Northwest **Power** and **Conservation** Council

October 5, 2022

MEMORANDUM

TO: **Council Members**

FROM: **Patty O'Toole, Fish and Wildlife Division Director**

SUBJECT: **Opening the oceanic black box: highlights from the 2022 International Year of the Salmon, High Seas survey**

BACKGROUND:

Presenter: Laurie Weitkamp, Research Fisheries Biologist, NOAA's Northwest Fisheries Science Center, Newport Research Station

Summary: The Council will hear about the largest pan-Pacific research expedition to study the winter ecology of salmon in the North Pacific Ocean. The most recent expedition occurred earlier this year.

Relevance: The presentation will include new information about Columbia River salmon such as coho, chum, sockeye, chinook and steelhead gained during the expedition. Improved understanding of high seas ecology will provide increased insight into factors affecting survival of Columbia River salmon and steelhead. The Council's Fish and Wildlife Program calls for monitoring ocean conditions and related salmon survival and endorsing mitigation and management actions that improve the survival, growth and viability of Columbia River salmon in varying ocean conditions.

Workplan: Fish and Wildlife Program Implementation, task G: Implement Science & Policy Forums/Regional Coordination Forum/Ocean Forum

Background: At the October Council meeting, we will hear about a unique, international effort to learn about how salmon in the North Pacific use the ocean. For salmon of the Columbia River, we know a little about what they experience in the marine environment from the Ocean Survival of Salmonids project (project number 1998-014-00) recommended by the Council and funded by the Bonneville Power Administration. This project focuses its research and monitoring on the northern California Current, just off the coast of Oregon and Washington on the continental shelf. These surveys occur in spring (May and June), when juvenile fish are present and when weather conditions generally support consistent surveys. The Council receives regular reports from the project staff, typically in March of each year. But what about salmon that do not remain on the continental shelf or in the California current?

Pacific salmon are a uniquely important resource for countries across the entire North Pacific, but there remain significant gaps in our understanding of the mechanisms that regulate salmon distribution and survival in coastal and especially in high seas environments. Since salmon cross ecosystem and international boundaries as they migrate across the North Pacific, a concerted international effort is imperative to improve our knowledge about the conditions that Pacific salmon face in the open ocean. By furthering our understanding of the ocean phase of the salmon life cycle, we can improve our efforts to assess, forecast and manage salmon into the future.

The International Year of the Salmon (IYS) is an initiative by the North Atlantic Salmon Conservation Organization (NASCO) and the North Pacific Anadromous Fish Commission (NPAFC). The focal year of the IYS was 2019, with activities continuing into 2022.

The IYS put together the pan-Pacific research expedition to study the ecology of salmon in the North Pacific Ocean. In a major effort to fill our gaps in knowledge, several research vessels were to go out to sea in late winter 2022 to conduct the largest ever pan-Pacific, epipelagic ecosystem survey during winter, focused on understanding salmon and their ecosystems.

The 2022 Expedition brought together scientists from Canada, Japan, the Republic of Korea, the Russian Federation, and the United States — the five member countries of the North Pacific Anadromous Fish Commission (NPAFC) — to build on research from the 2019 & 2020 International Gulf of Alaska Expeditions.

The major objective of the 2022 Expedition is to 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,

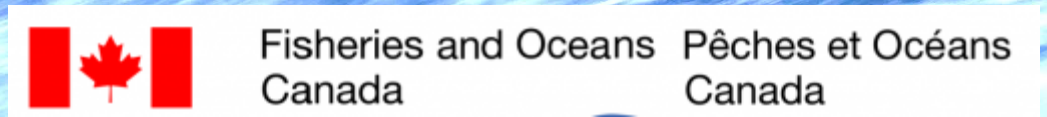
distribution, migration, growth, fitness and survival of Pacific salmon and surrounding species.

This expedition was not funded through the Council's Fish and Wildlife Program, however the information gained about Columbia River salmon will help deepen our understandings of the mechanisms of Columbia River salmon survival.

More Info: https://yearofthesalmon.org/2022expedition/

Opening the oceanic black box: highlights from the 2022 IYS High Seas survey

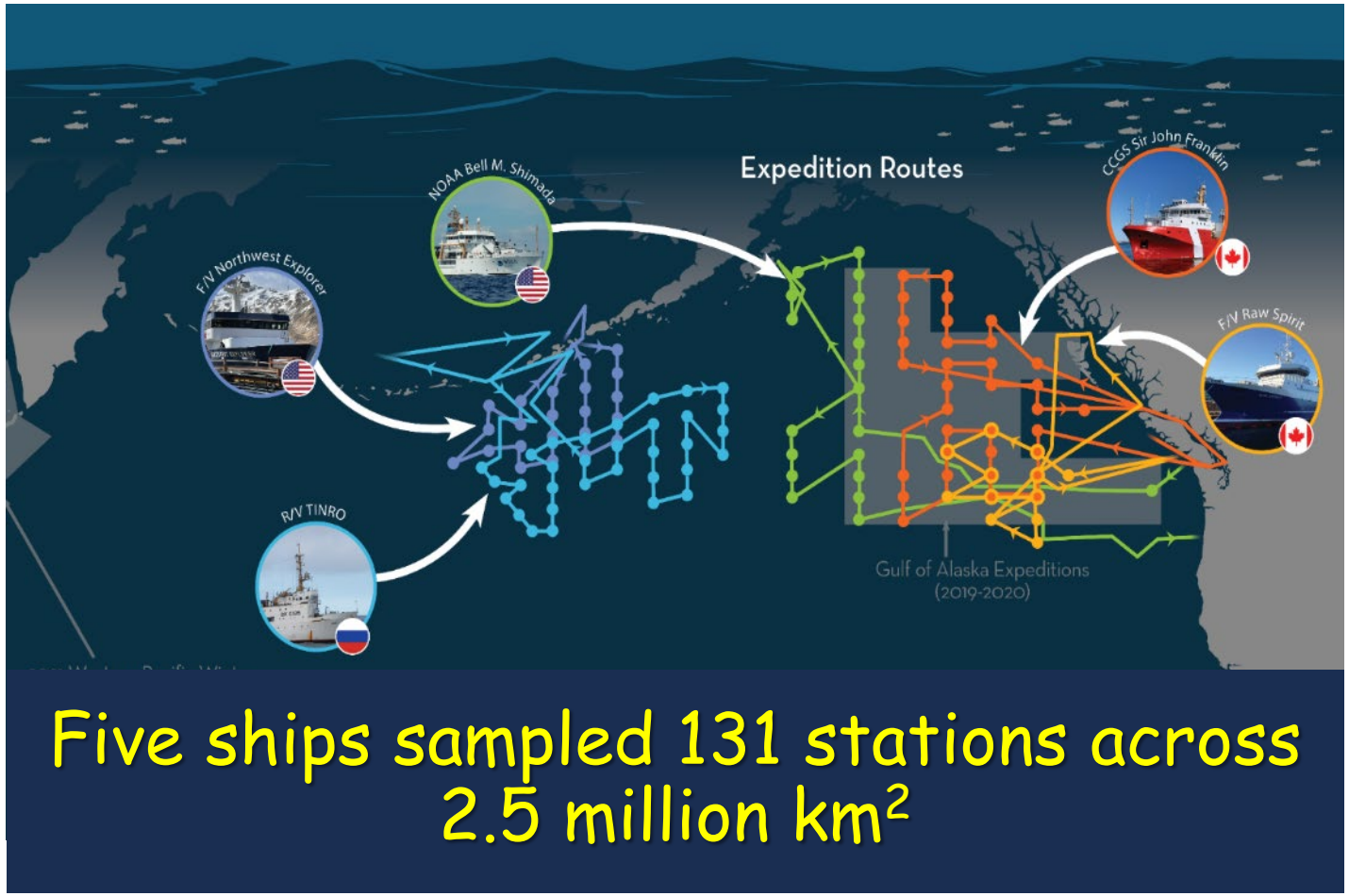
Laurie Weitkamp and Ed Farley: U.S. NOAA Fisheries
Evgeny Pakhomov: University of British Columbia
Jackie King and Cam Freshwater: Fisheries & Oceans Canada
Aleksey Somov: Russian Res Inst Fisheries & Oceanography-Pacific
Mark Saunders, Caroline Graham, Aidan Schubert: IYS/NPAFC
Vladimir Radchenko: North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



Opening the oceanic black box: highlights from the 2022 IYS High Seas survey

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-expeditions/

As Columbia River managers, why should you care about salmon on the high seas?

1) Columbia River coho, chum, sockeye, and some Chinook use the high seas, where they co-mingle with stocks from N America and the Pacific Rim.

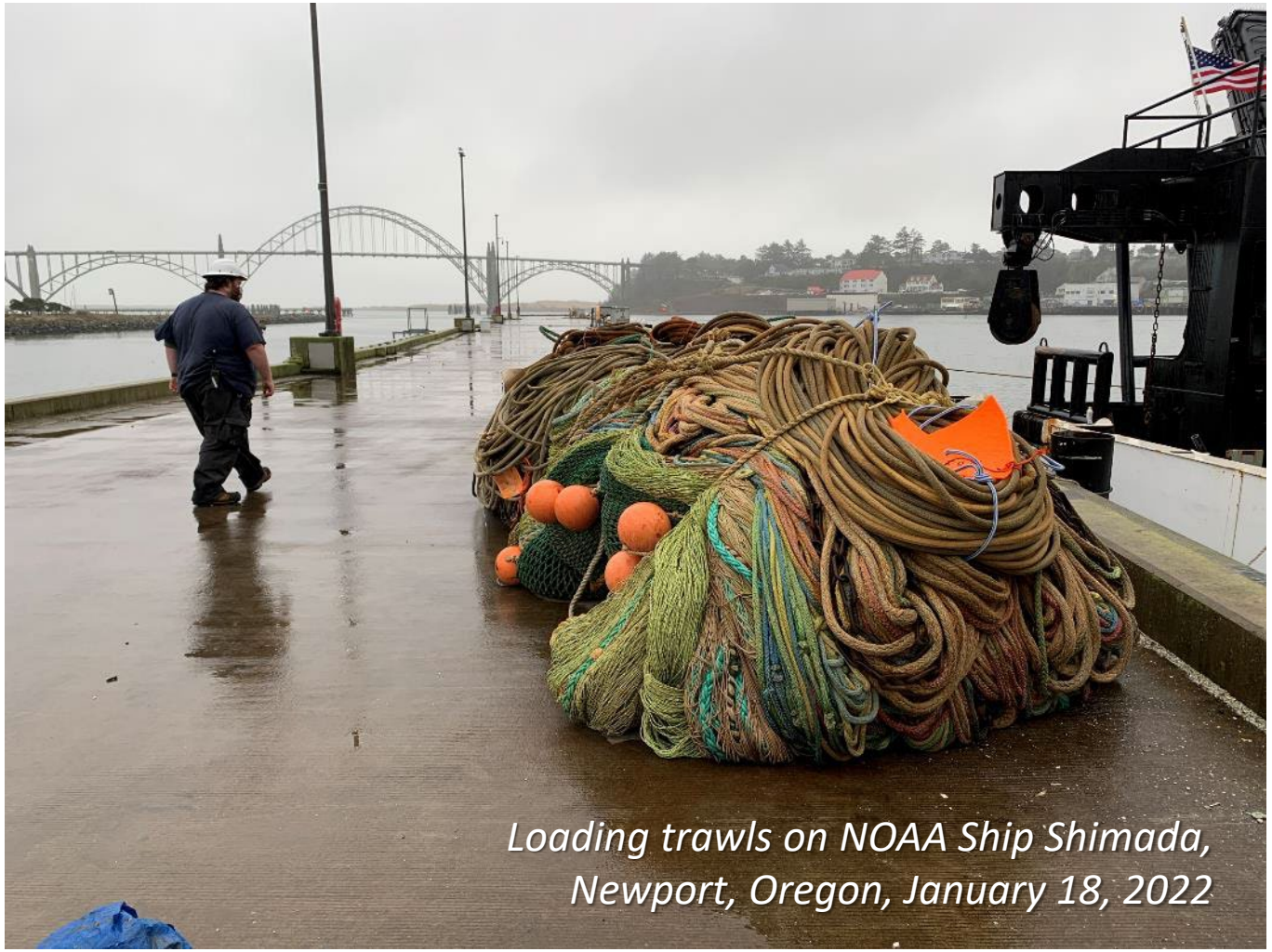
2) Knowing which parts of the ocean they're using (i.e., distributions) allows prediction of impacts of unusual conditions like marine heat waves.

3) Better understanding of high seas ecology should provide increased insight into factors affecting survival in the ocean (and therefore things we can do in freshwater and estuaries to increase survival).

(Surface trawls don't work well to catch steelhead [need different gear]).

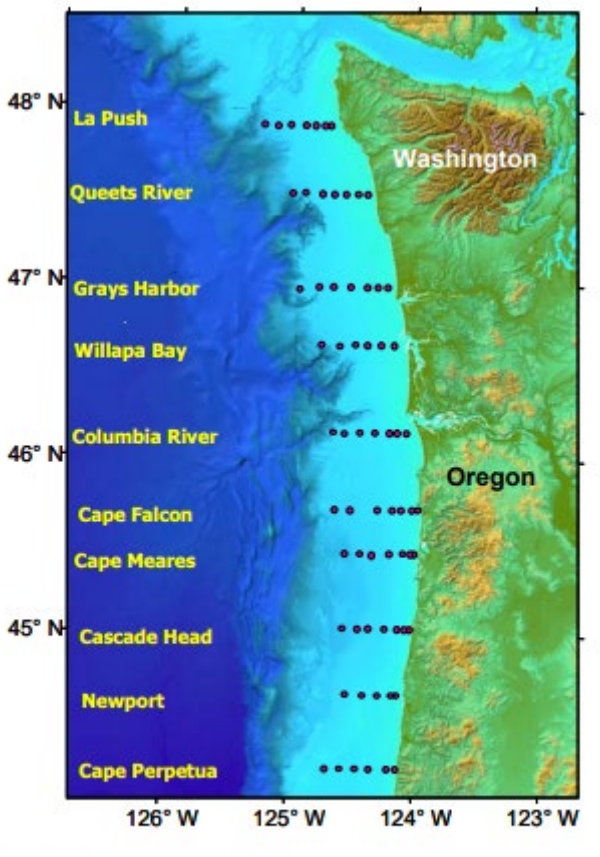
Today's talk

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



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

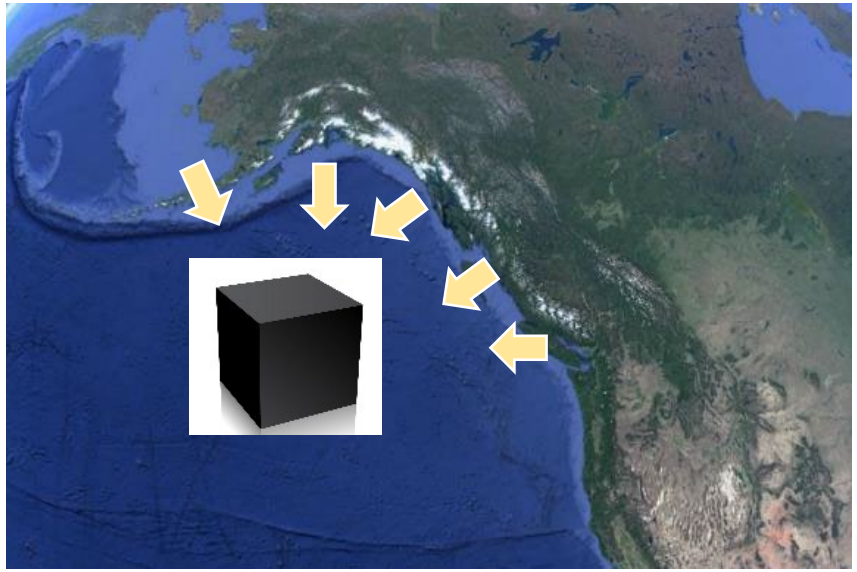
Why the survey?



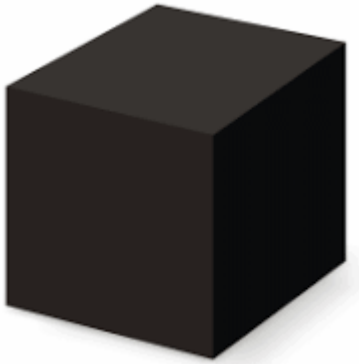
JSOES sampling stations

- Studies of juvenile Pacific salmon in coastal waters by US and Canada have greatly increased our understanding of initial marine ecology and factors affecting survival.

- Once salmon leave the coastal areas for the high seas, they enter the “black box” where far less is known, especially in winter



We know less about salmon on the high seas in winter than any other part of the 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 in winter
  - High mortality if low salmon energy reserves entering winter?
- If mortality is high, what is the source of mortality?
  - Starvation or predation or …..?
- 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

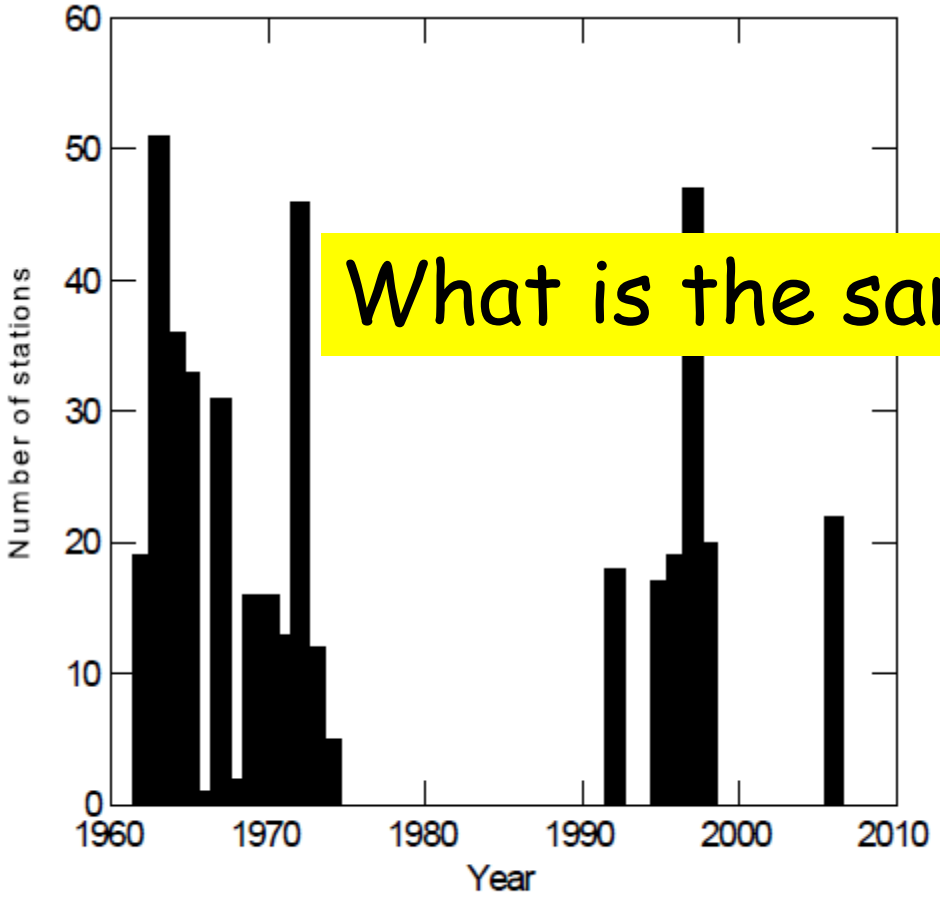


Figure 1: Number of salmon fishing stations in winter in the North Pacific Ocean by year.

What is the same? What is different?

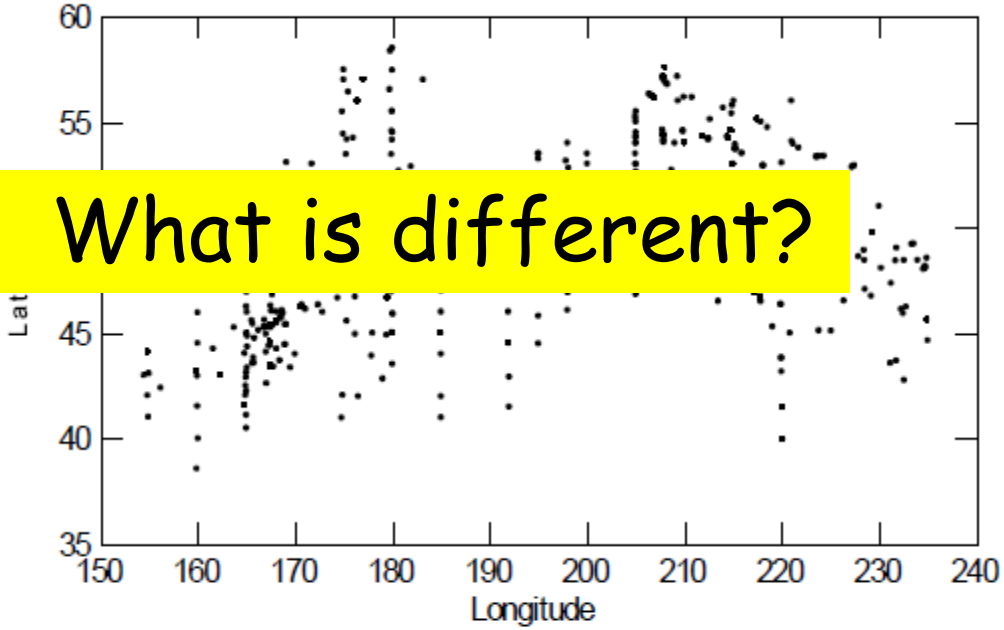


Figure 2: January through March fishing locations in the North Pacific Ocean and Bering Sea prior to IYS and where SST was also measured.

Figures from Skip McKinnell

Common methods across ships

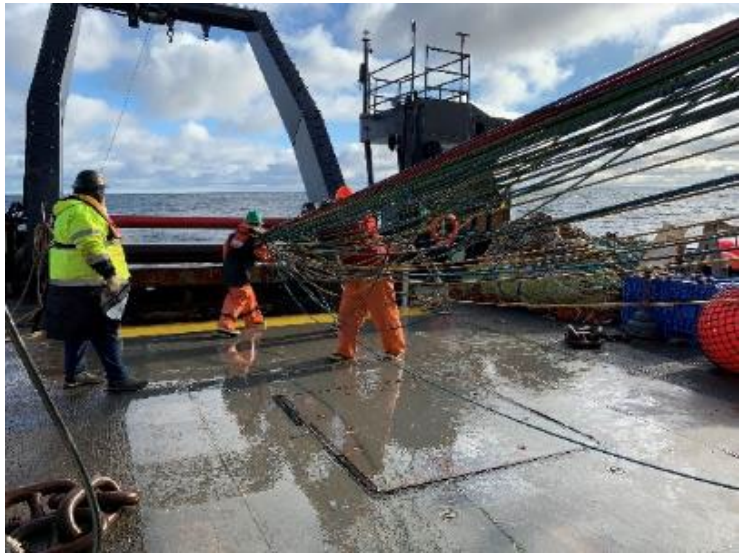
Physical oceanography

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)

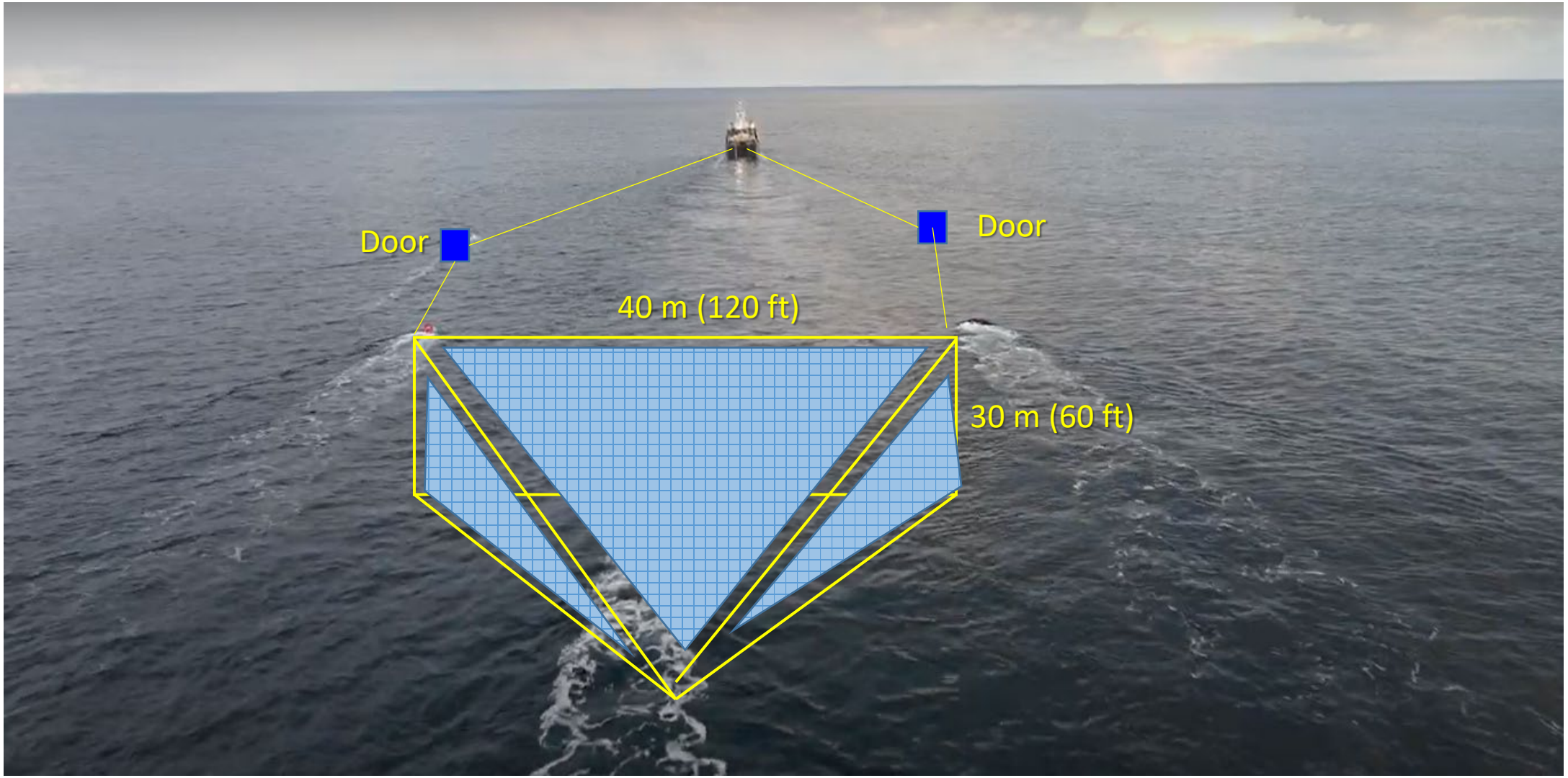


Surface trawls or Japanese-style research gill net (F/V Raw Spirit)

Trawl deployed behind the F/V Northwest Explorer

Courtesy Andrew Dimond, NOAA Fisheries/AFSC

Trawl deployed behind the F/V Northwest Explorer



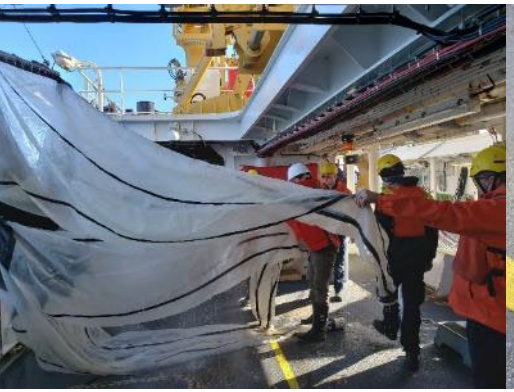
Courtesy Andrew Dimond, NOAA Fisheries/AFSC

Bongo Tows

Slide from Jackie King, CDFO



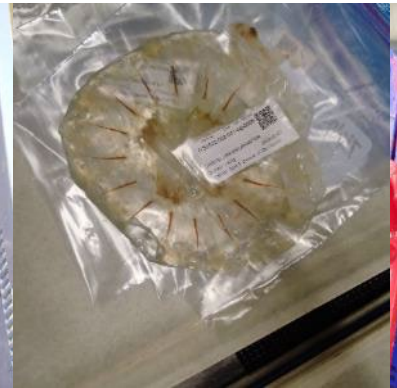

Tucker Trawls




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*

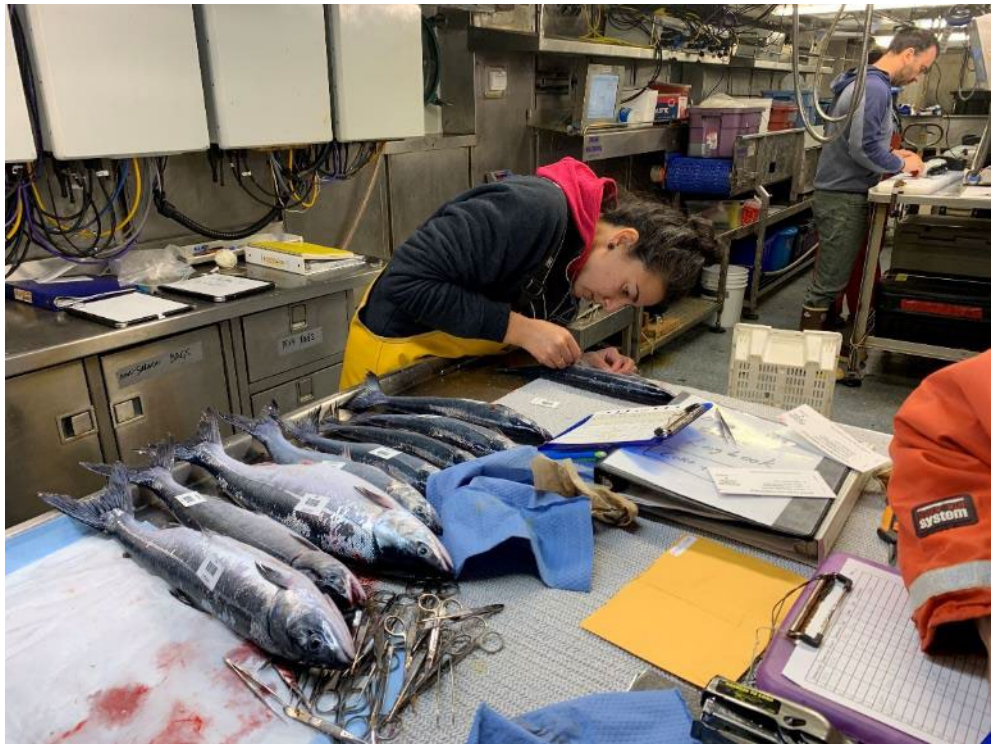
Fin clips (Genetic Stock Identification)

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

Blood (Insulin-like Growth Factor hormone)

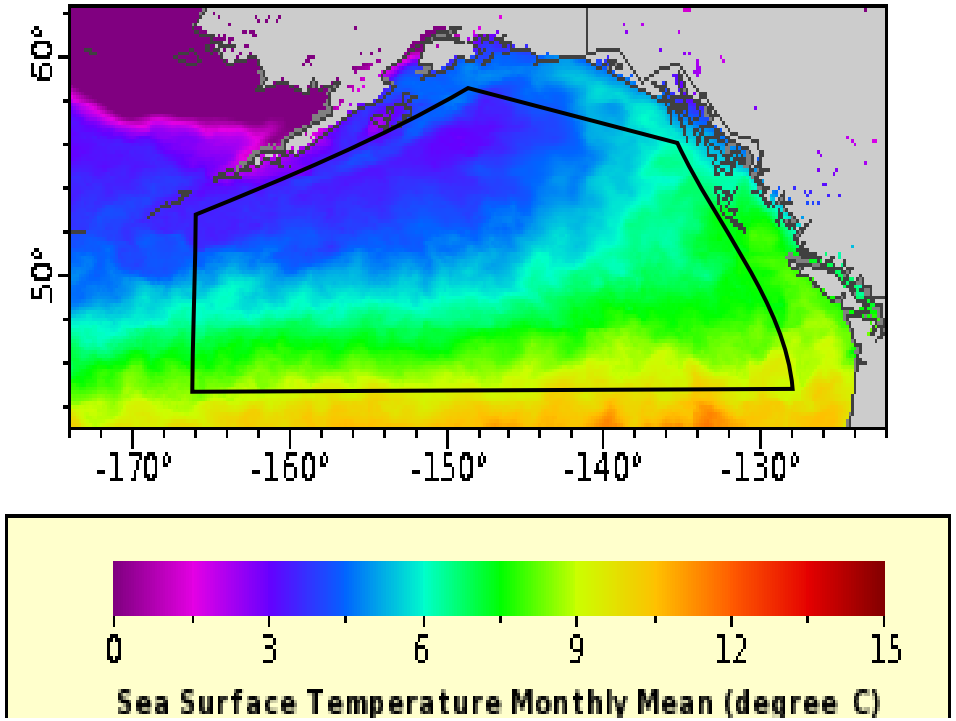
Stomachs (microplastics)

Processing the catch on the *Shimada*

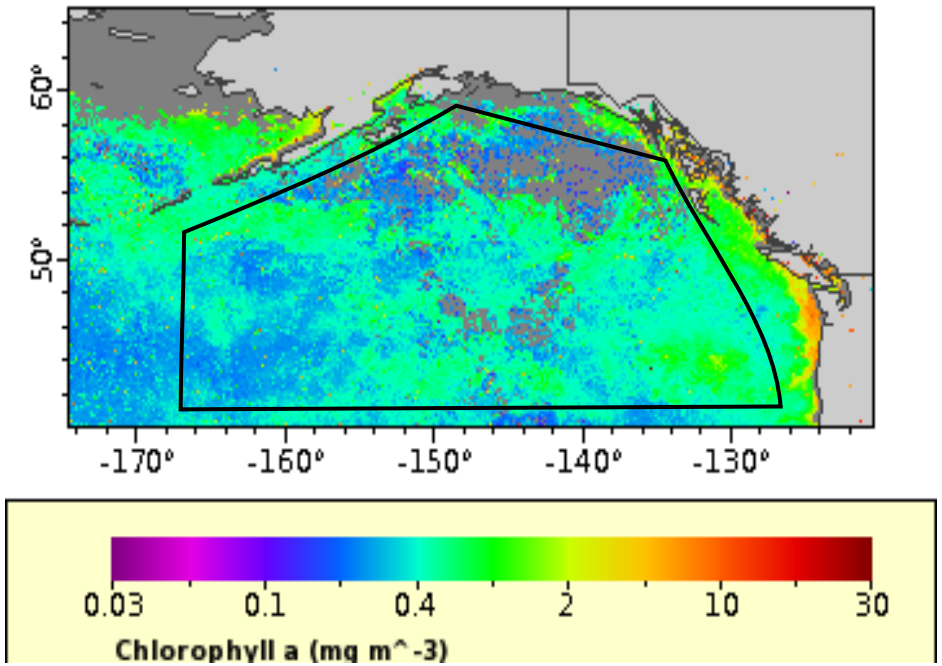


Temperatures and Chl a across the survey area (monthly means for February 2022)

Sea surface temperature



Chlorophyll a

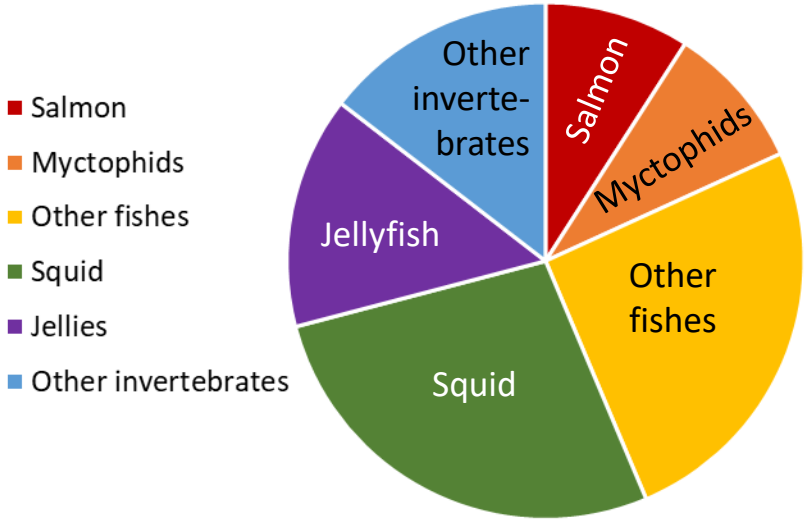


Results

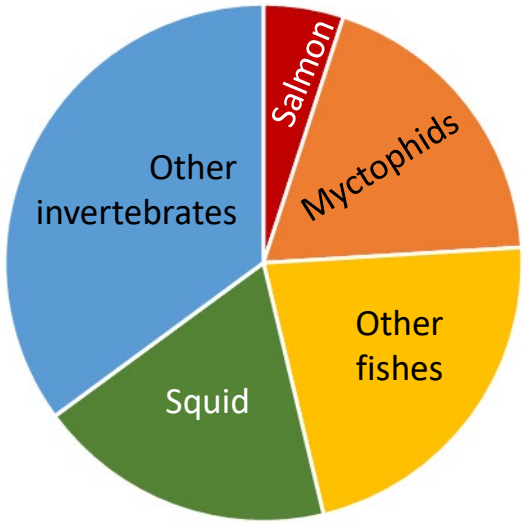
Catches on the Shimada

Catches by taxonomic group (all trawls combined)

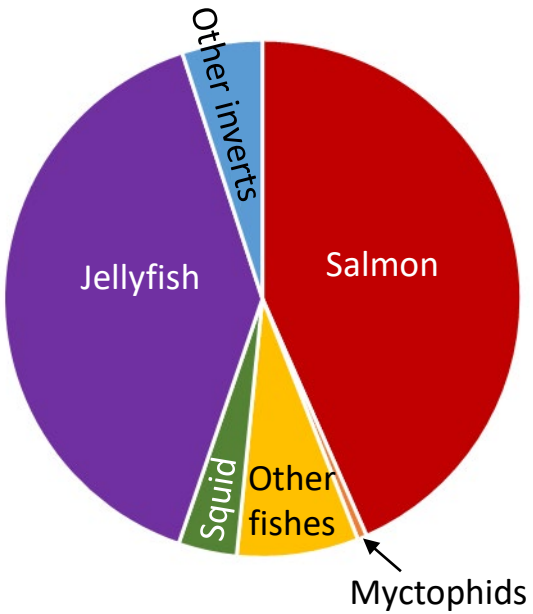
55 taxonomic groups identified



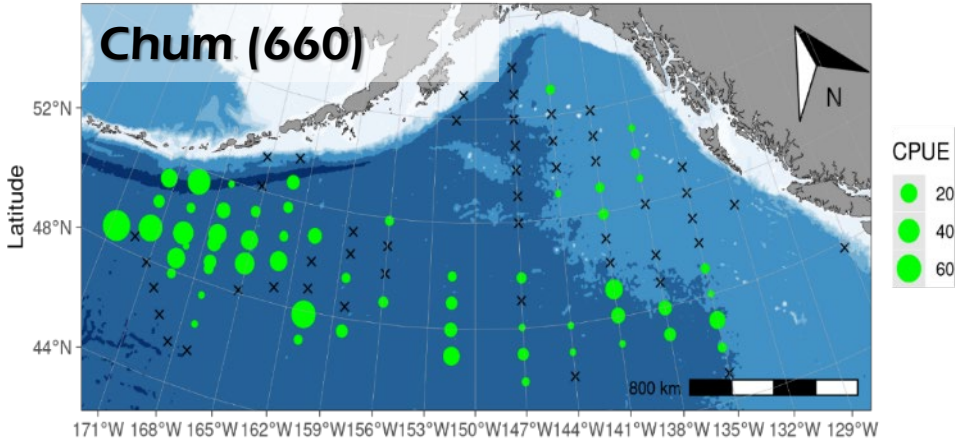
42,567 organisms counted (excludes jellyfish)

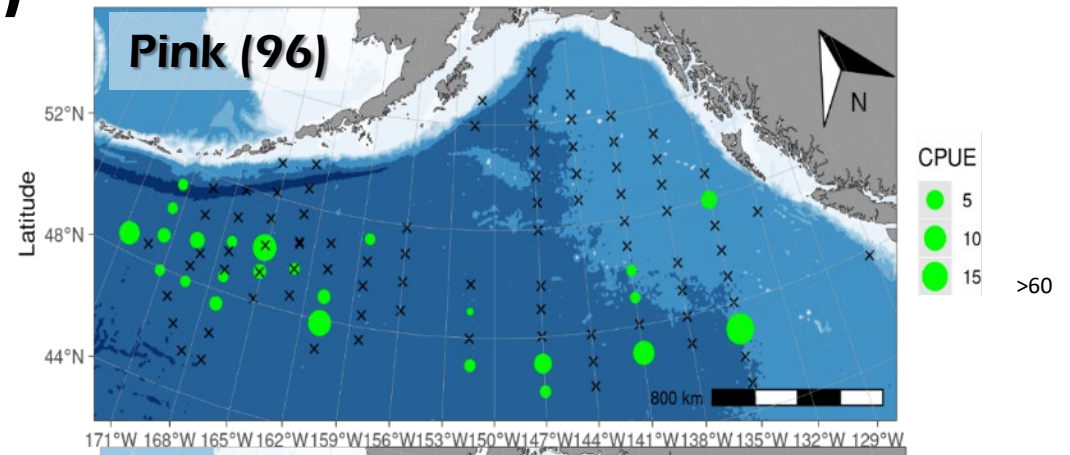


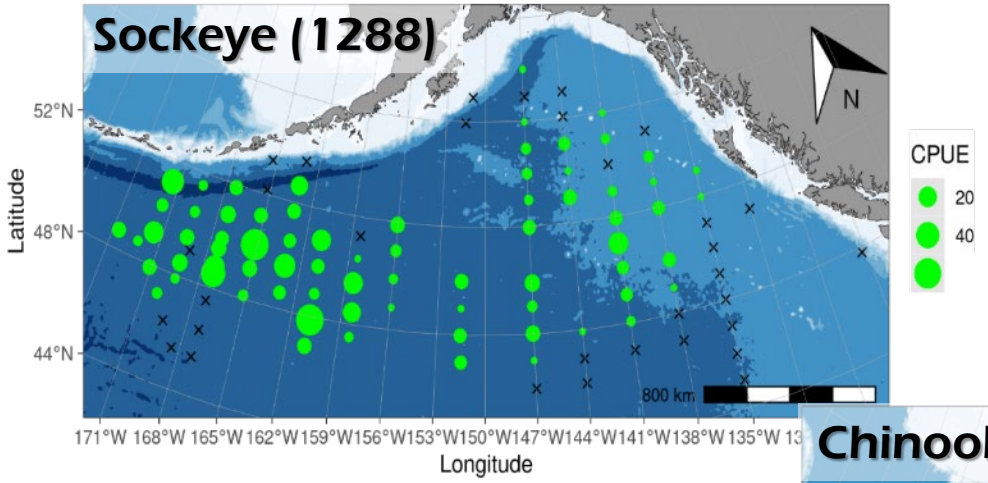
2,932 kg of trawl contents weighed

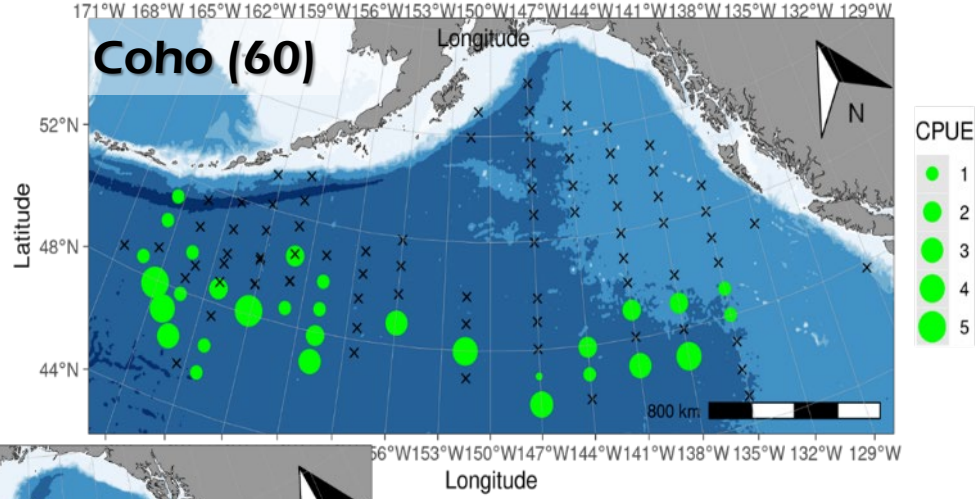


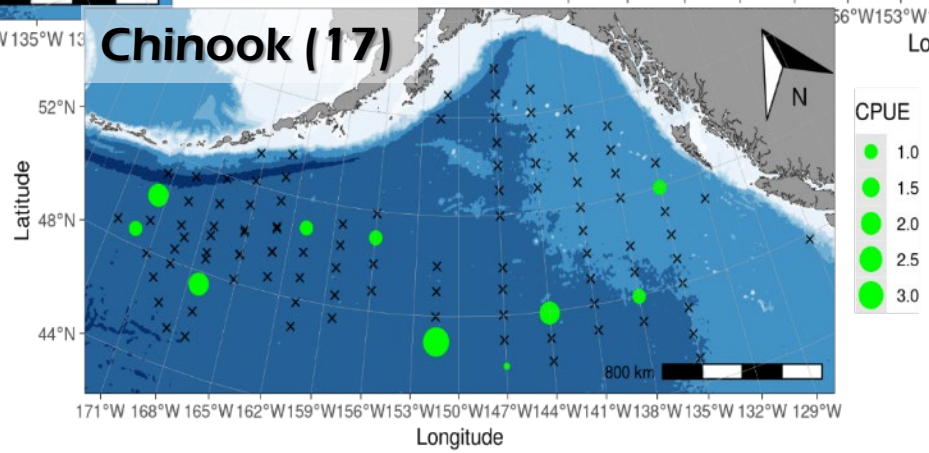
Salmon counts/hour (total)









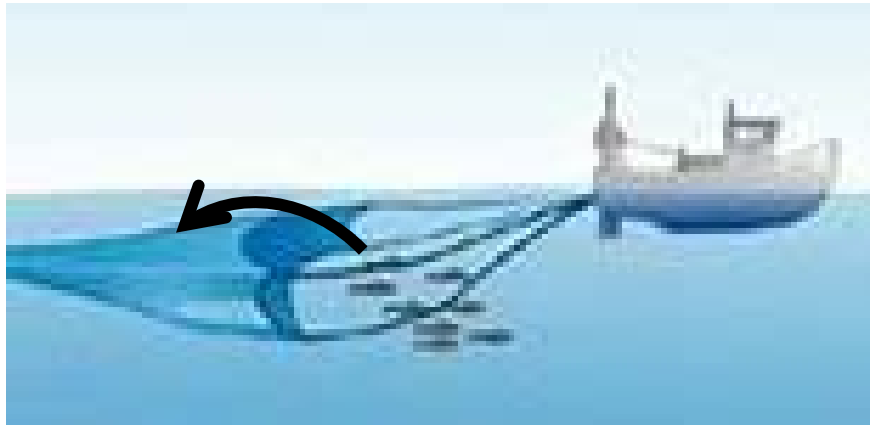


All steelhead were caught by the gill netter (F/V *Raw Spirit*), none by the trawls

Gill nets fish all the way to surface

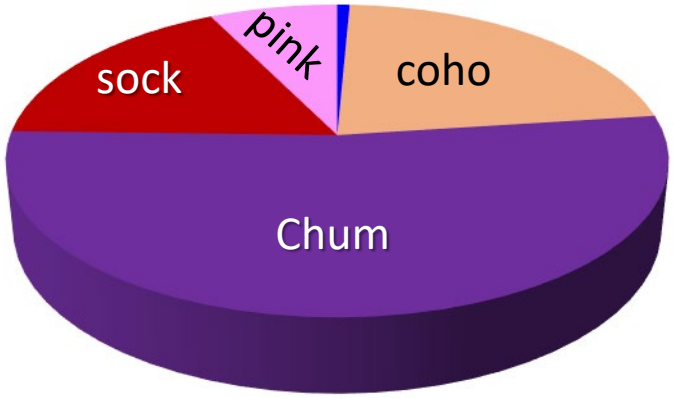
Extremely surface-oriented steelhead go over trawl headropes but not gillnet corklines!

Although towed at the surface, trawls have a gap between the top of the net (headrope) and the water's surface.

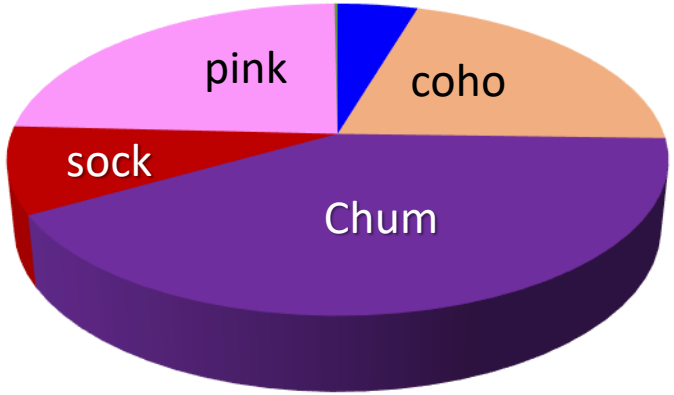


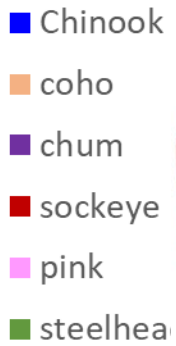
Gulf of Alaska catches by year

2019 (423)

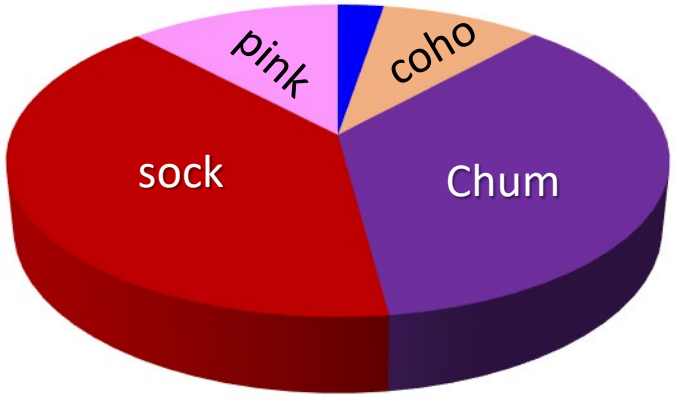


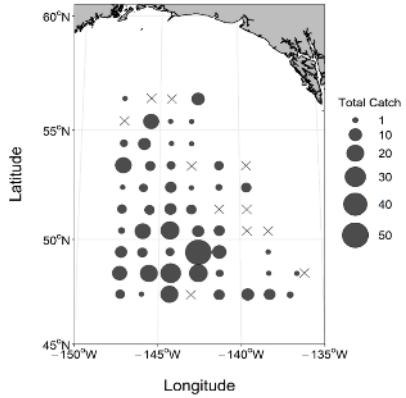
2020 (566)



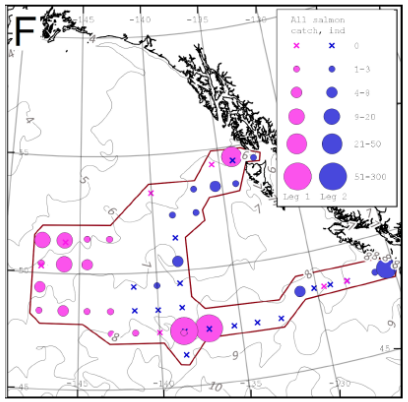


2022
Franklin &
Shimada (383)

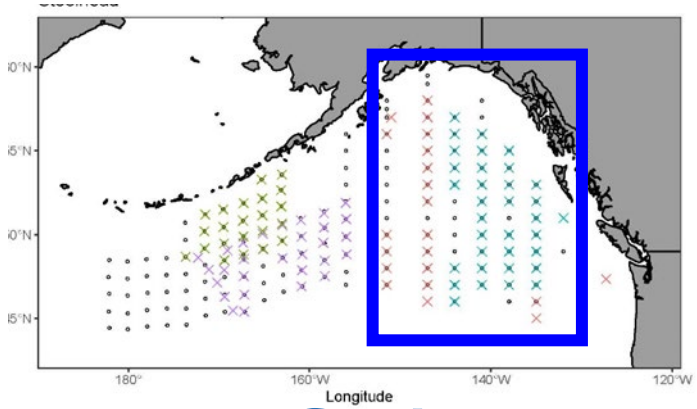




Warm



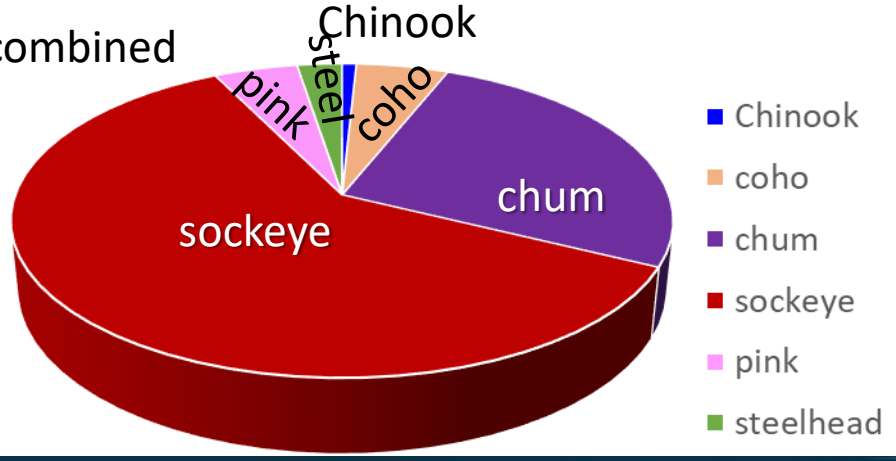
"Normal"



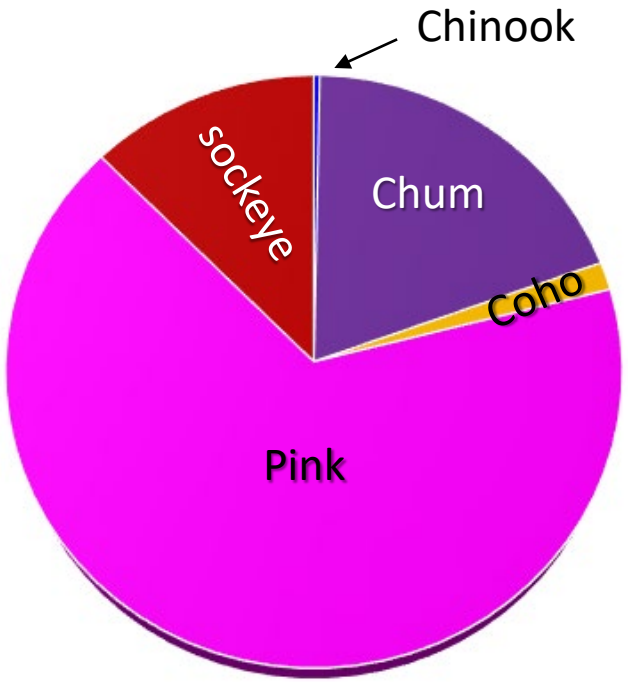
Cool

Expected vs observed catch in 2022

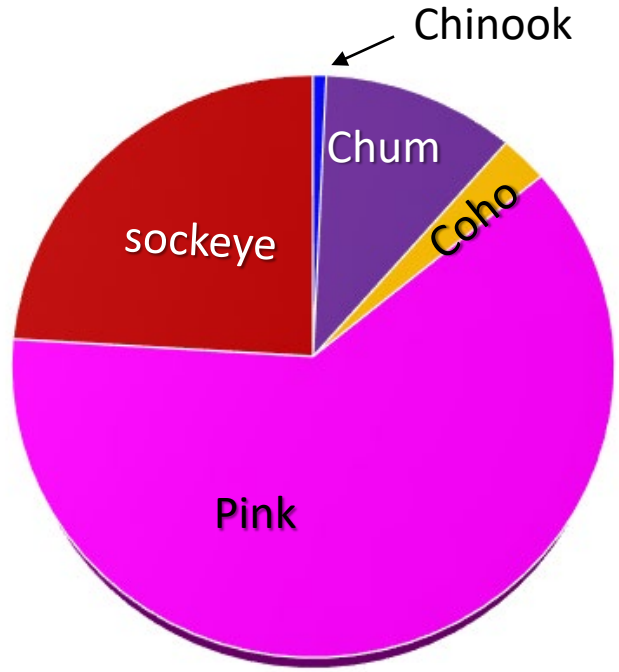
All ships combined

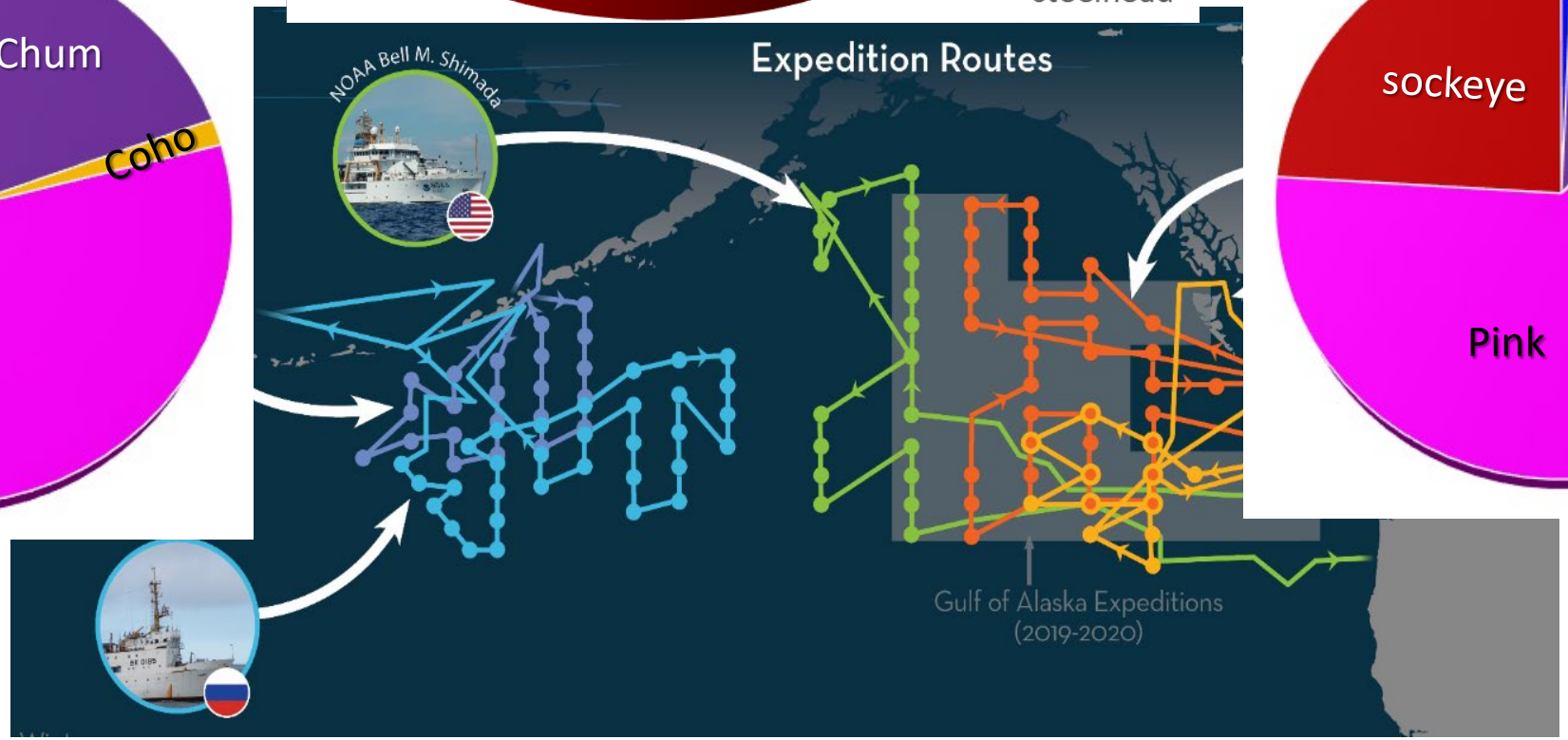


Whole Pacific catch
2000-2021



US & Canada catch
2000-2021

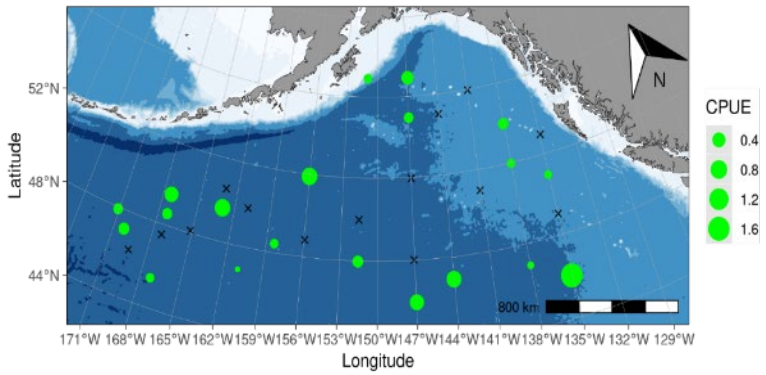




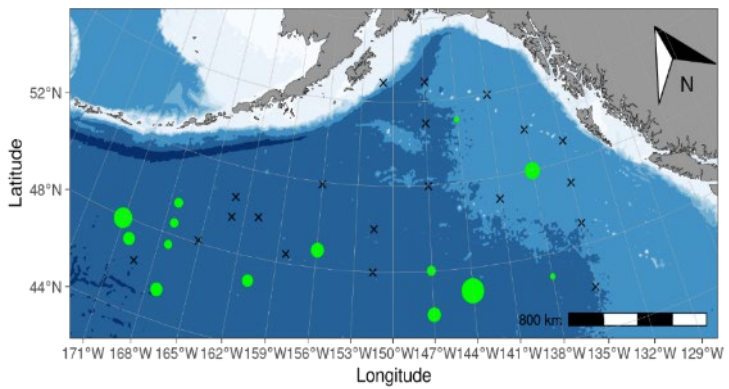
Other frequently caught species: squid, myctophids and jellyfish (kg/hour)

Prey & competitors

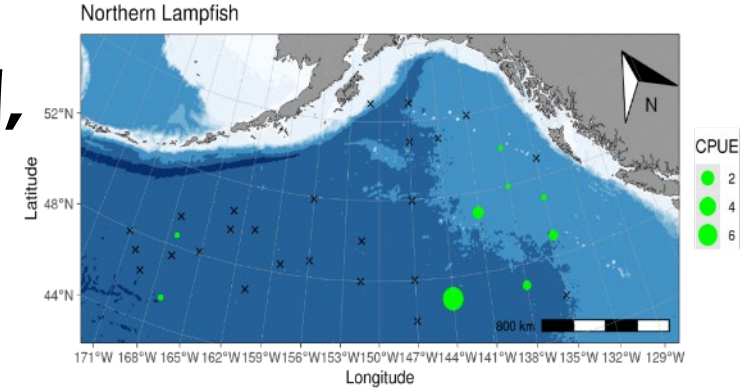
Boreopacific armhook squid



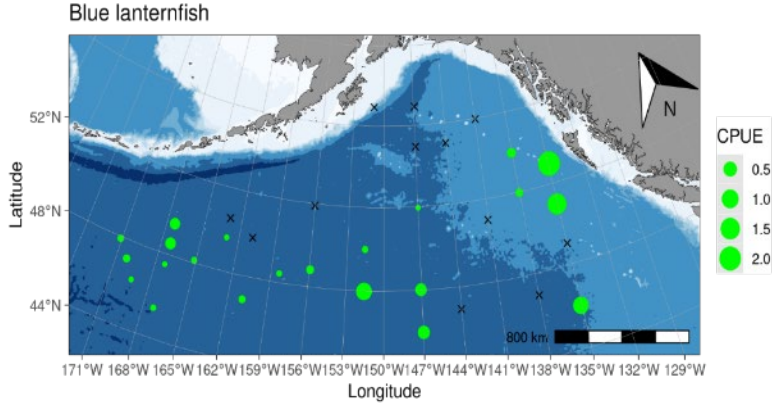
Boreal clubhook squid



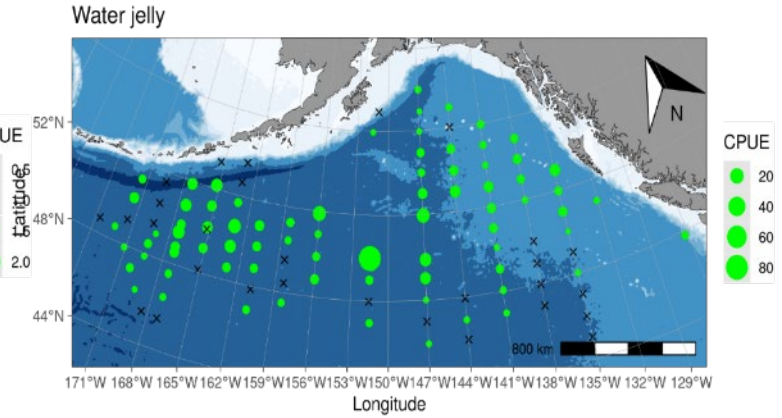
Northern Lampfish



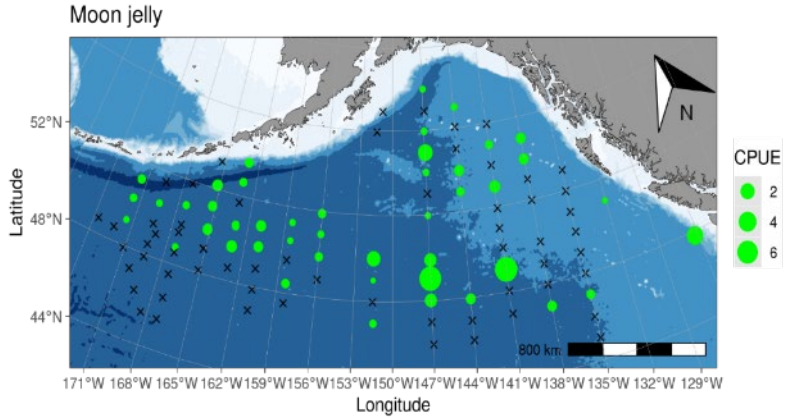
Blue lanternfish



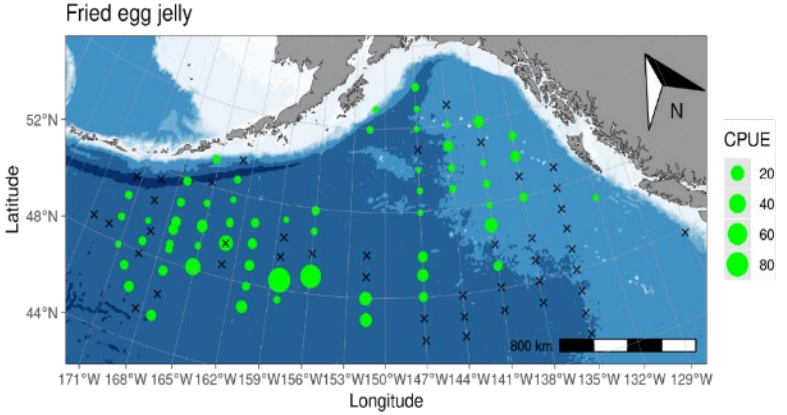
Water jelly



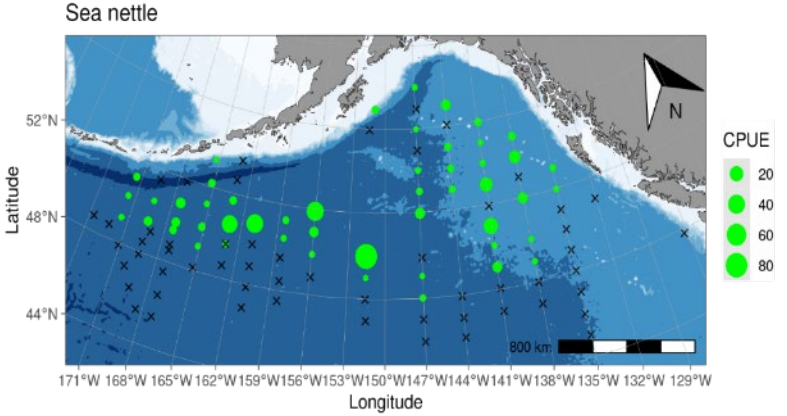
Moon jelly



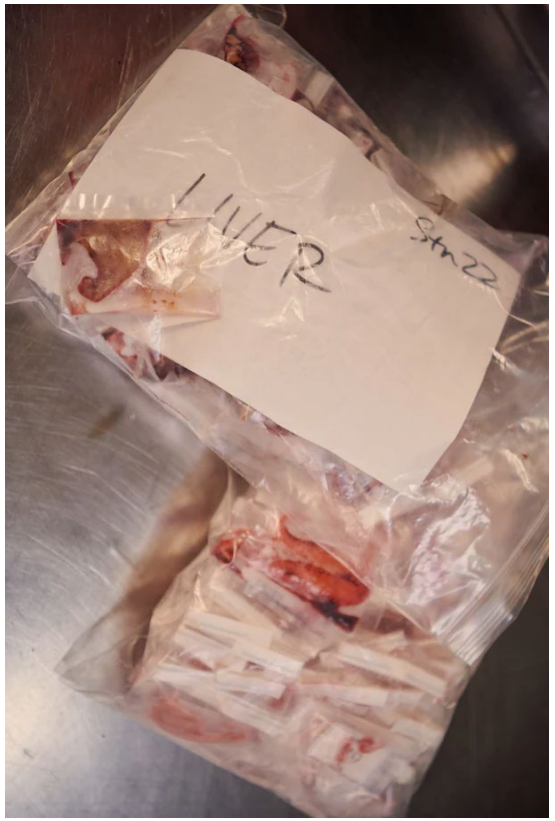
Fried egg jelly



Sea nettle



Detailed analyses just starting to emerge



Oceanological environment

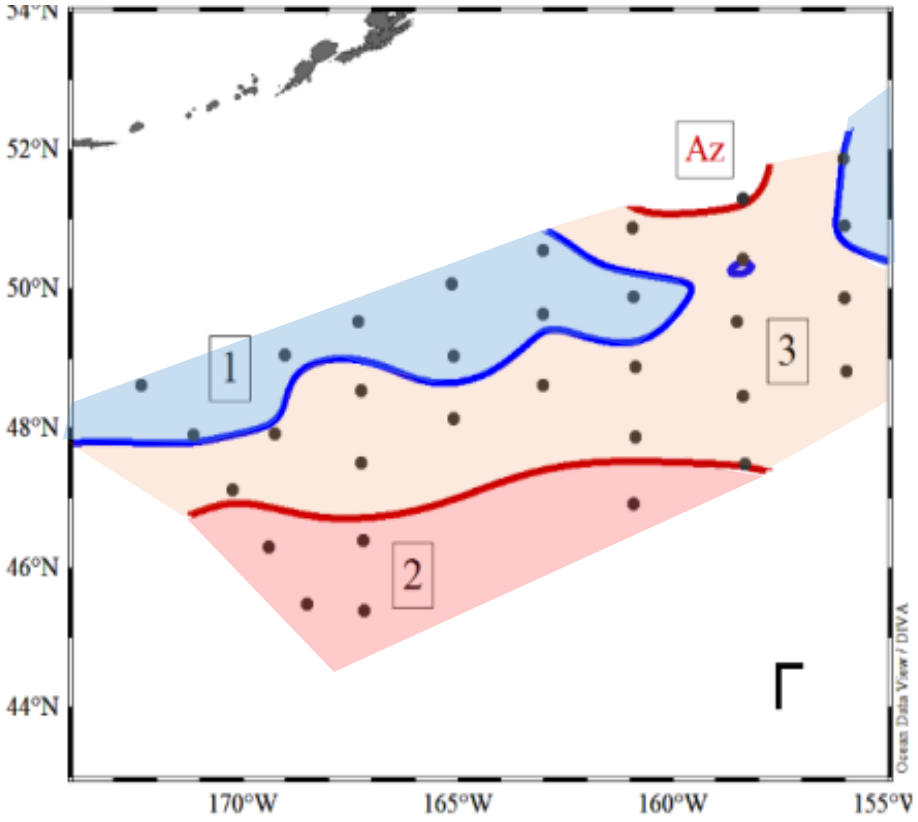


Figure 4 - distribution of water masses (left) and water surfac
subtropical waters, 3 - mixing zone, Az - a

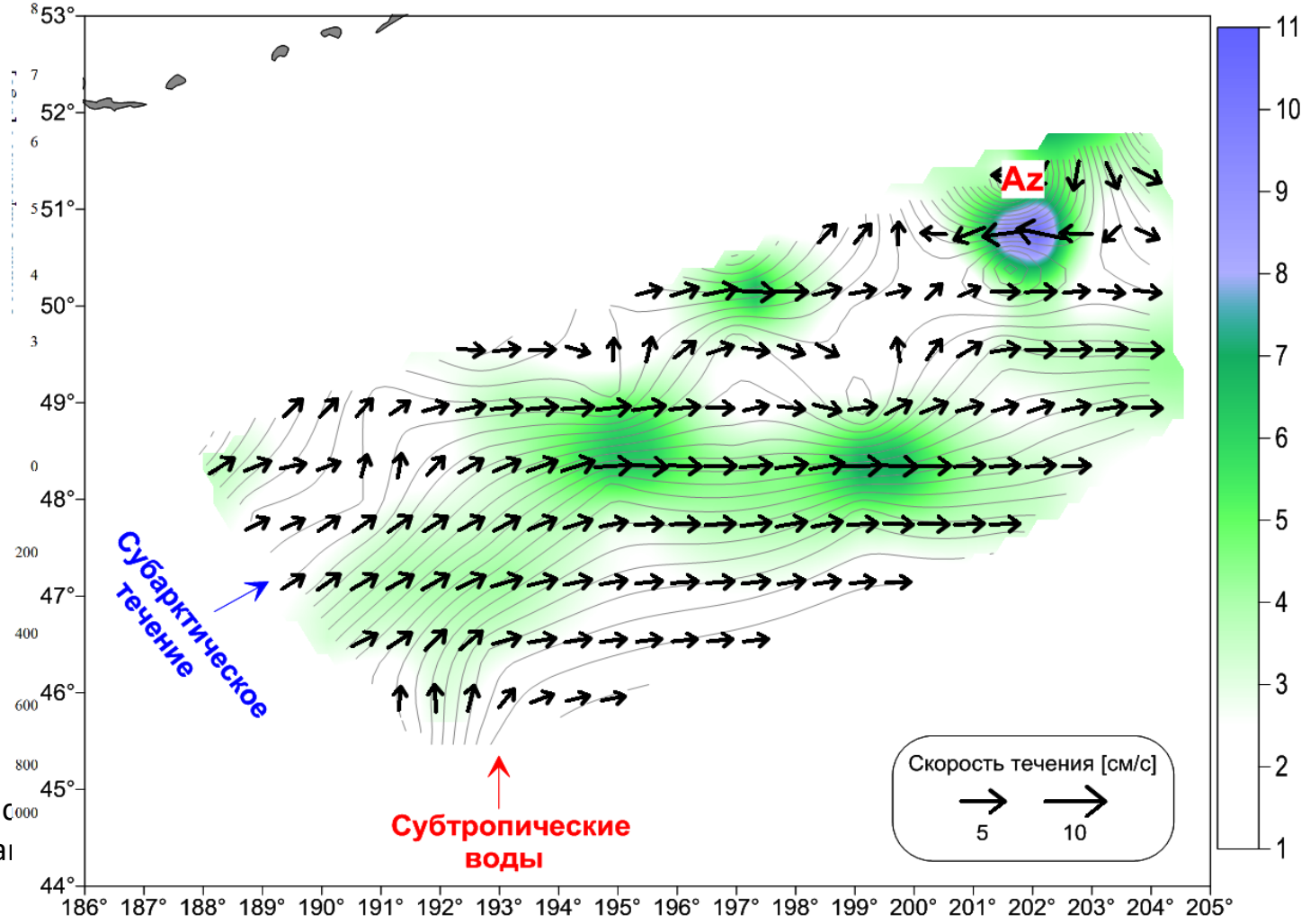
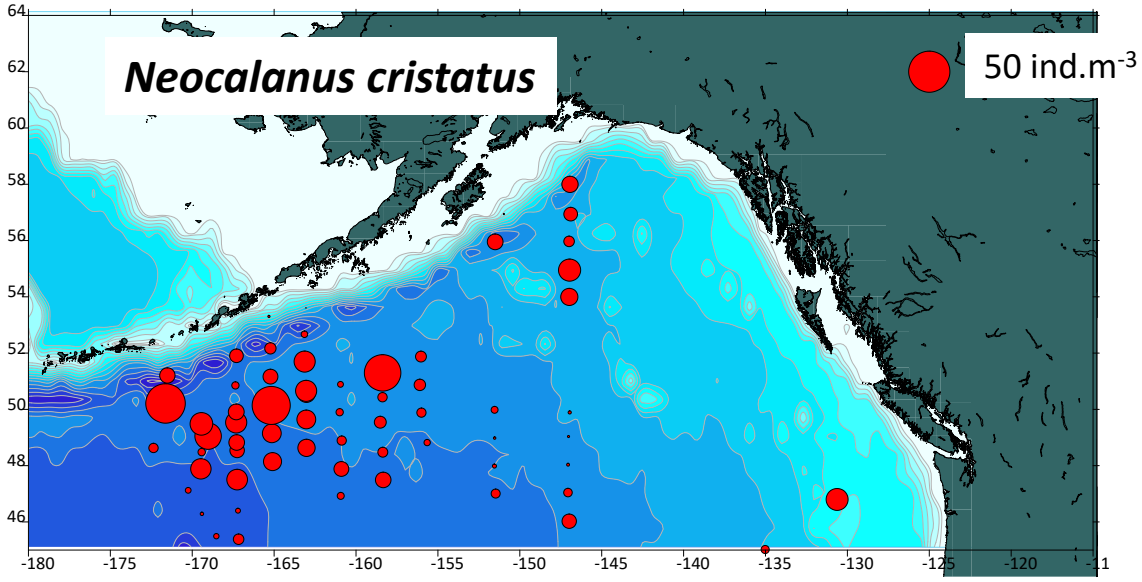
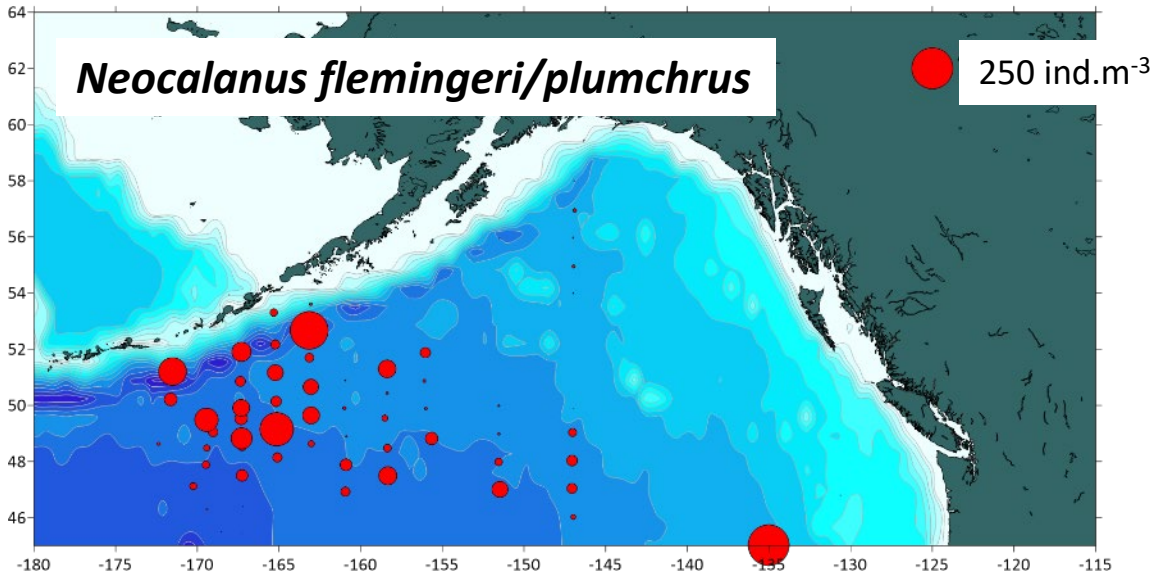


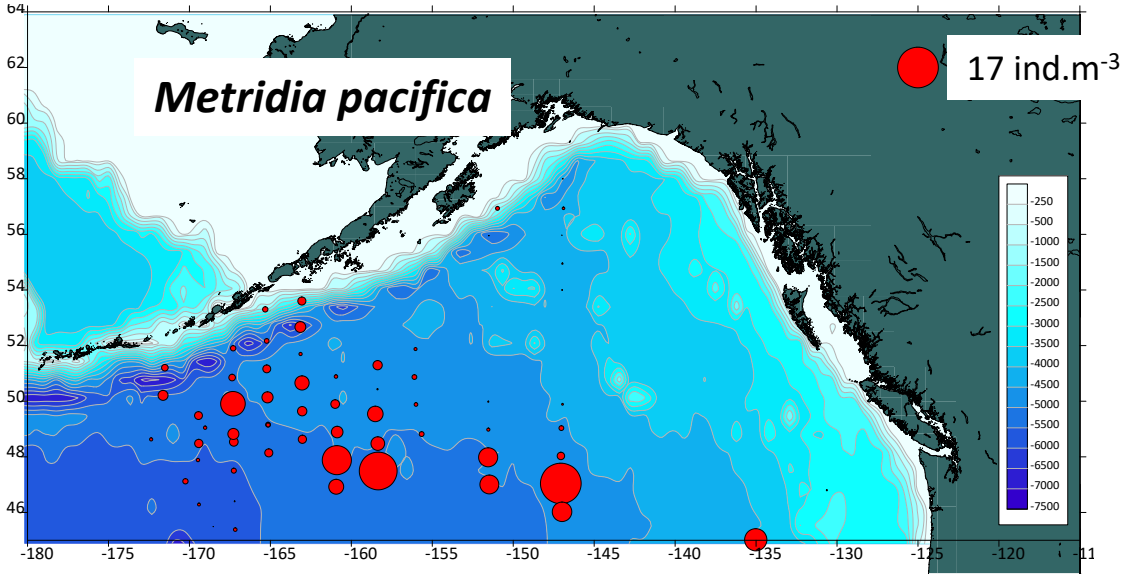
Figure 5 - TS-diagrams and characteristic vertical profiles of different types of water masses within the study area

Figures from Aleksey Somov, TINRO

Preliminary bongo zooplankton results







Figures provided by Alexei Pinchuk, Univ Alaska Fairbanks

Salmon diets from TINRO

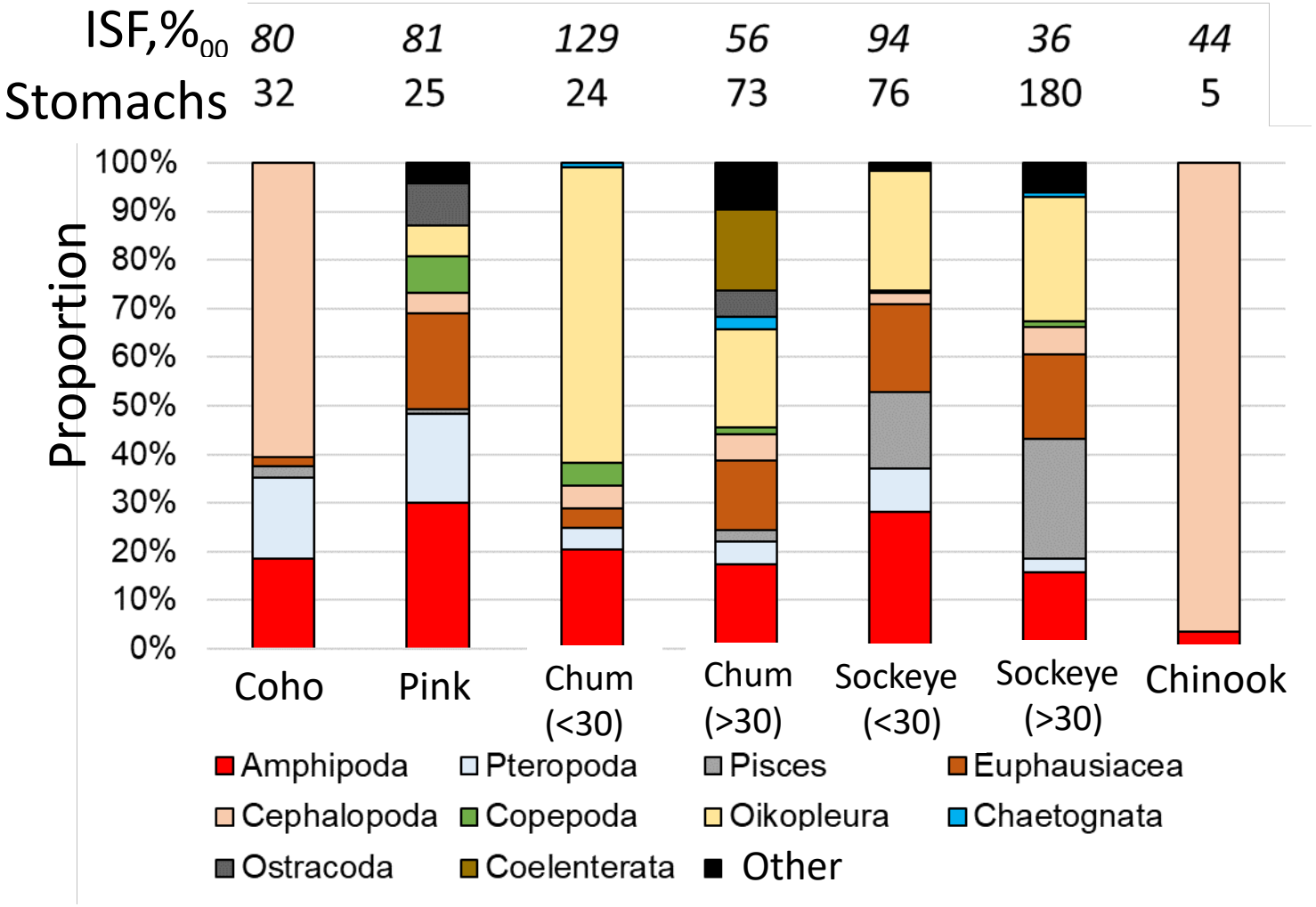
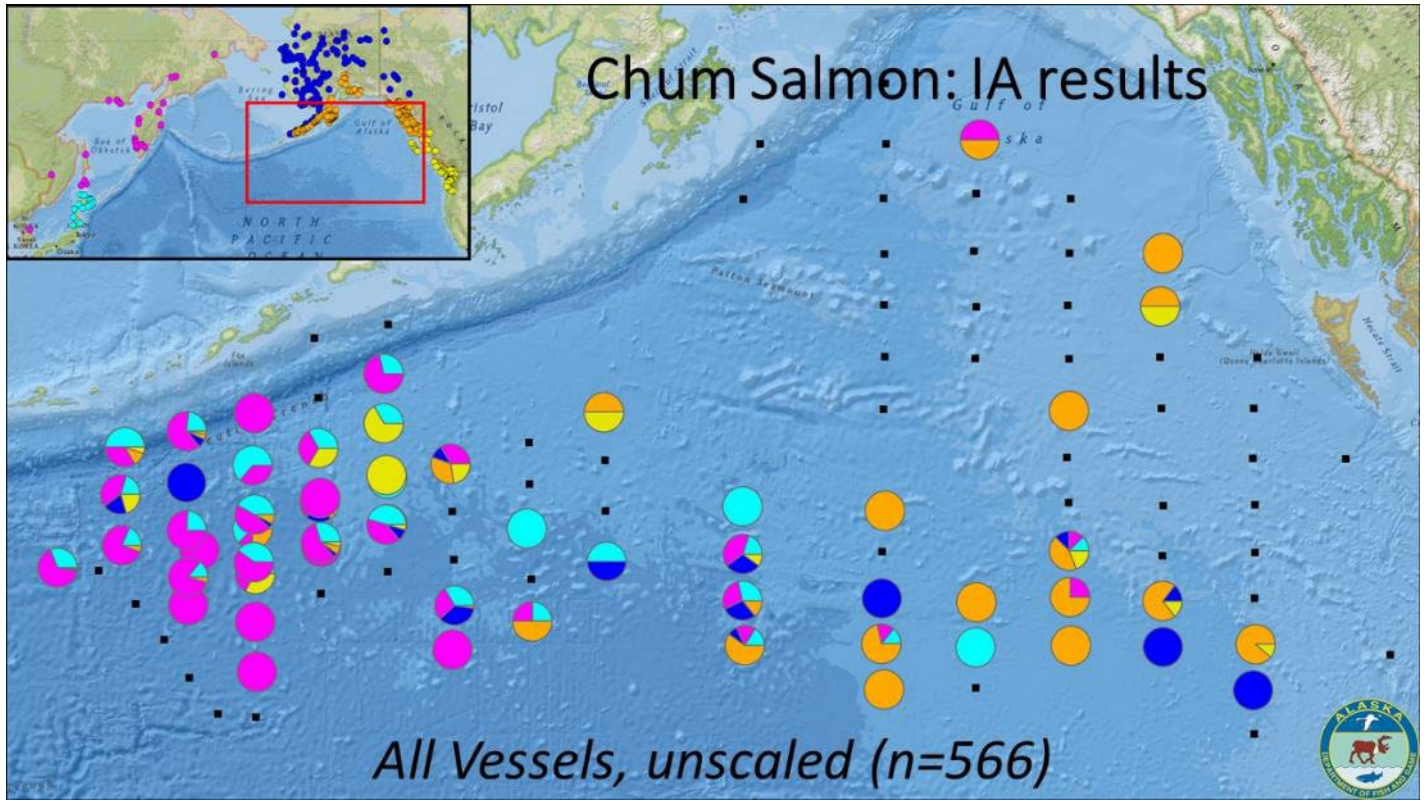
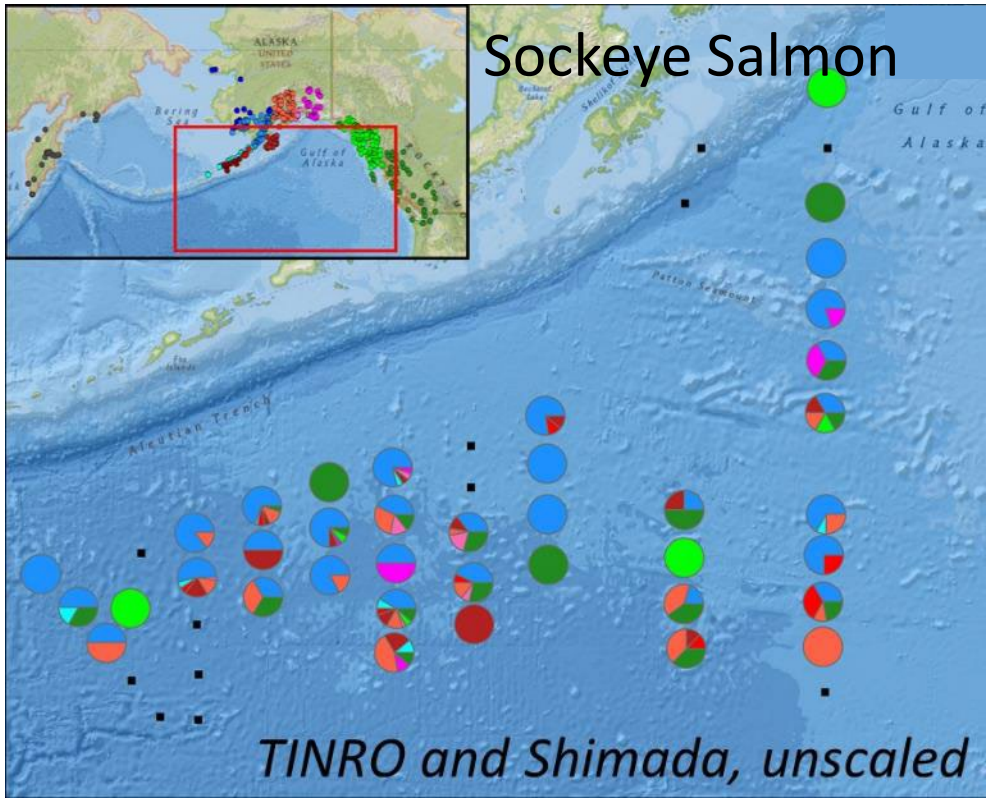


Figure 13 - Ratio of Pacific salmon diet groups in near-Aleutian waters of the NPO in March 2022.

Figure from Aleksey Somov, TINRO

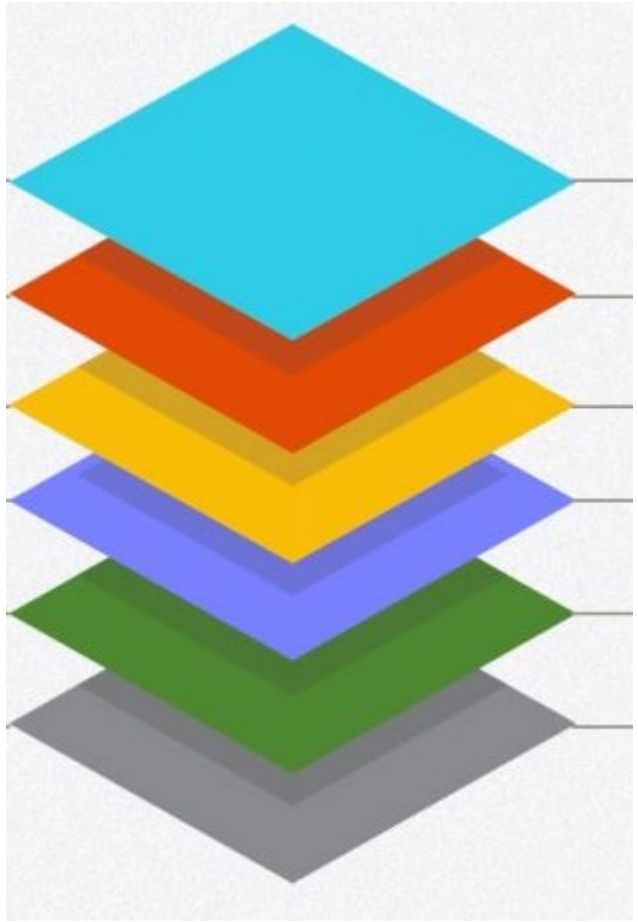
Preliminary genetic stock identification results





Slide from Liz Lee, Alaska Dep Fish and Game

Understanding the entire ecosystem



Predators

Salmon, squid, other fishes, jellyfish

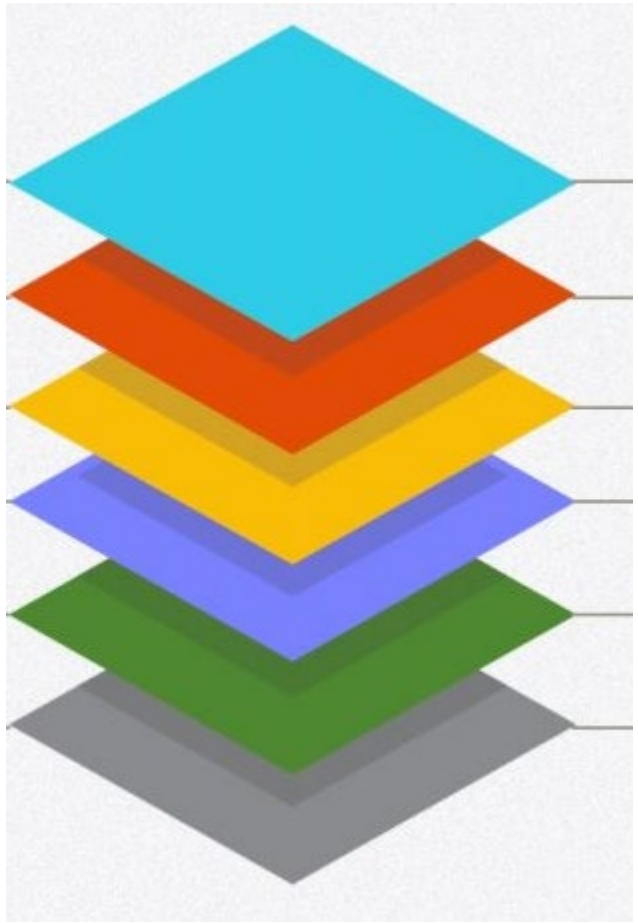
Zooplankton

Primary productivity (phytoplankton)

Chemical oceanography (salinity, nutrients)

Physical oceanography (temperature, currents)

Understanding the entire ecosystem



Predators

Salmon

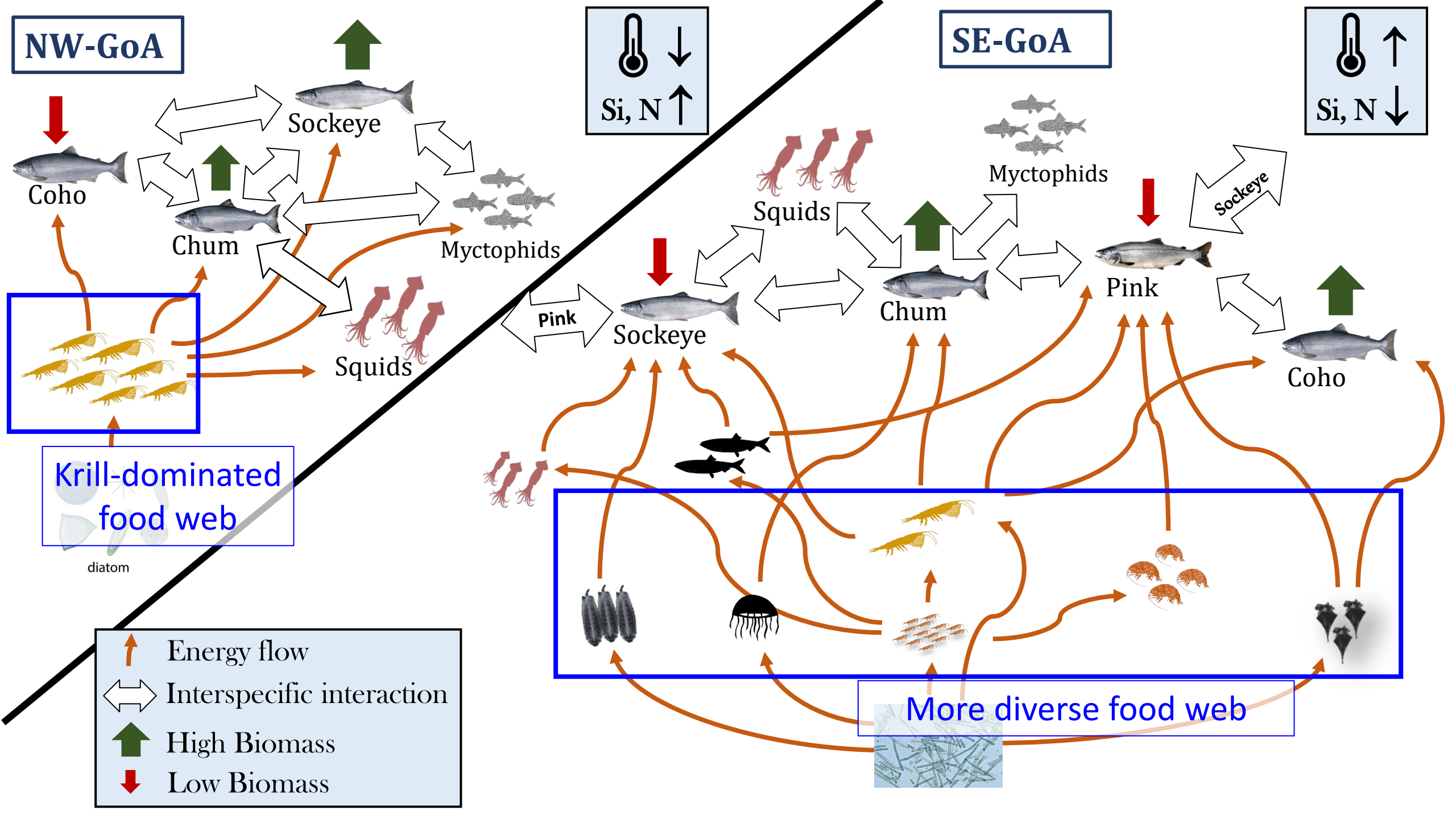
Zooplankton

Species
Stock
Condition
Growth rates

Primary productivity (phytoplankton)

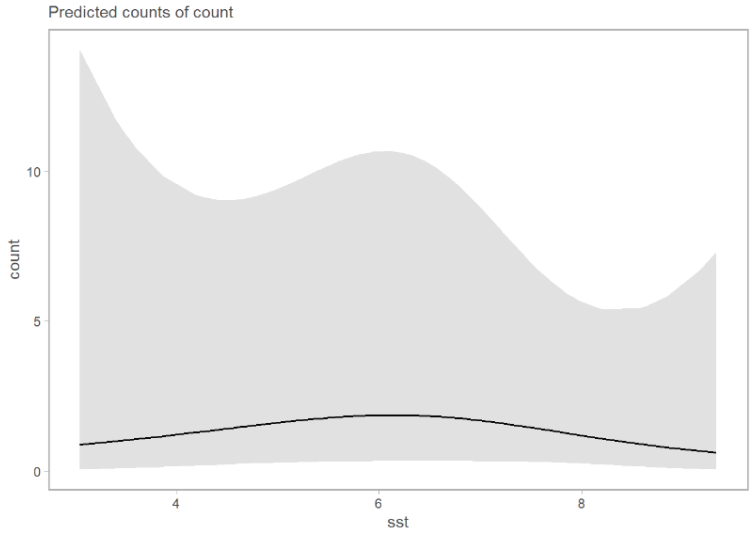
Chemical oceanography (salinity, nutrients)

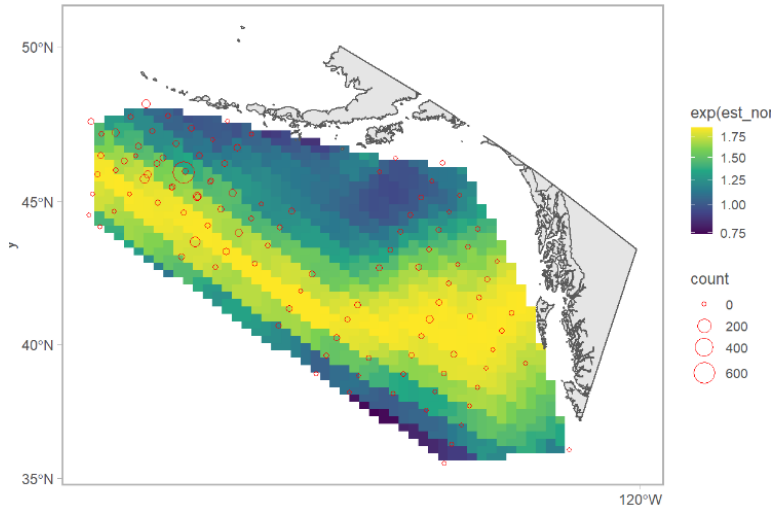
Physical oceanography (temperature, currents)

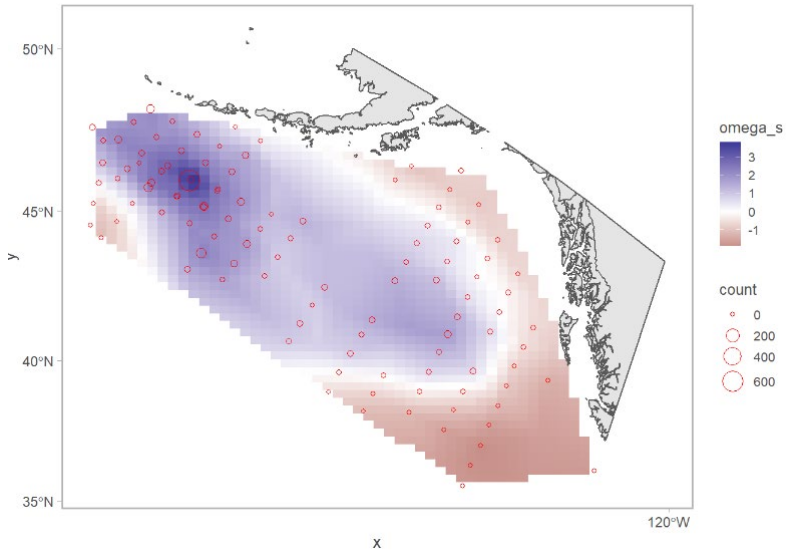

NW-GoA
Si, N ↑
Si, N ↓
SE-GoA
Sockeye
Coho
Chum
Myctophids
Squids
Pink
Krill-dominated food web
diatom
Energy flow
Interspecific interaction
High Biomass
Low Biomass
More diverse food web

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







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

2022 Fraser River Sockeye

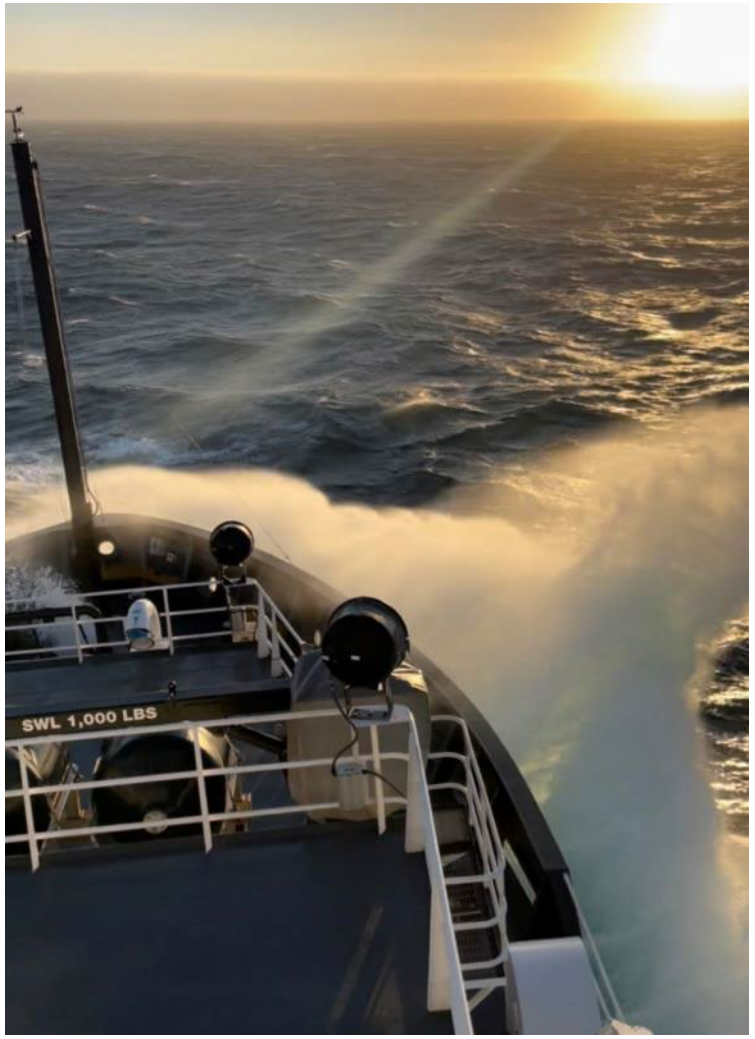
	Sockeye caught	From Fraser River	Fraser River	
			Summer-run	Late-run
Franklin	88	7%	83%	17%
Raw Spirit	53	28%	86%	16%
Total Eastern	135	16%	85%	15%
Shimada	68	13%	78%	22%
TINRO	313	0.03%	88%	12%
NW Explorer*	207	.005%	100%	0%*
Total Central	588	3.1%	83%	17%

*survey occurred later than other vessels

Table provided by Jackie King, CDFO

Looking forward

- Many samples to run, data to analyze
- Another meeting next year (PICES in Seattle, Fall 2023)
- Synthesize many data sets (multiple layers)
- Why stop high seas expeditions now?
  - Dick Beamish organizing Apr 2023 cruise to Gulf of Alaska
  - Basin Scale to Ocean Impacts (BECI) study approved as UN Decade of Ocean Sciences project, fundraising & planning underway (https://beci.info)



Shimada in rough water
Photo by Ethan Beyer

Questions?

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

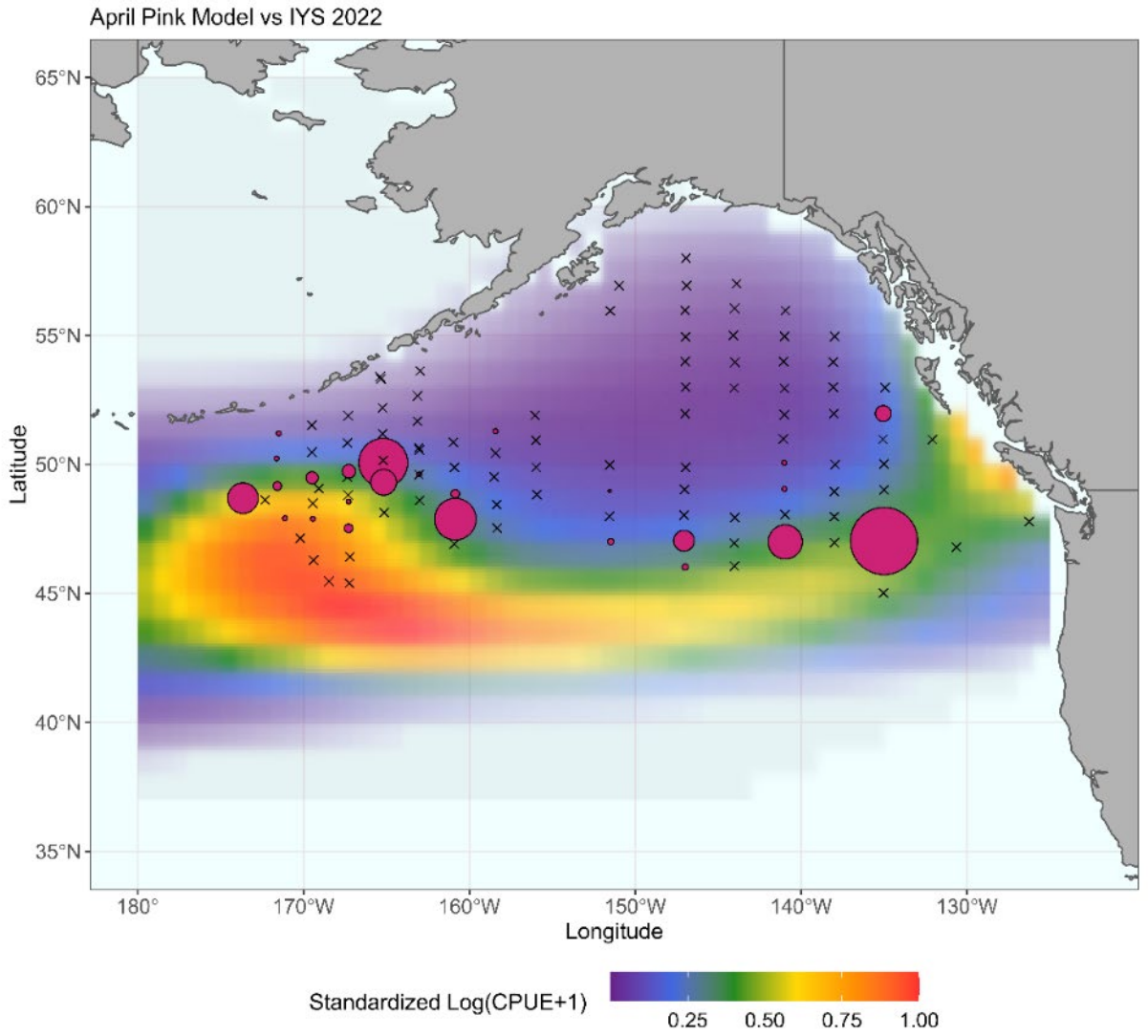


Figure by Joe Langan
Univ. Alaska Fairbanks