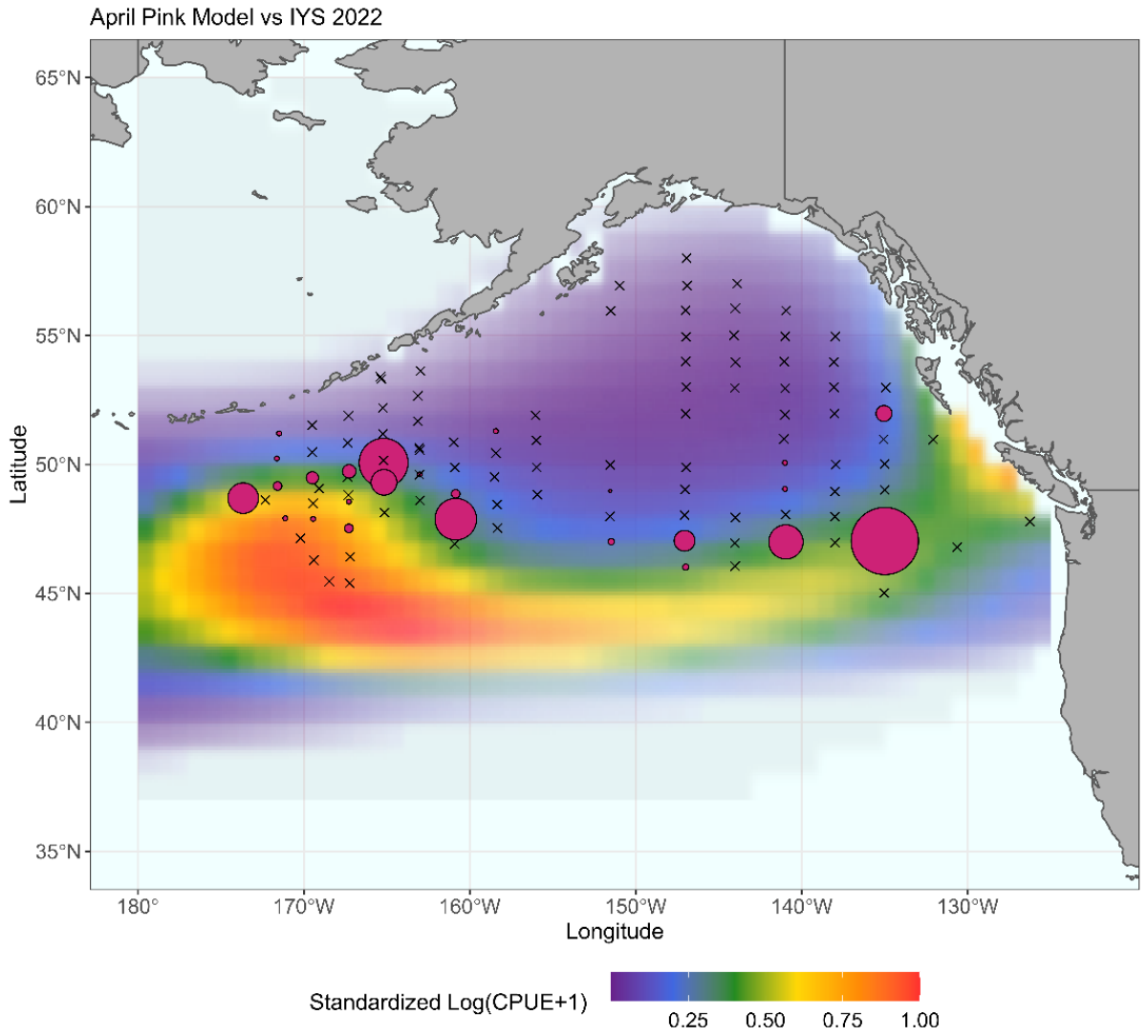


Figure by Joe Langan
Univ. Alaska Fairbanks

Likely high seas salmon predators

(Bugaev and Shevlyakov 2007, Naydenko and Temnykh 2016)

Dolphins and porpoises

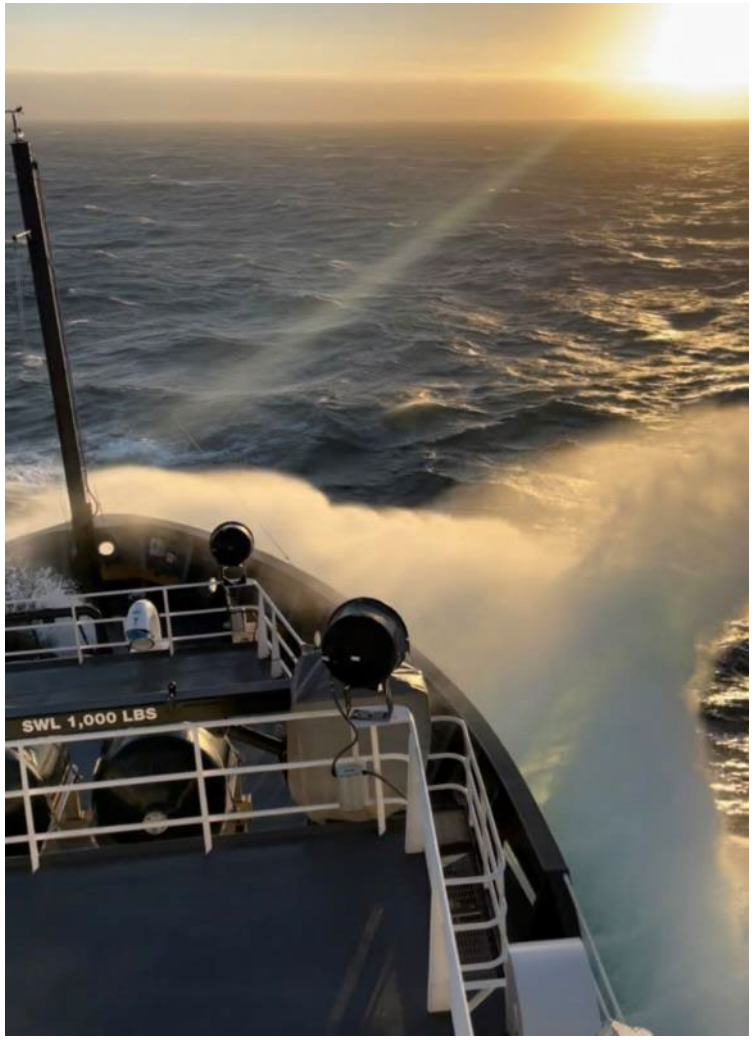
Few potential predators caught by nets or eDNA or observed

If predation isn't the source of mortality, what is?

Pinnipeds

Looking forward

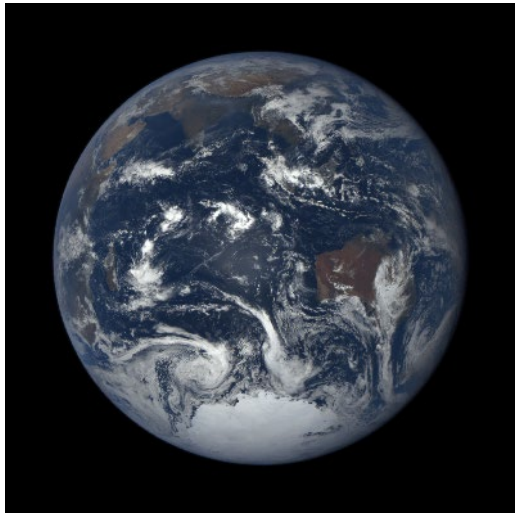
- Many samples to run, data to analyze
- Another meeting 1 year from now (PICES?)
- Synthesize many data sets (multiple layers)
- Why stop high seas expeditions now?



Shimada in rough water
Photo by Ethan Beyer

What does it all mean?

- We are changing the ocean but can't control the change, such as increasingly frequent marine heat waves
- We can improve freshwater habitats throughout the range of salmon
  - We know what to do, we have the resources
- If we want salmon in the future, we have to give them the best possible chance
  - Diversity FW habitats produce diverse salmon life histories
  - Hatchery practices can increase diversity
  - Diverse salmon have highest chance of survival in an increasingly uncertain ocean



Questions?