Life-history, Ecology, and Potential Threats to Mat-Su/Cook Inlet Chinook Salmon in the Marine Environment

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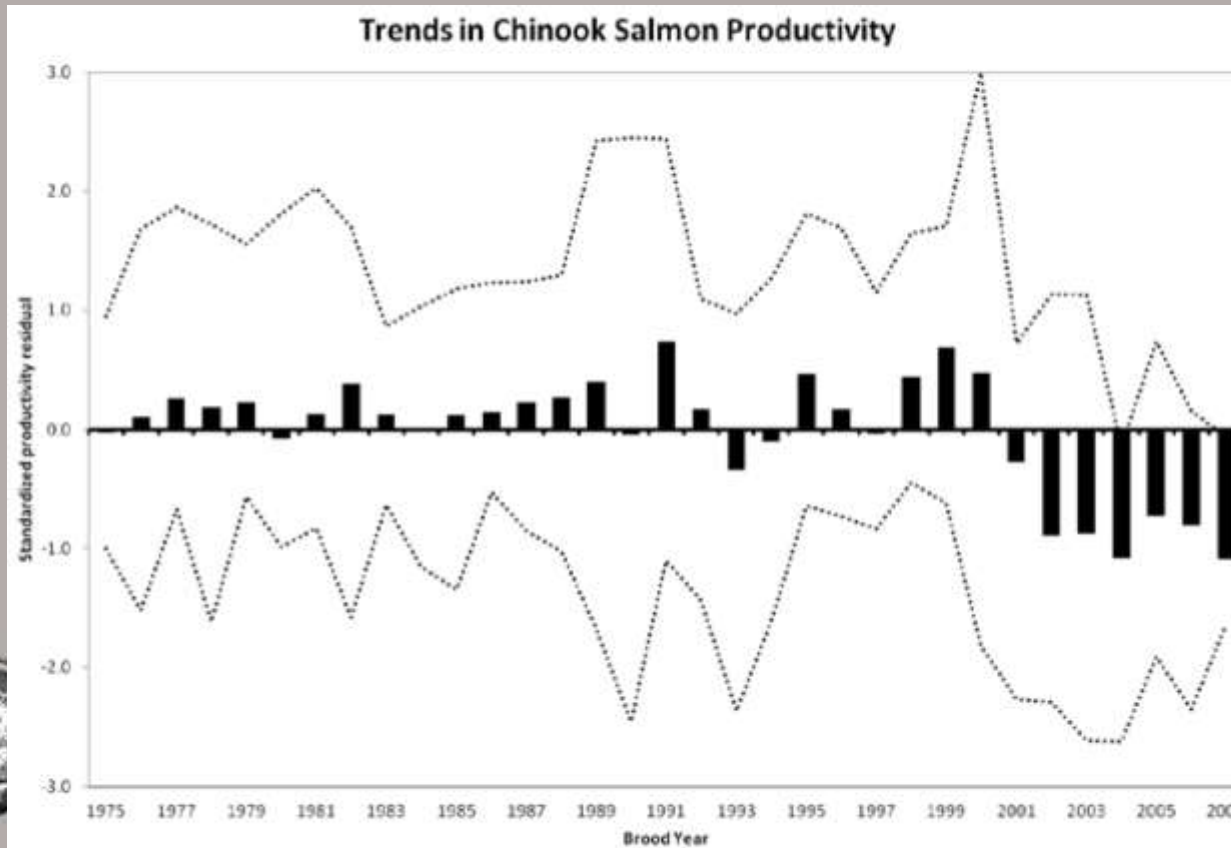
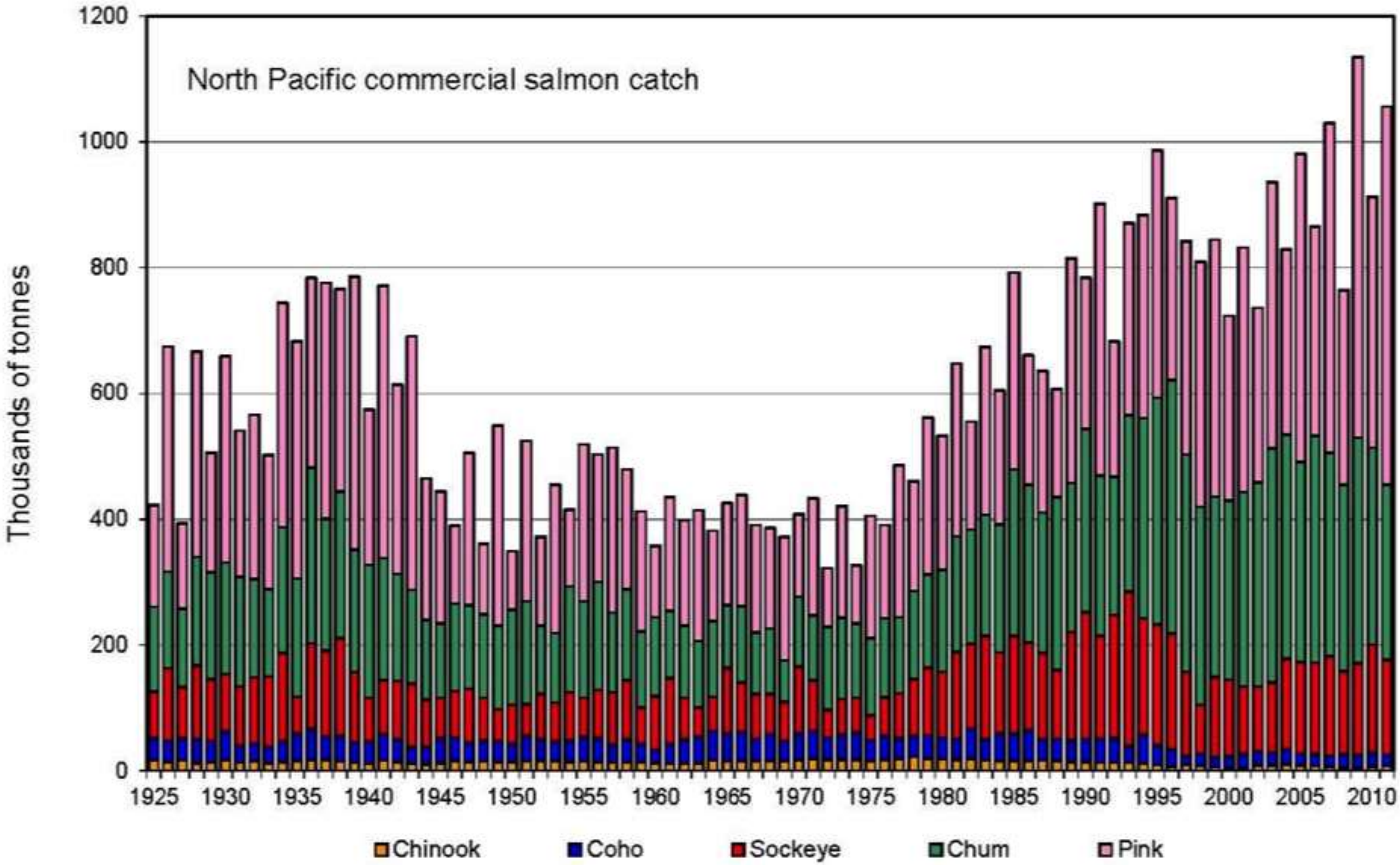
Photo: S.V. Naydenko

Issue: recent low productivity of Alaska Chinook



Source: ADFG Chinook Salmon Research Team 2013

Total Pacific Rim salmon catches high



Key Questions

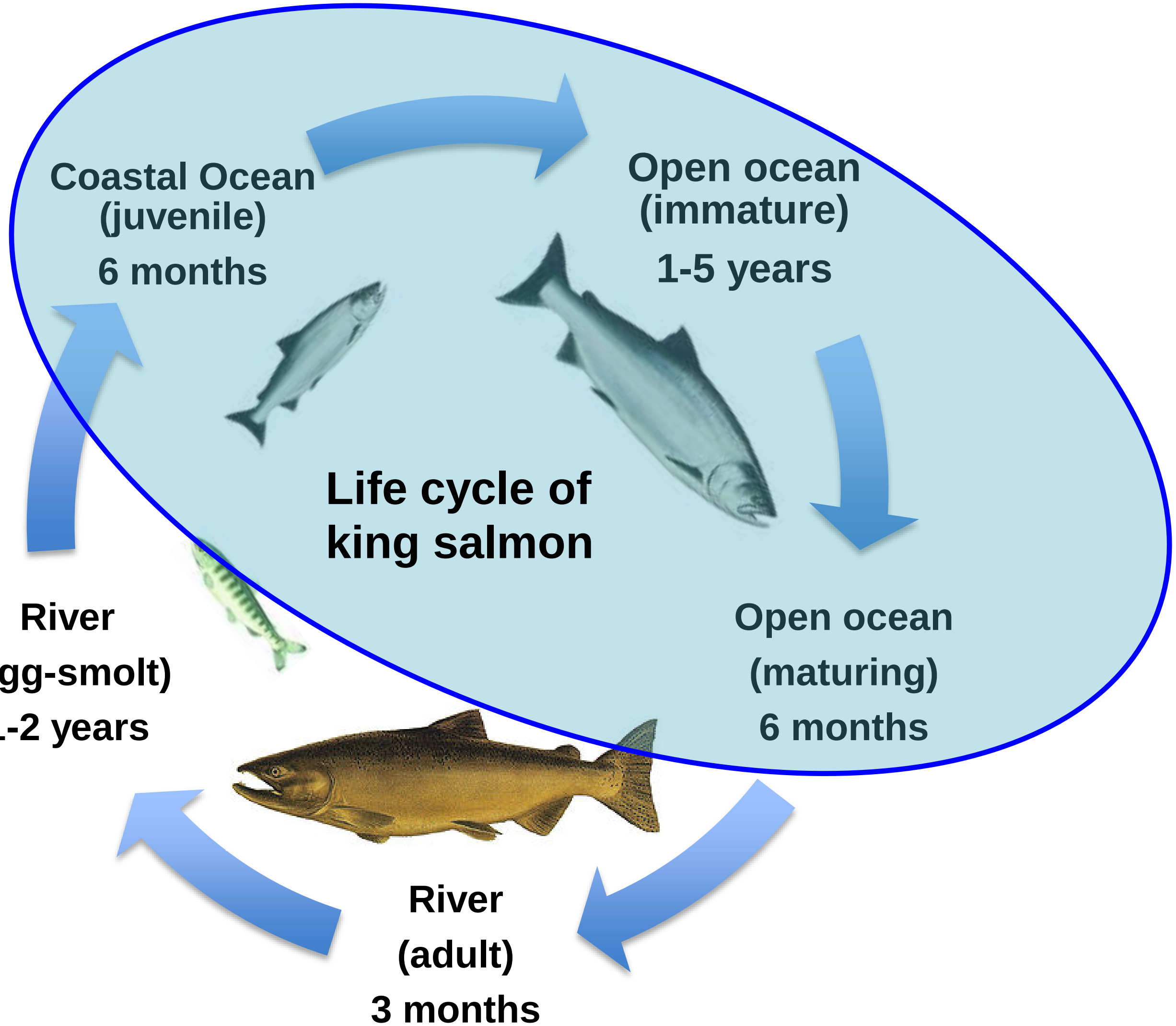
- Is recent low productivity of Alaska kings due to changes in survival in freshwater or the ocean or both?
- What caused recent changes in freshwater or marine survival?

Outline

- Brief review of marine life history & ecology and potential threats in marine habitats
- Introduce leading hypotheses linking changes in marine and freshwater habitats to recent declines
- Suggestions for next steps

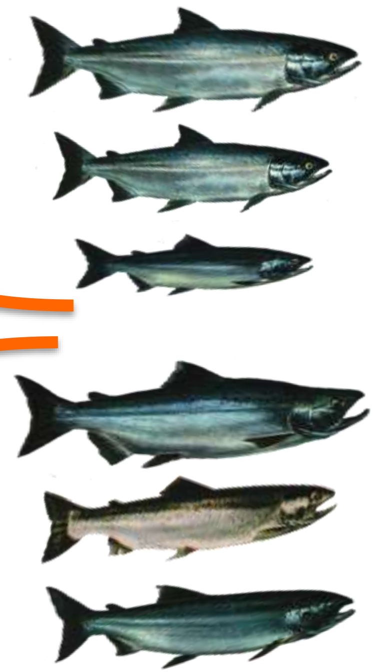
Why is marine life history & ecology important to king salmon?

~99% of total growth occurs in the ocean; ~3% average marine survival (Quinn 2005)



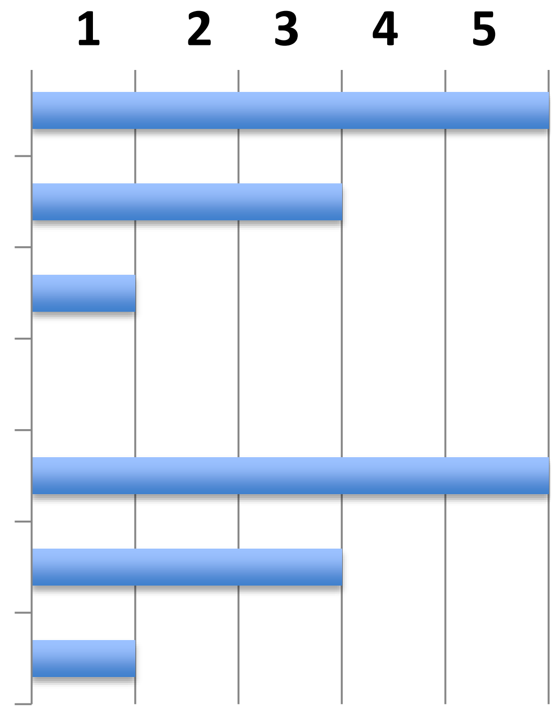
General salmon ocean life history

Six species (% survival)



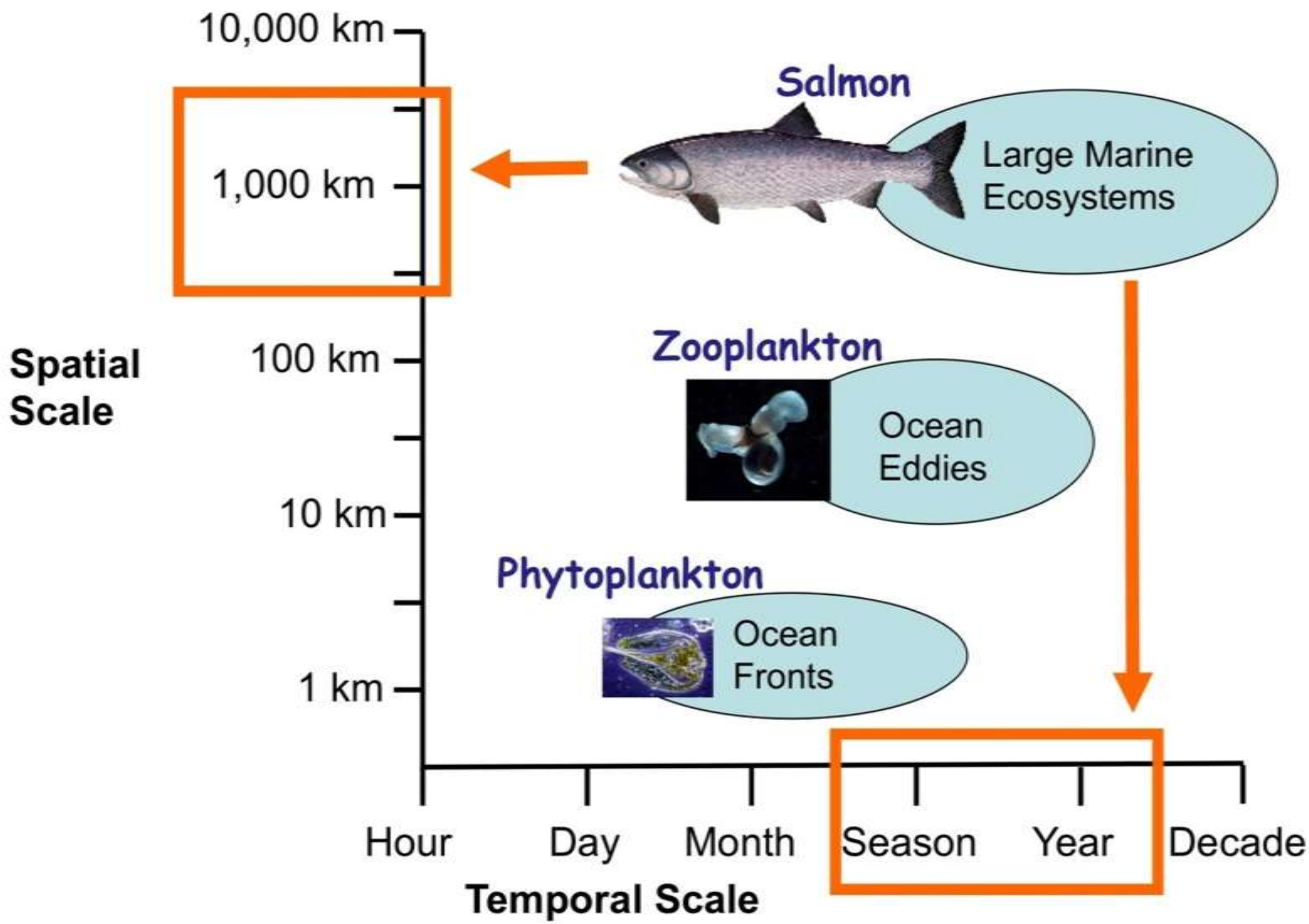
	% survival	Species
High abundance Zooplankton feeders	1.4	Chum
	13.1	Sockeye
	2.8	Pink
Low abundance Micronekton feeders	3.1	Chinook
	13.0	Steelhead
	10.4	Coho

Ocean age groups (winters at sea)



% survival = smolt to adult survival estimates (Quinn 2005)

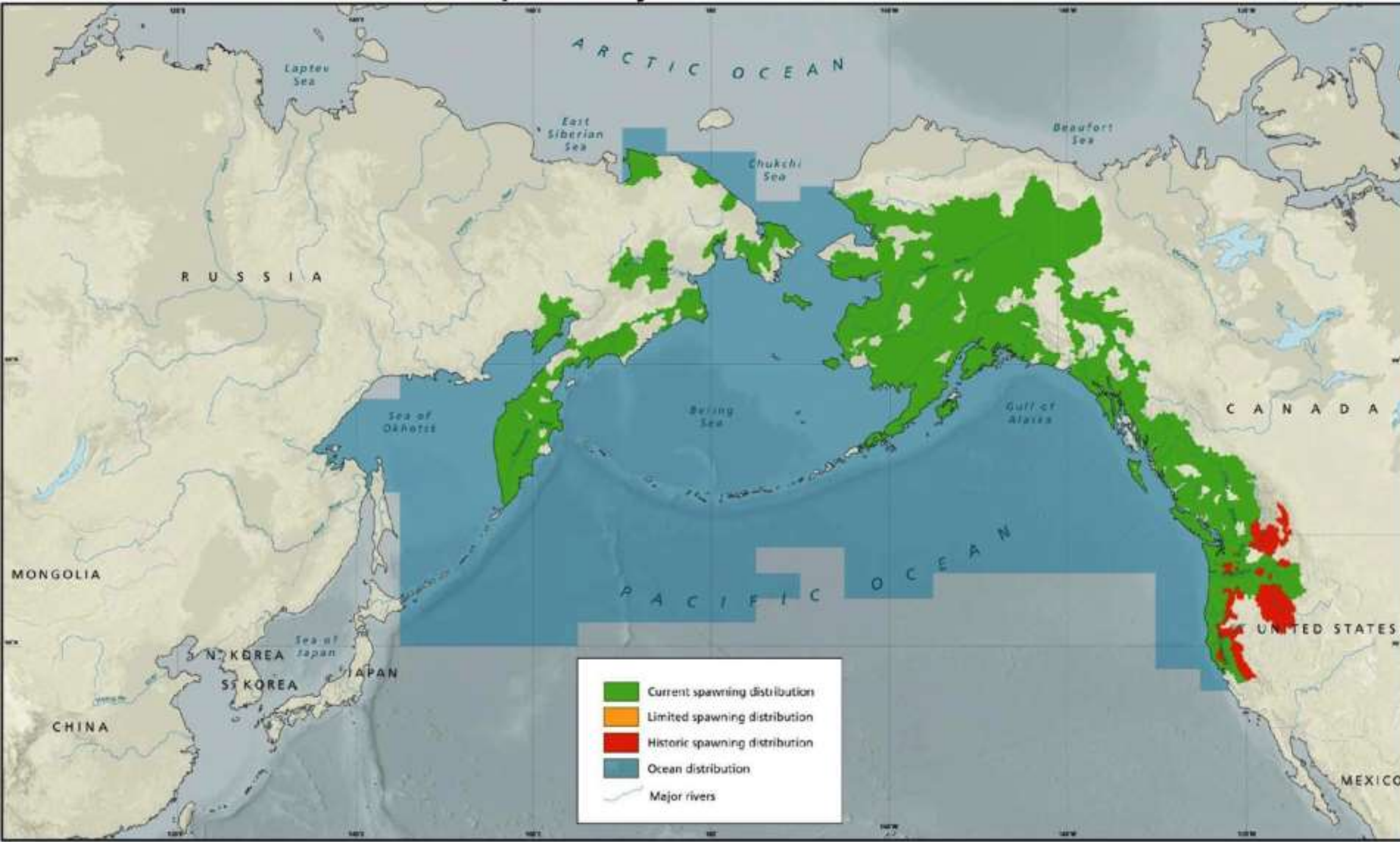
What is the appropriate spatial & temporal scale to address this issue?



Chinook Salmon Geographic Distributions

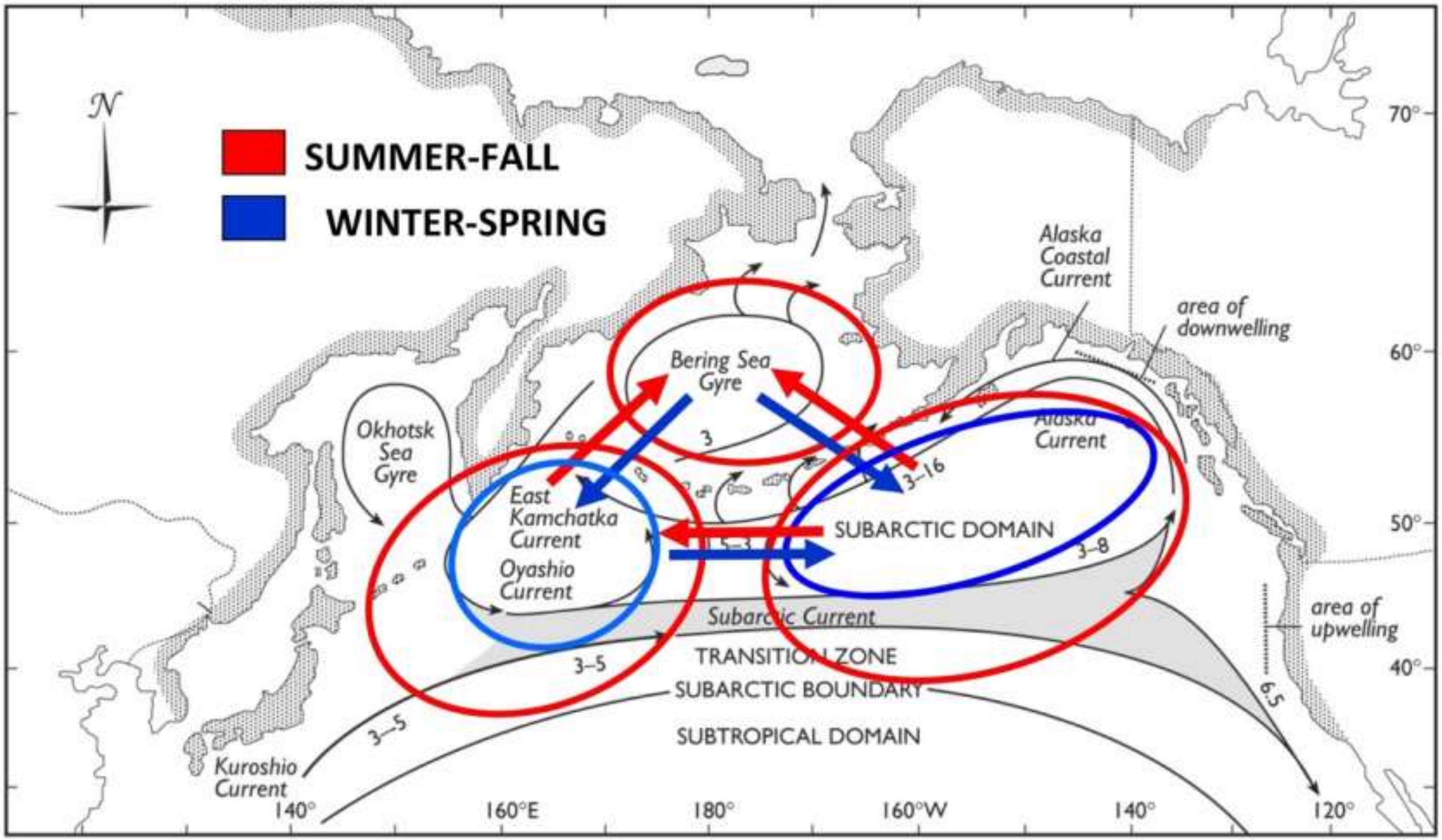
Chinook Distribution

Map Courtesy of State of the Salmon



Salmon make seasonal movements across broad fronts

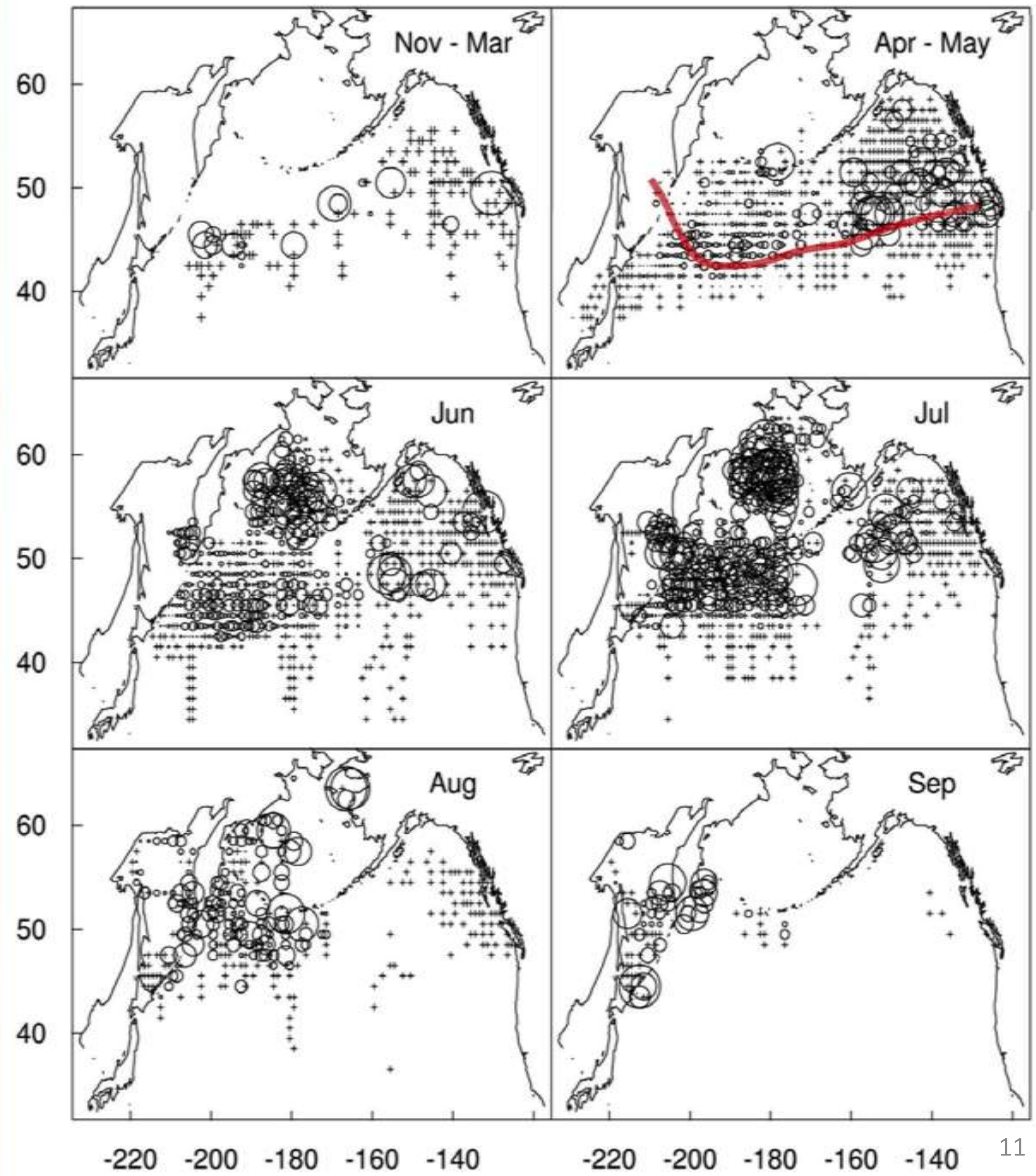
(north & west in summer, south & east in winter)



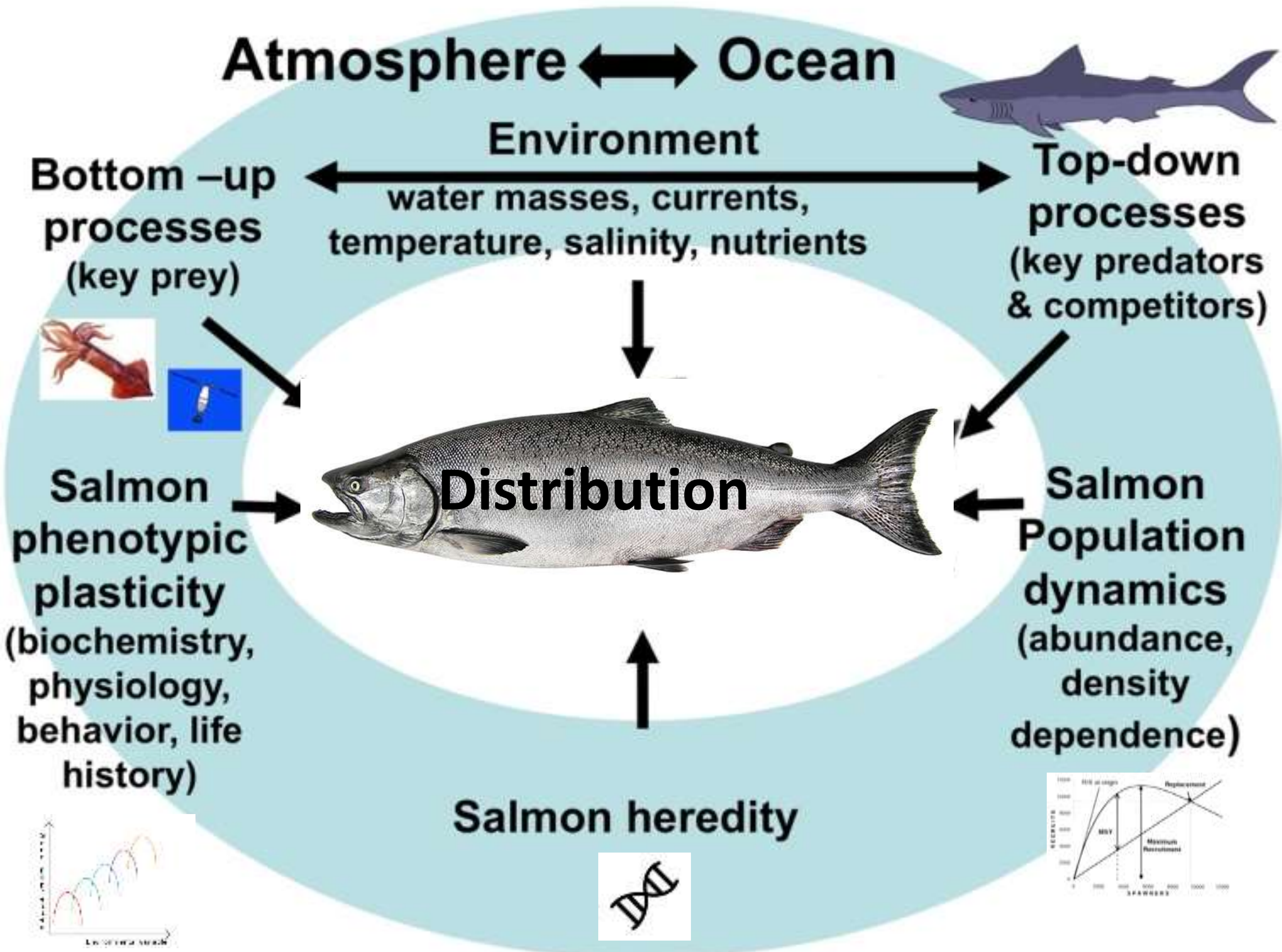
Source: Myers et al. 2007

Seasonal distribution of Chinook in research vessel surveys (1956-1996) in the North Pacific Ocean & Bering Sea

Source: Welch et al. 2014 PICES Presentation (pices.int)



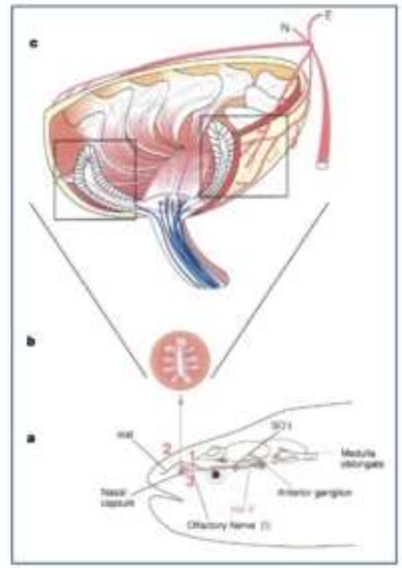
Many factors influence ocean distribution



Recent evidence supports concept that ocean migration patterns of salmon are inherited

An Inherited Magnetic Map Guides Ocean Navigation in Juvenile Pacific Salmon (Putman et al 2014, Current Biology 24)

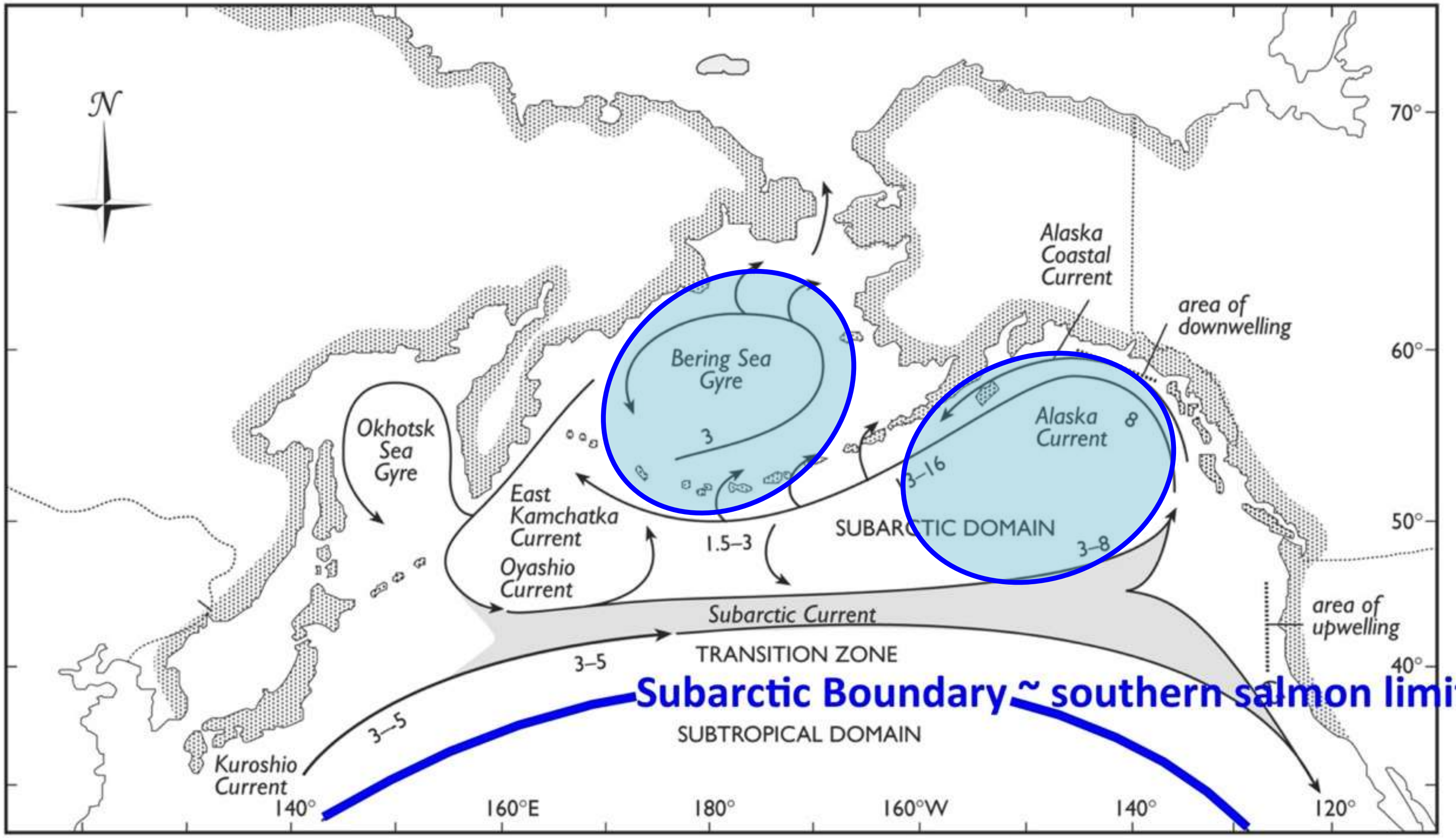
- Experimental demonstration that juvenile salmon respond to magnetic fields by orienting in directions leading toward marine feeding grounds
- Salmon use combination of magnetic intensity and inclination angle to assess geographic location
- The "magnetic map" of salmon appears to be inherited, as fish had no prior migratory experience



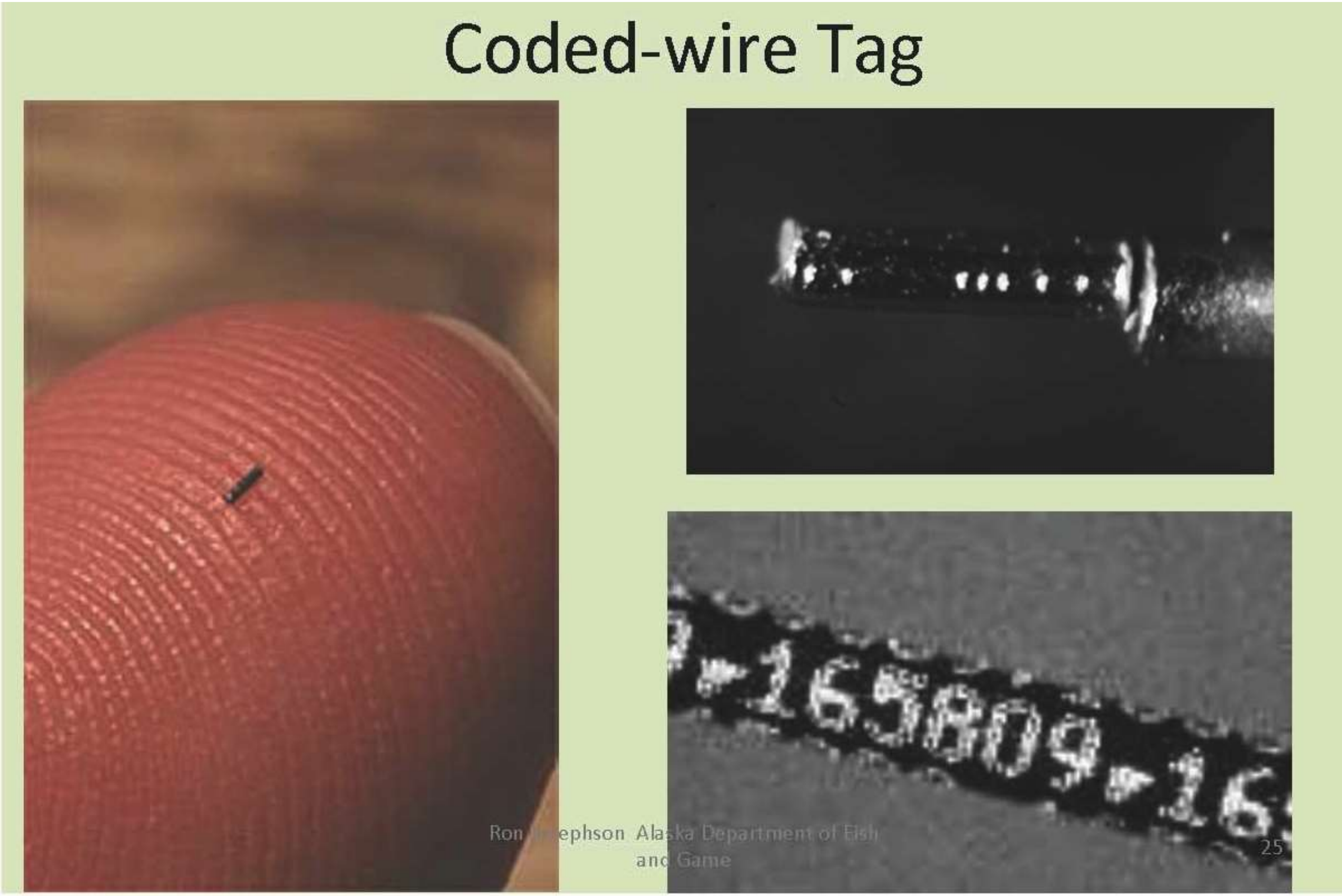
Area in nose of trout where candidate magnetoreceptor cells are located (Walker et al. 1997, Nature 390)

Evidence indicates Upper Cook inlet kings are distributed in the Gulf of Alaska and Bering Sea

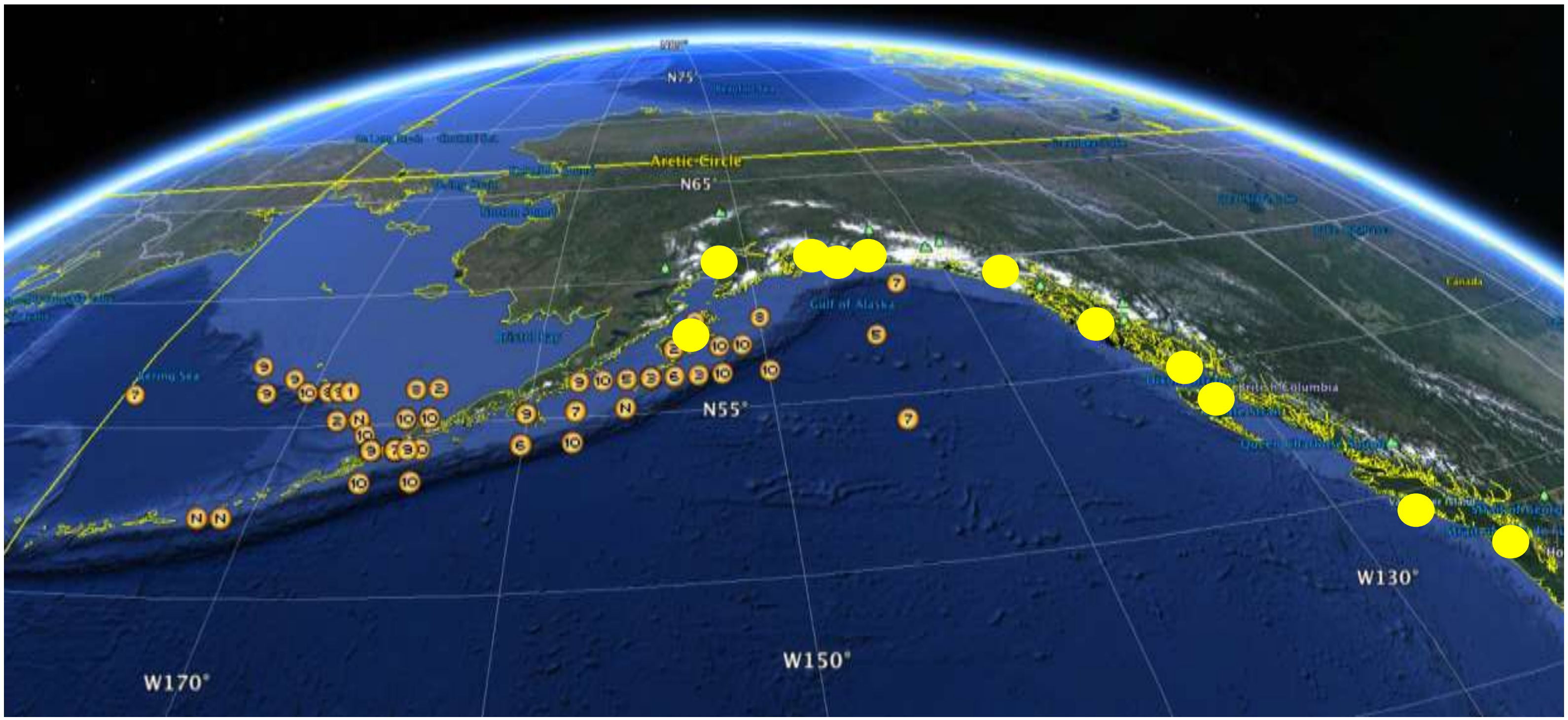
Map Source: Quinn (2005) - redrawn from Favorite et al. 1976 and others)



Tag recovery data provide information on age- specific seasonal distributions of Upper Cook Inlet Kings



Known ocean distribution of Upper Cook Inlet salmon from tag recoveries



Composite of all recoveries 1981-2013

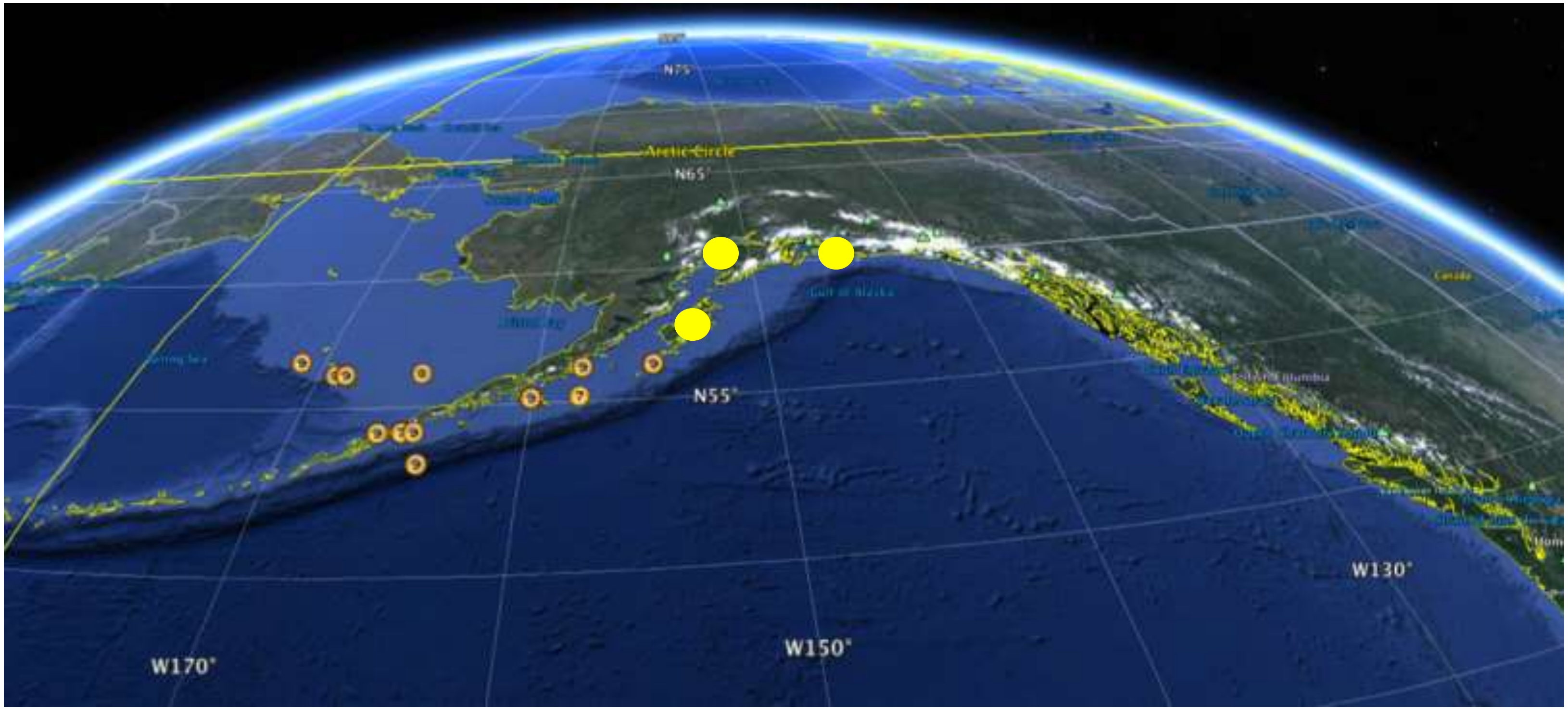
Data source: Pacific States Marine Fisheries Commission, Regional Mark Information System

UCI –1st ocean summer-fall – Age 1.0

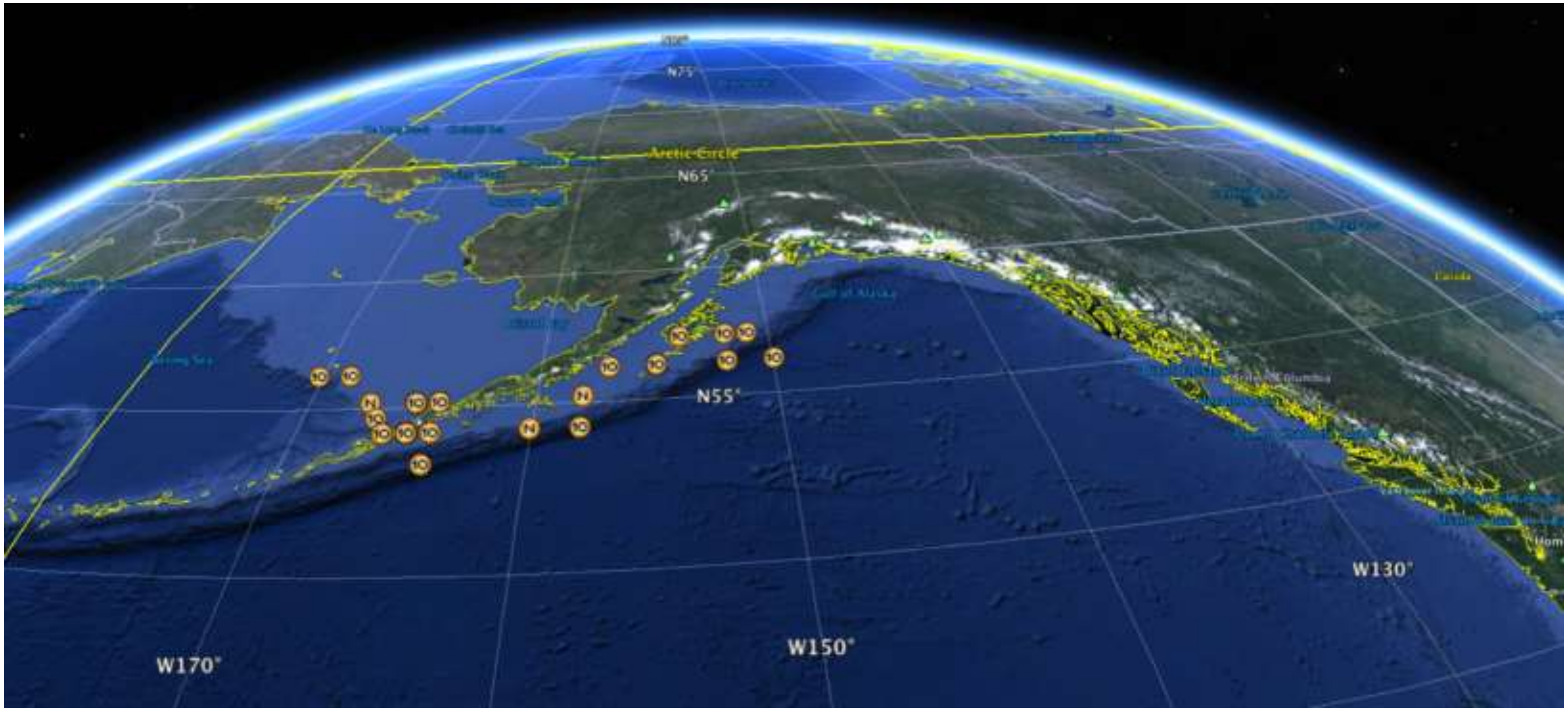
UCI –1st ocean winter – Age 1.1

UCI – spring – Age 1.1

UCI – summer – Age 1.1



UCI – fall – Age 1.1



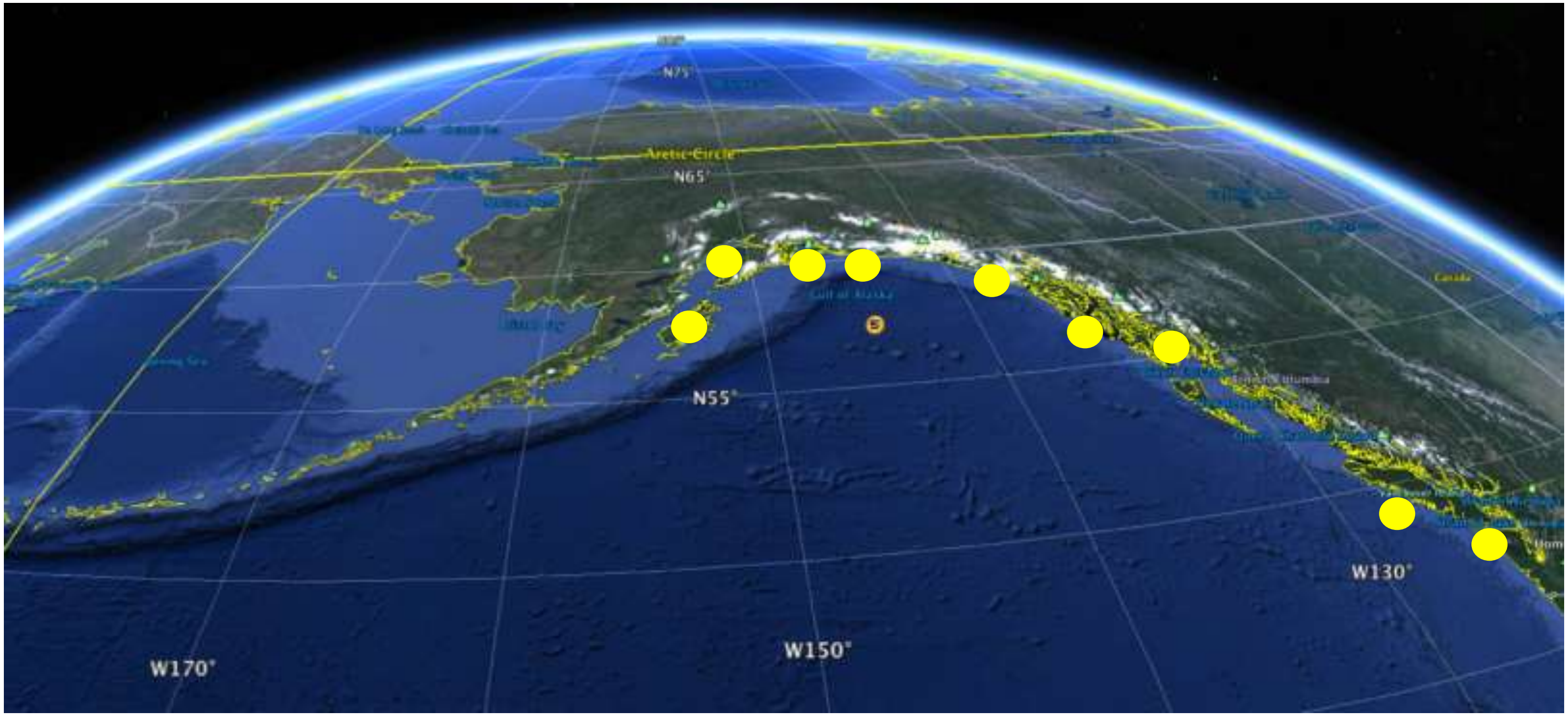
UCI – winter – Age 1.2

UCI – spring/summer – Age 1.2

UCI – fall – Age 1.2

UCI – winter – Age 1.3

UCI – spring – Age 1.3

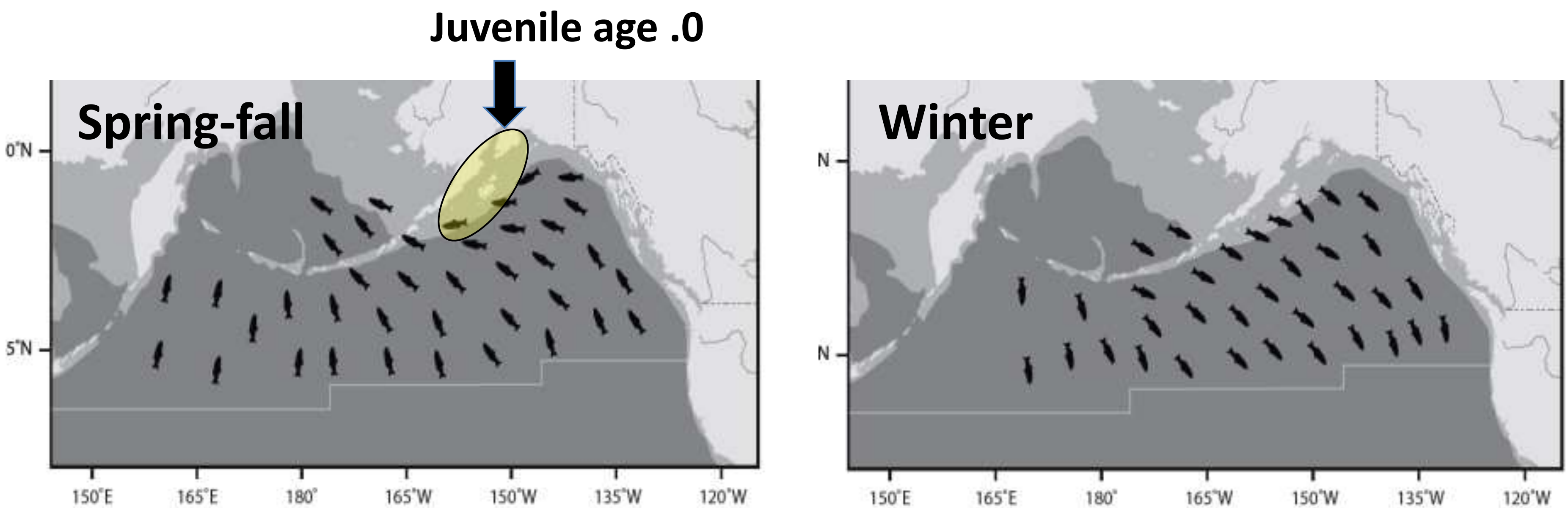


UCI – summer/fall – Age 1.3

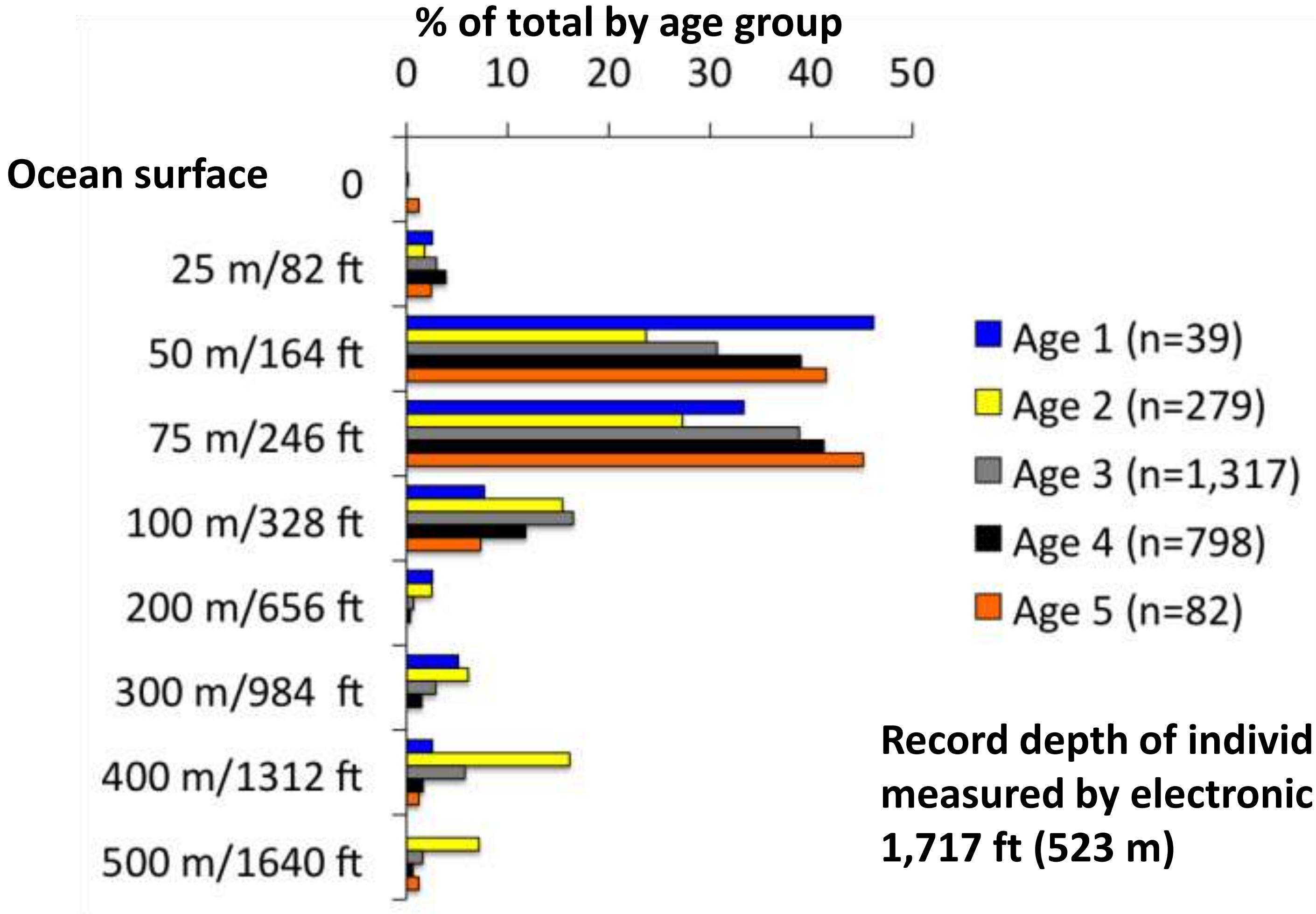
UCI – spring/summer – Age 1.4

UCI – spring– Age 1.5

Conceptual model of seasonal migration patterns of Upper Cook Inlet Chinook (modified from Larson et al. 2013)



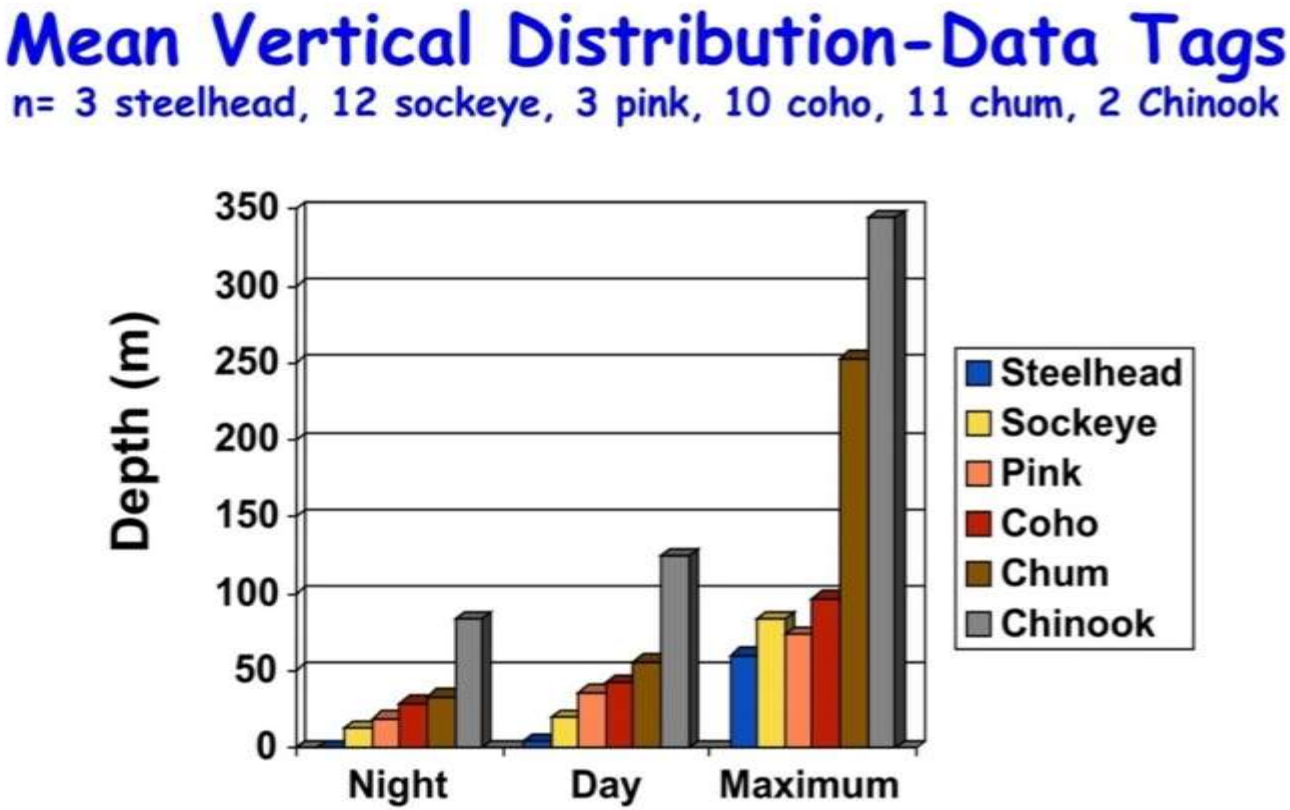
No apparent differences in vertical distribution by ocean age group in winter of trawl bycatch of kings



Record depth of individual fish measured by electronic tag = 1,717 ft (523 m)

Data are from 1997-1999

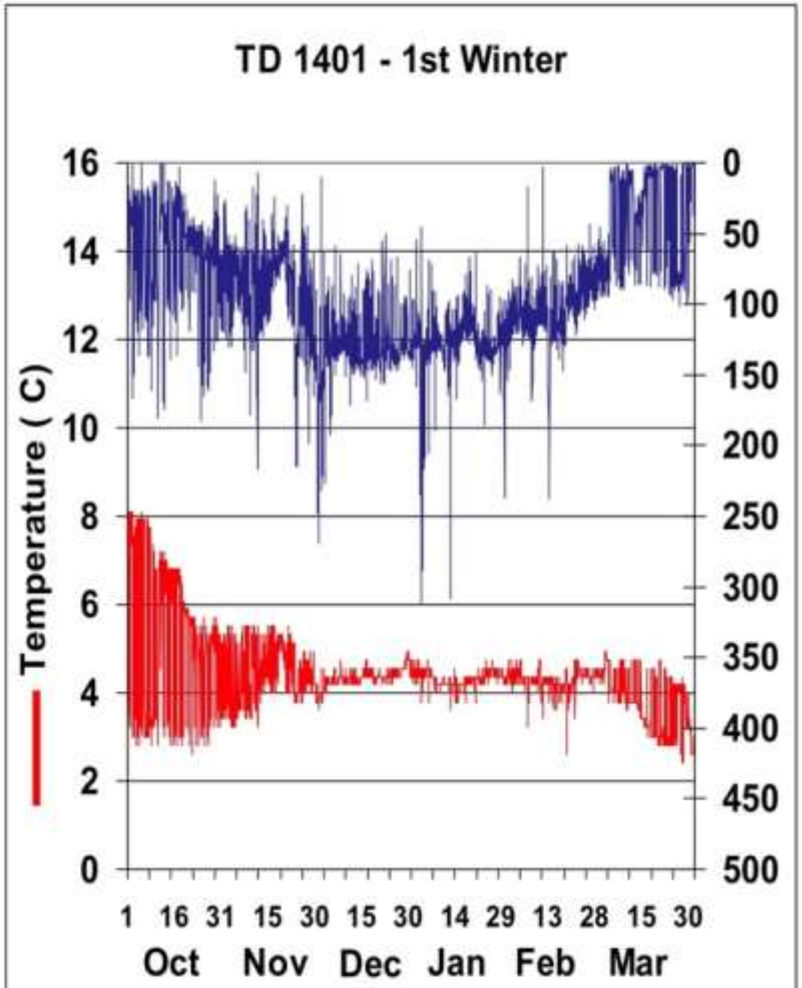
Electronic tag data indicate Chinook vertical distribution is deeper than other species

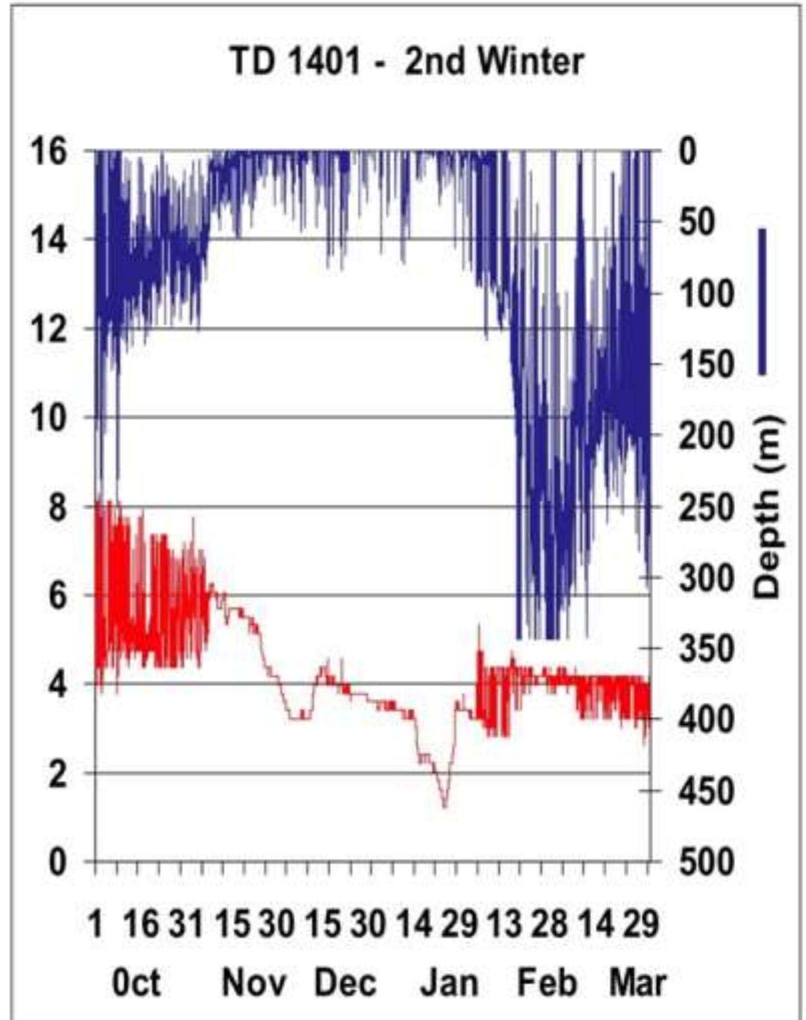


Data from Walker et al. 2000 (Fisheries Oceanography), 2007 (NPAFC Bulletin); Nielson et al. 2011 (CJFAS)

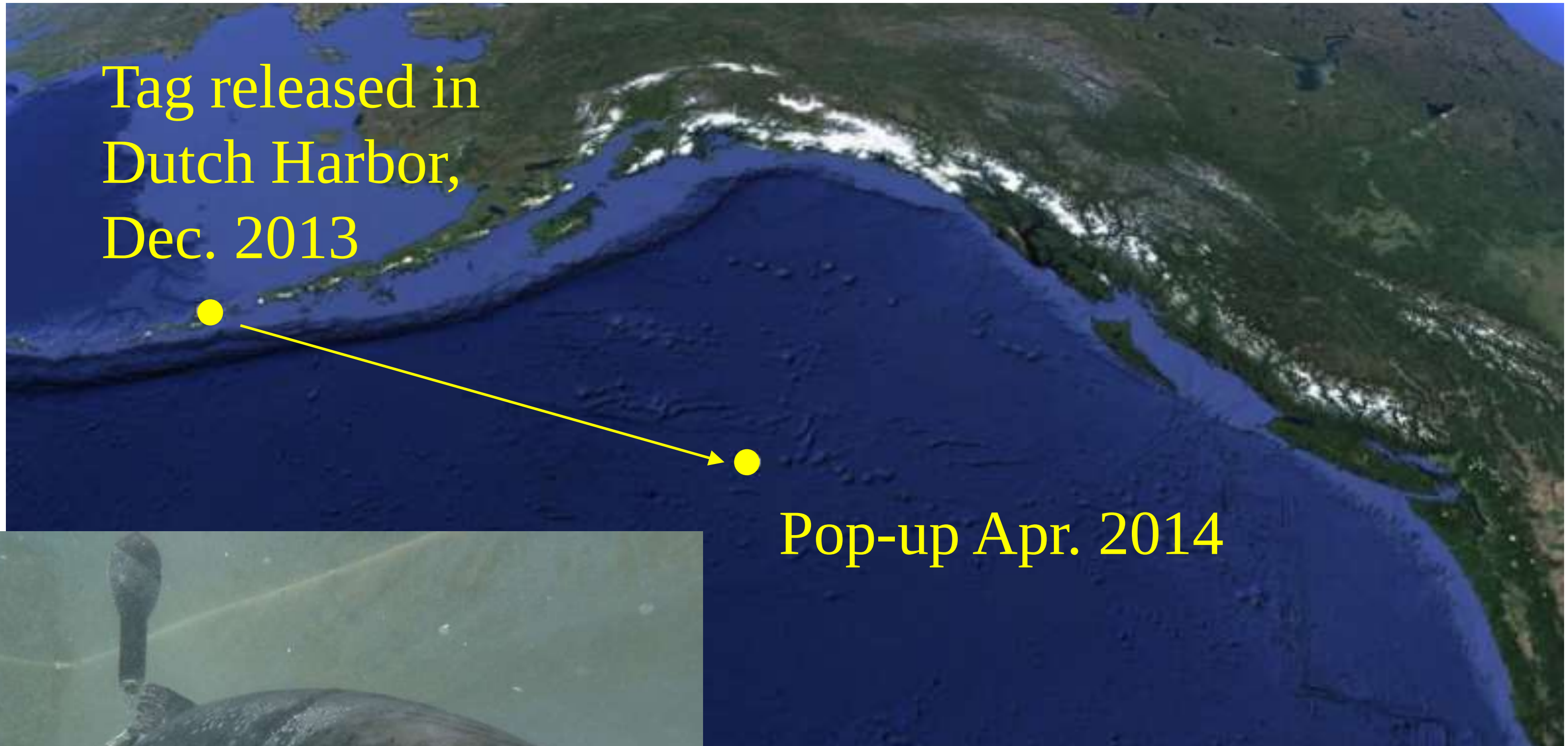
TD tag data show plasticity in winter depth distribution of individual fish

Comparison of Winters – Bering Sea Chinook

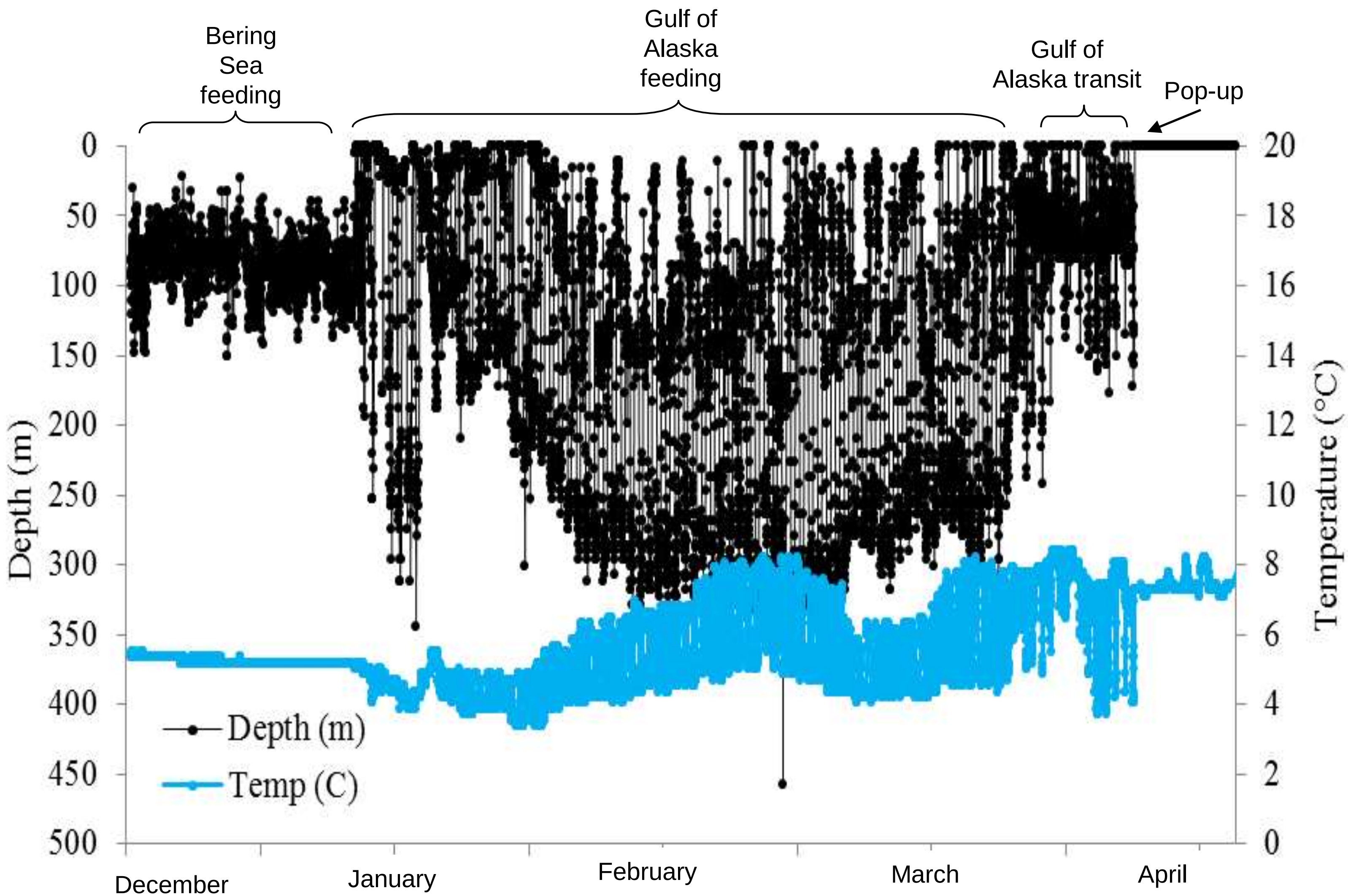




Pop-up satellite tag recovery shows temperature-depth distribution & estimates location

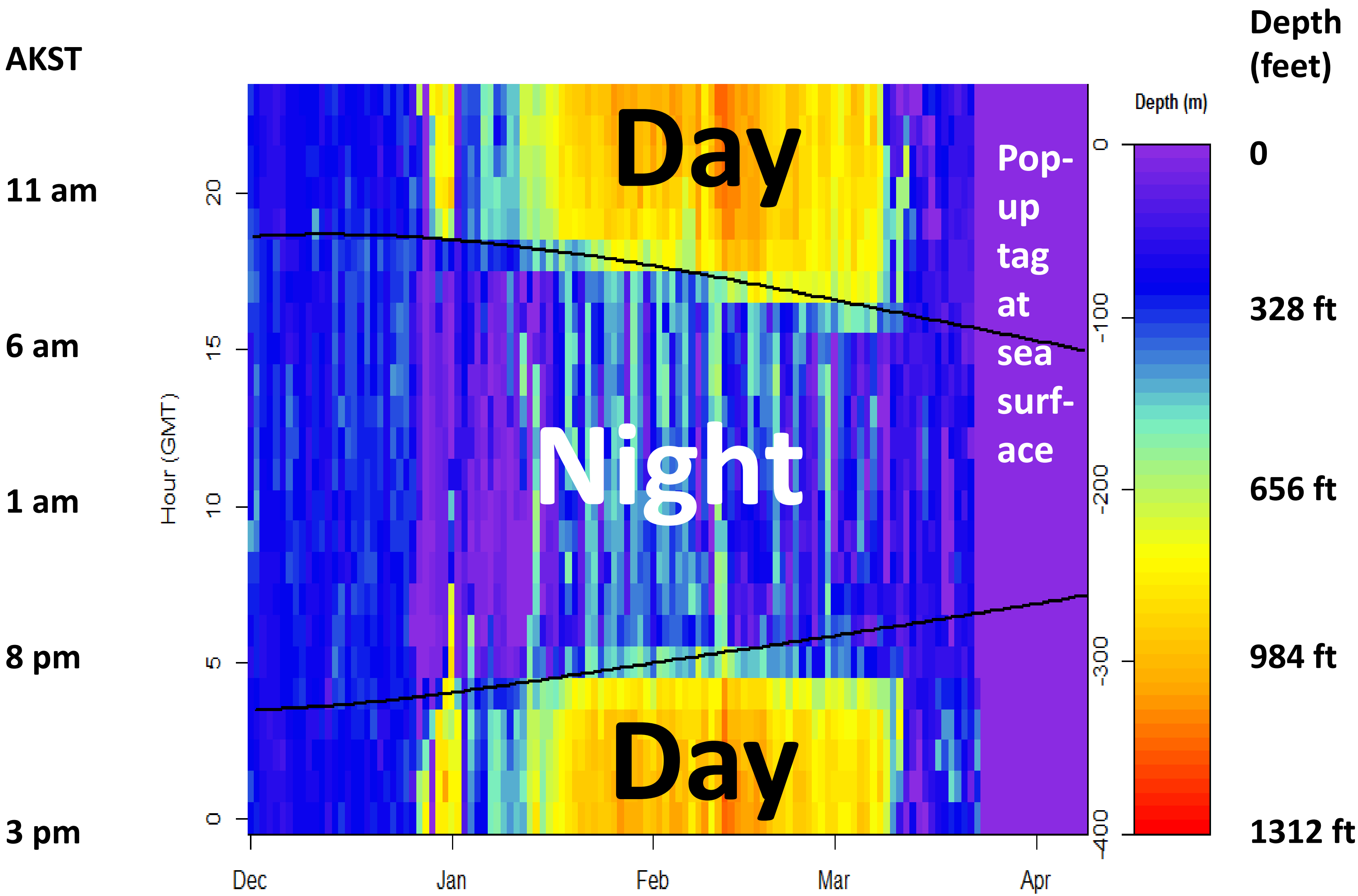


Data and slide provided by Andrew Seitz, UAF



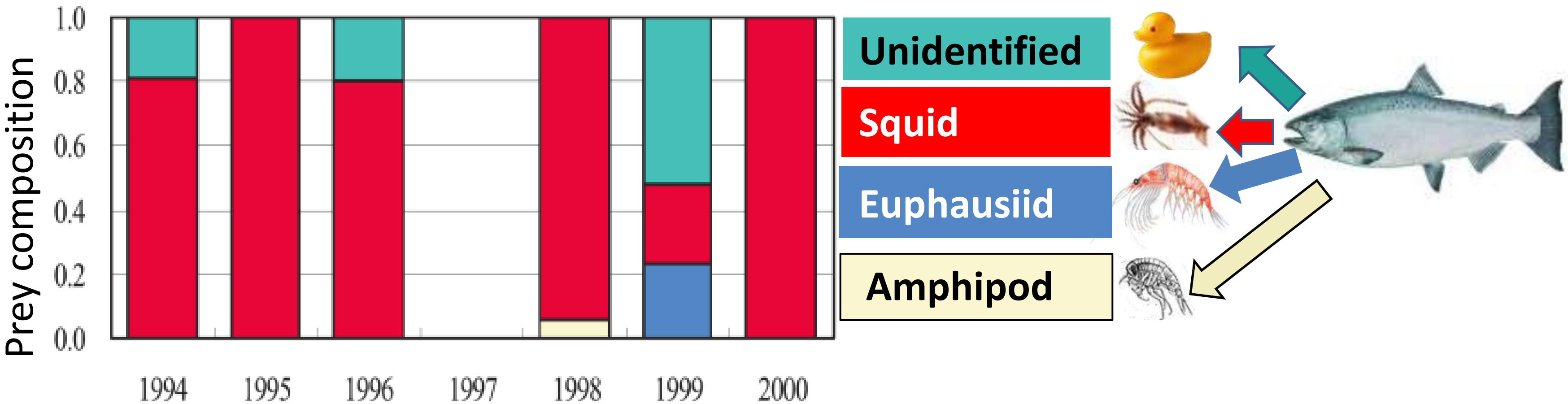
Data and slide provided by Andrew Seitz, UAF

Fish deep in day (yellow), shallow at night (purple-blue)



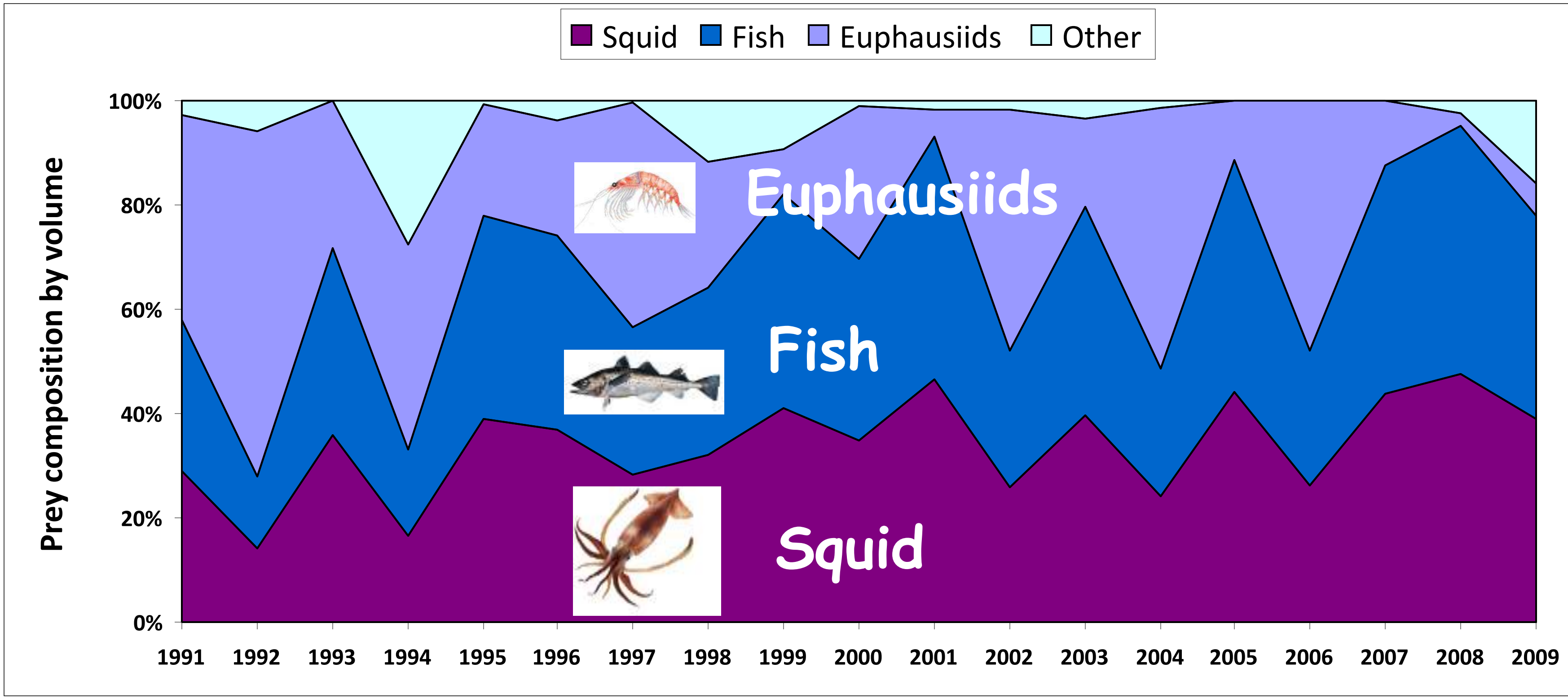
Data and slide provided by Andrew Seitz, UAF

Squid are the major prey of kings in the Central Gulf of Alaska in summer (50-56°N, 145°W)

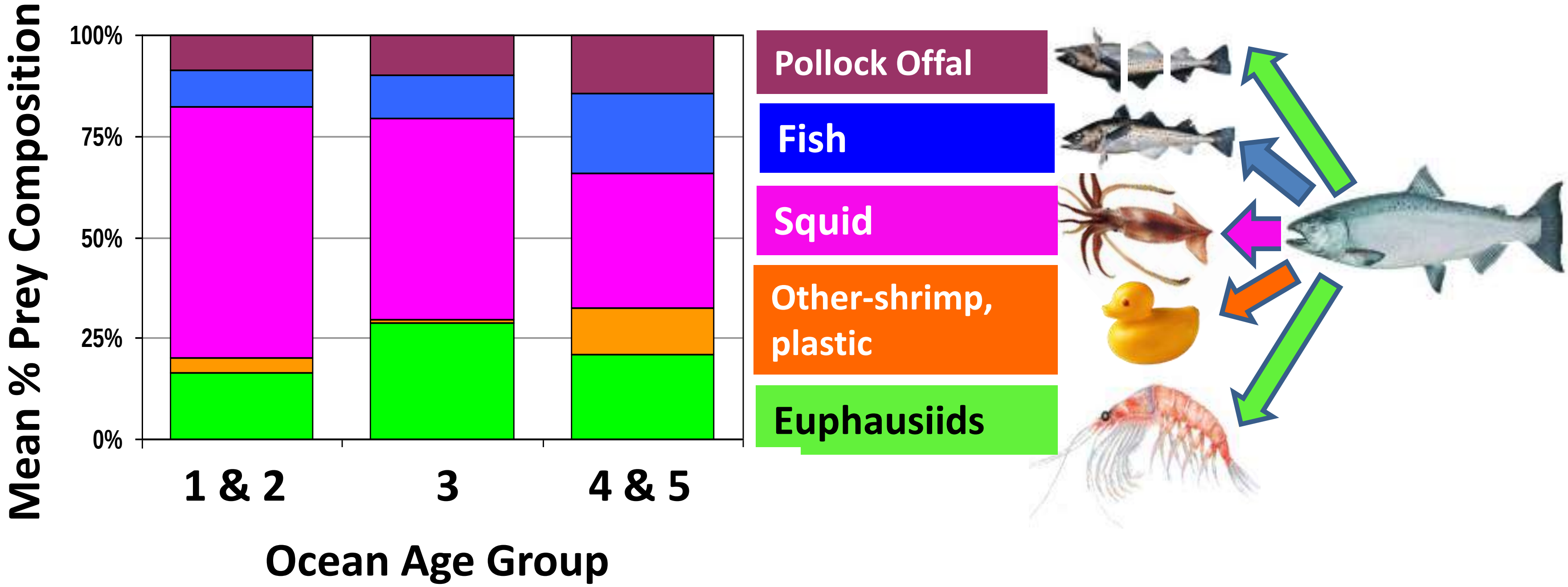


Data from Kaeriyama et al. 2004

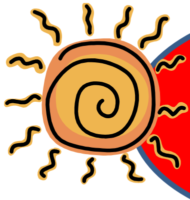
Squid, fish, and euphausiids are major prey in summer diets of kings in the Bering Sea



Winter diets of kings in Bering Sea shelf habitats varied by ocean age group – (samples from trawl bycatch contained pollock offal)



Life-stage specific responses of Alaska kings to natural climate change



Warm climate

↓

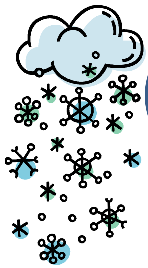
High survival & abundance

↓

High growth rate if prey not limited

↓

Early maturation; early return; adults younger, smaller at return



Cool climate

↓

Low survival & abundance

↓

Low growth rate if prey limited

↓

Late maturation; late return; adults older & larger at return

Open ocean life stage:

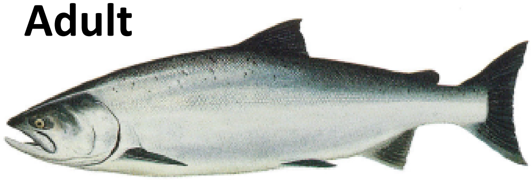
1st Ocean winter

↓

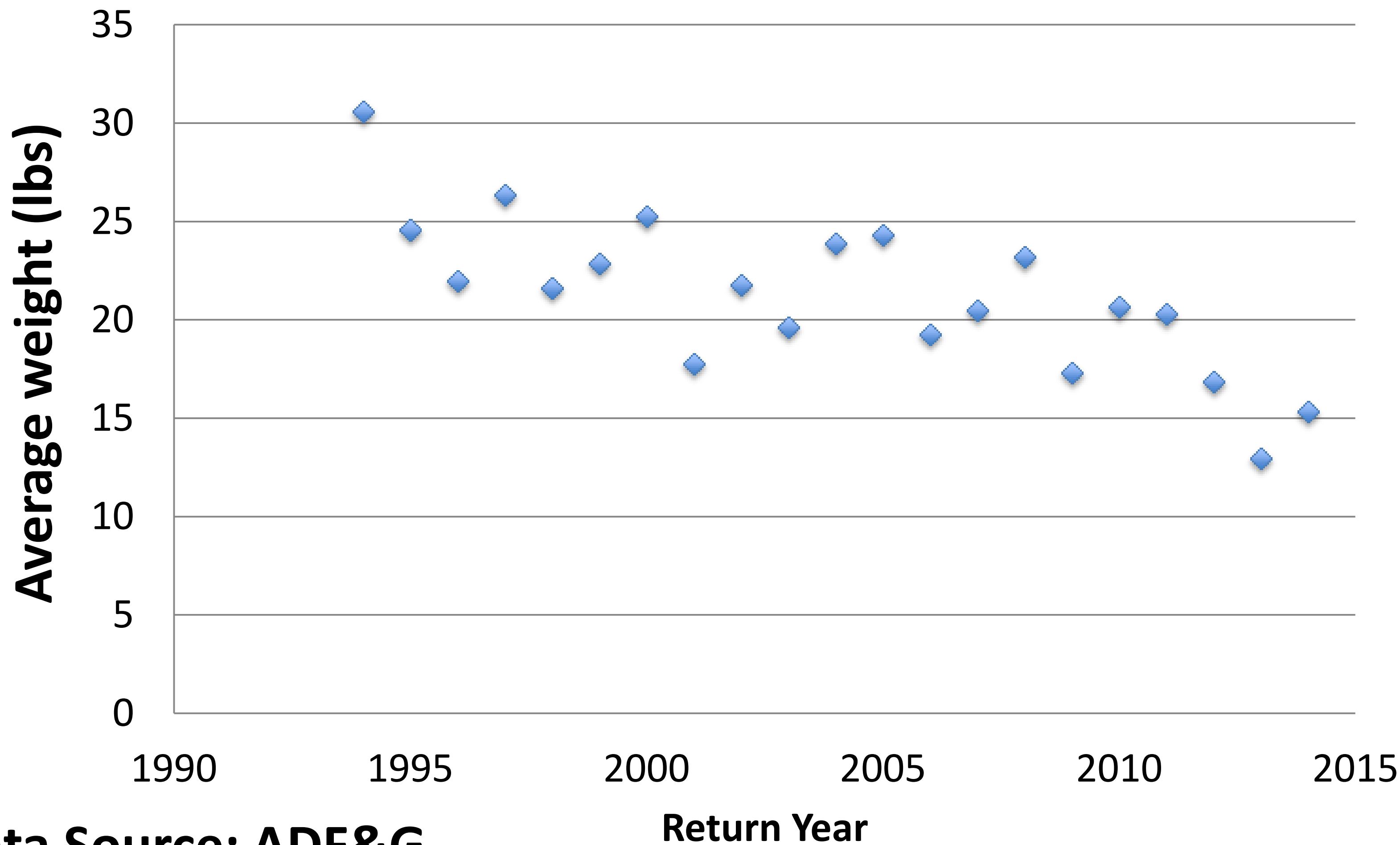
Immature

↓

Adult

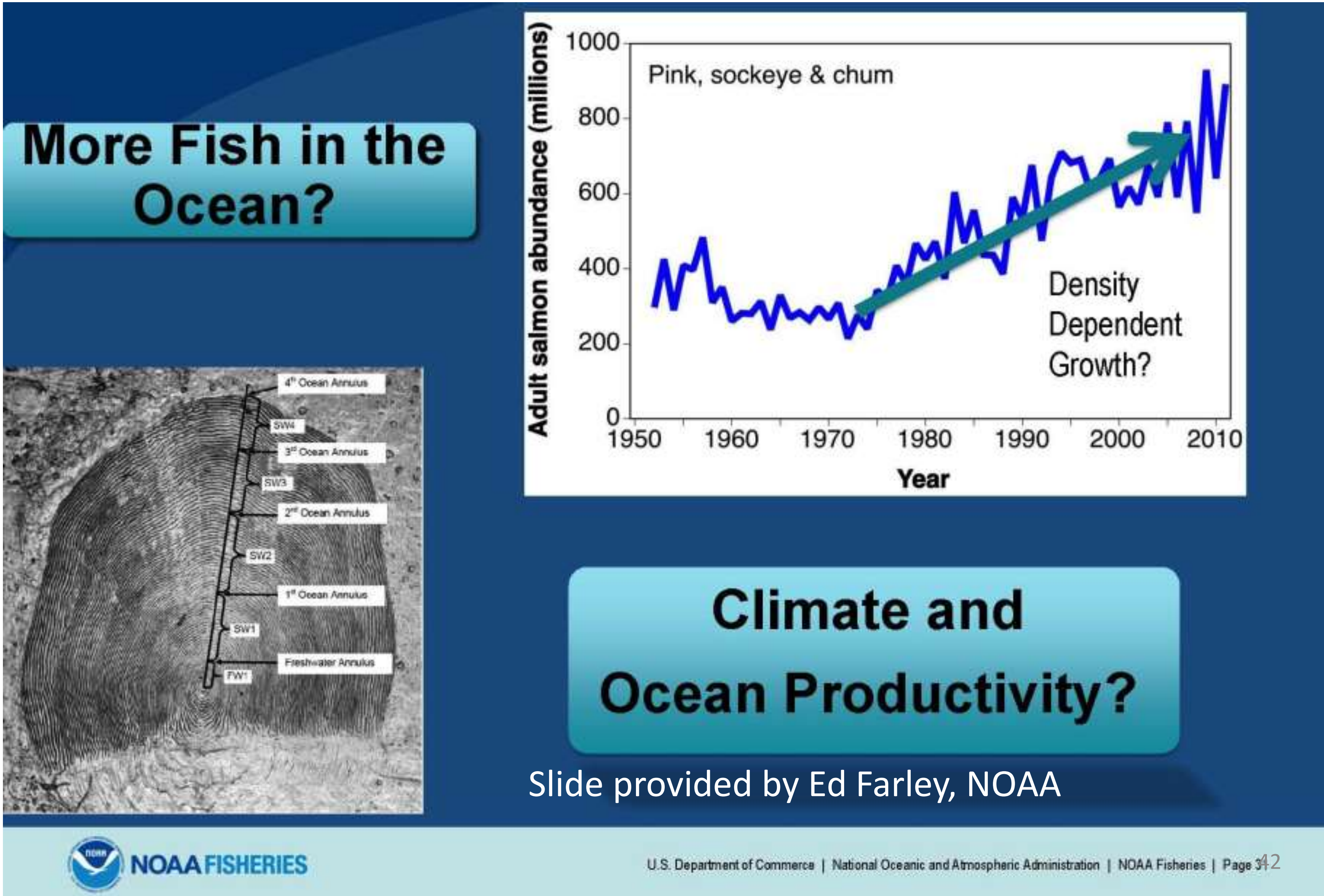


Decreasing trend in average weight of Kings in Upper Cook Inlet Commercial Catch



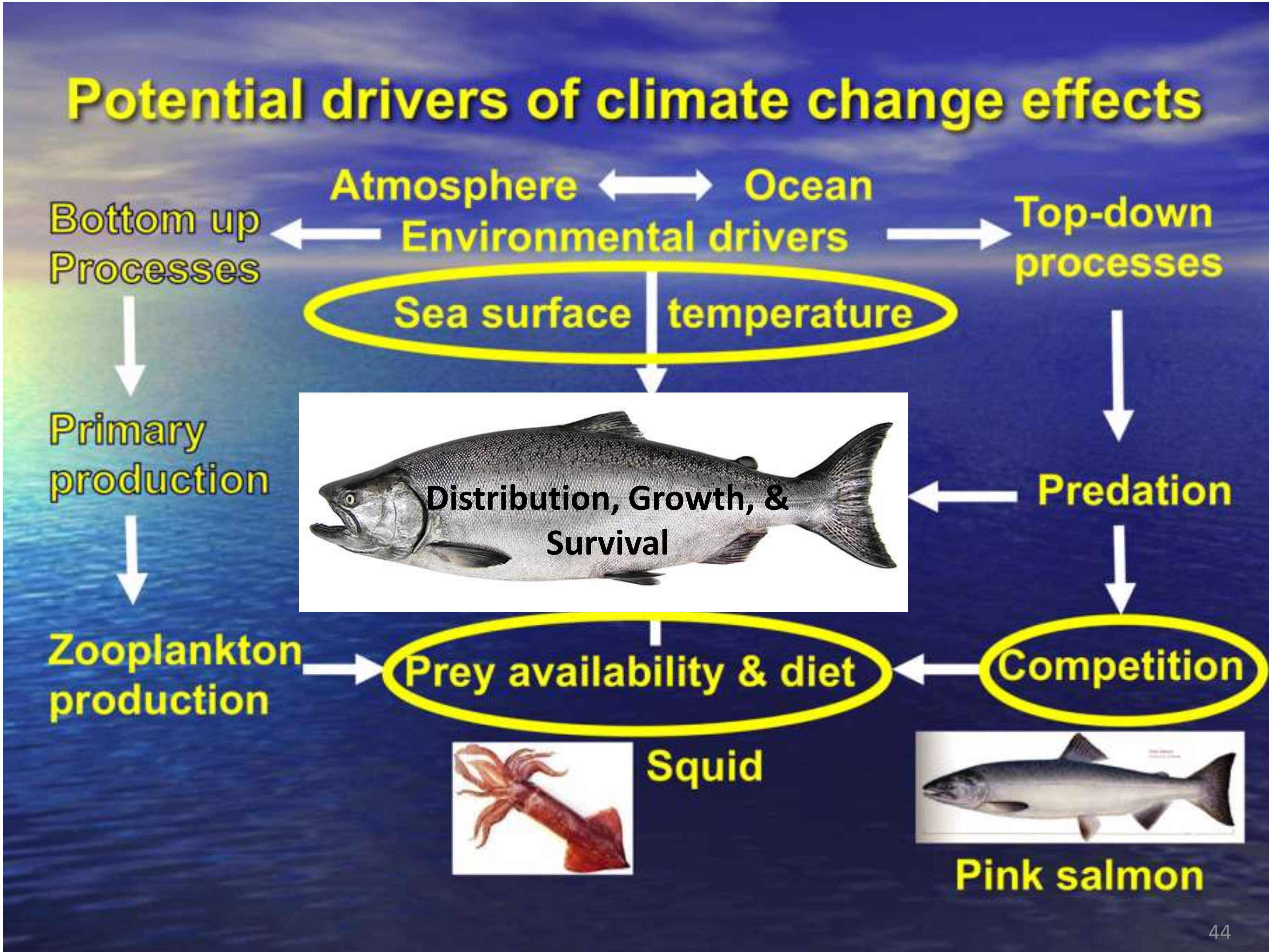
Data Source: ADF&G

Possible reasons for declining size and age

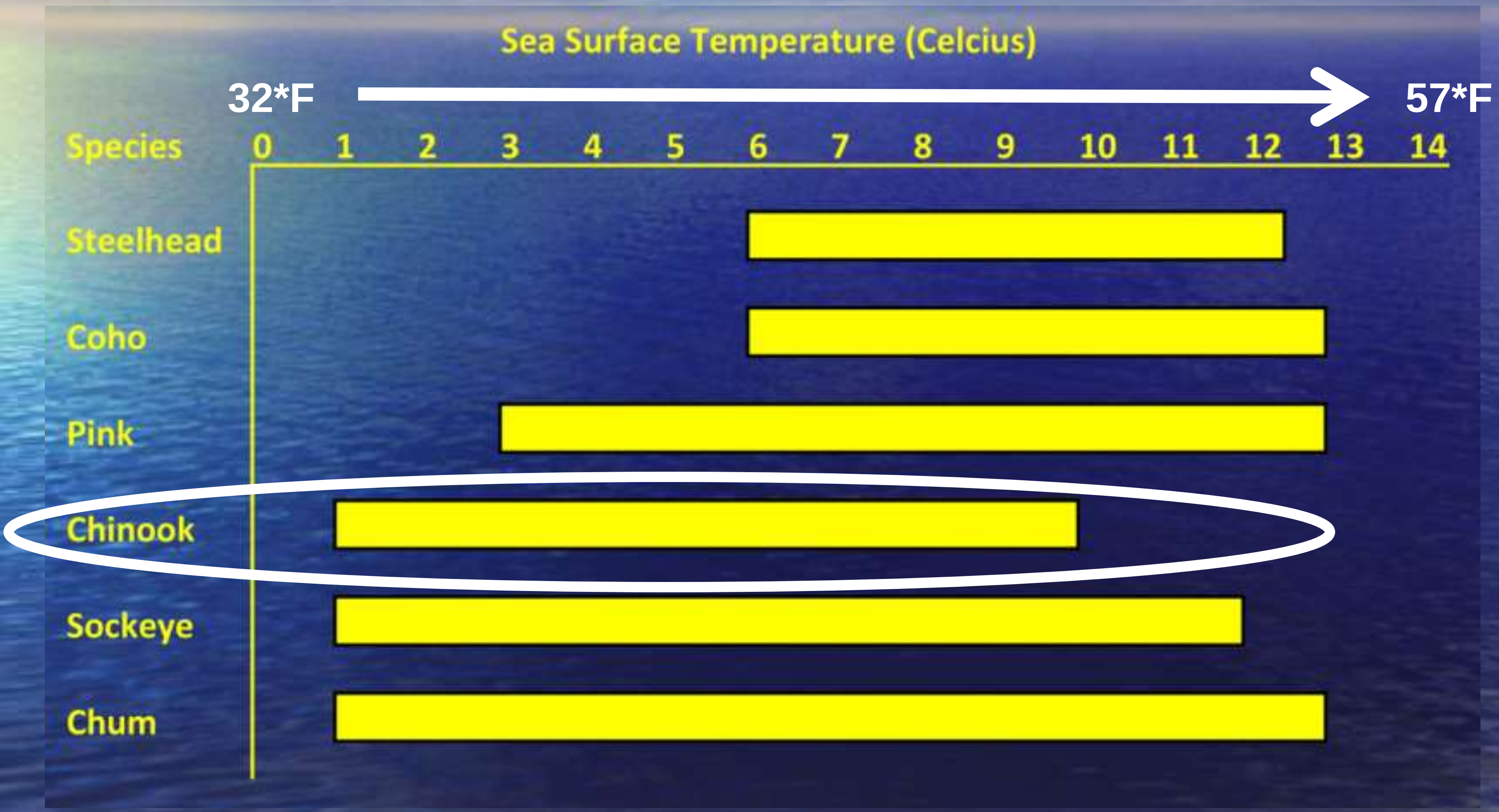


Potential threats to Mat-Su Kings

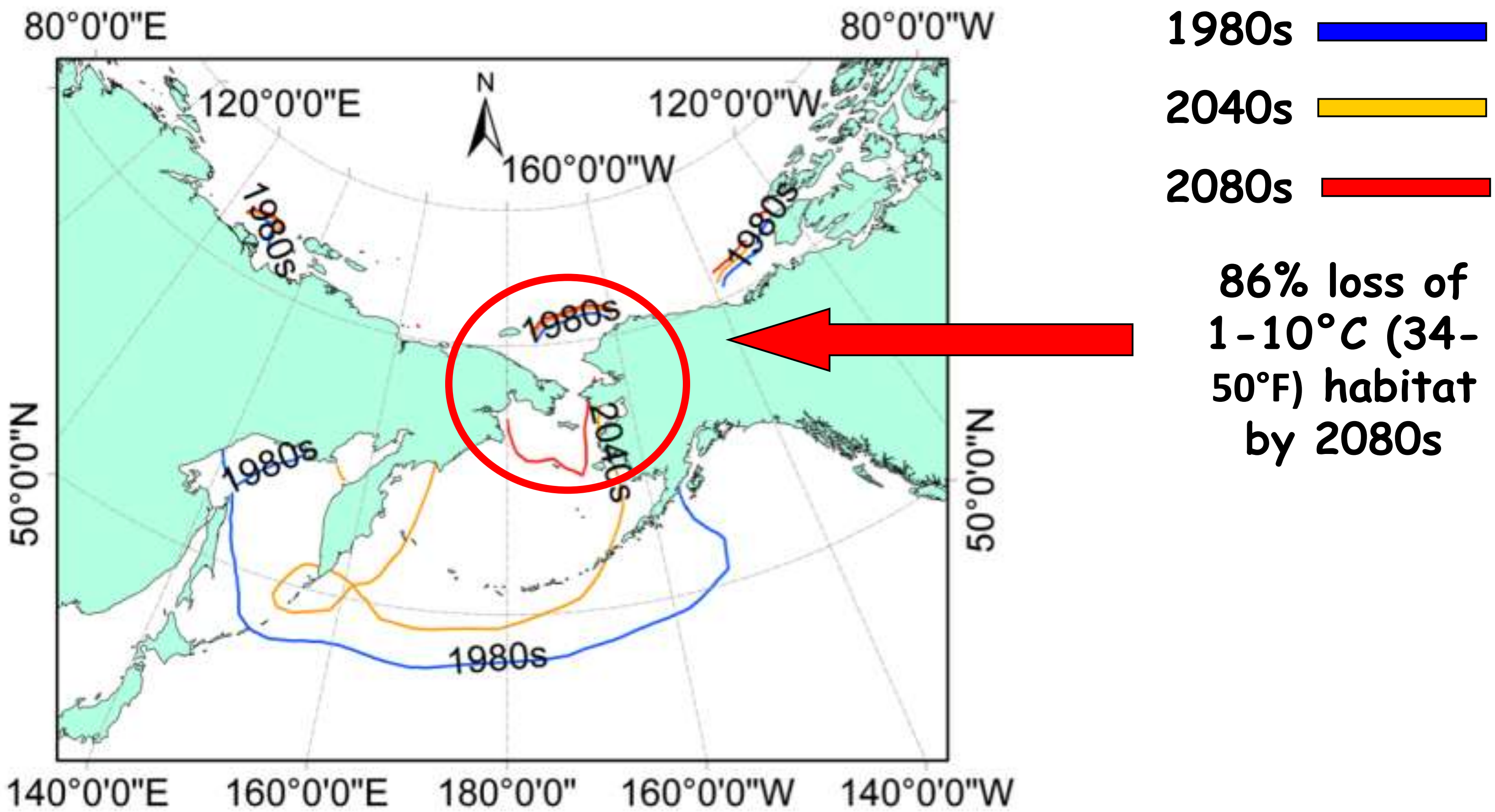
- Climate change
- Ocean Fishing
- Hatchery-wild interactions in the ocean
- Marine Pollution


Potential drivers of climate change effects
Atmosphere
Ocean
Bottom up Processes
Environmental drivers
Top-down processes
Sea surface temperature
Primary production
Distribution, Growth, & Survival
Predation
Zooplankton production
Prey availability & diet
Competition
Squid
Pink salmon

Chinook frequently caught at cooler range of summer sea surface temperatures (° C) than other salmon species (Abdul-Aziz et al. 2011)



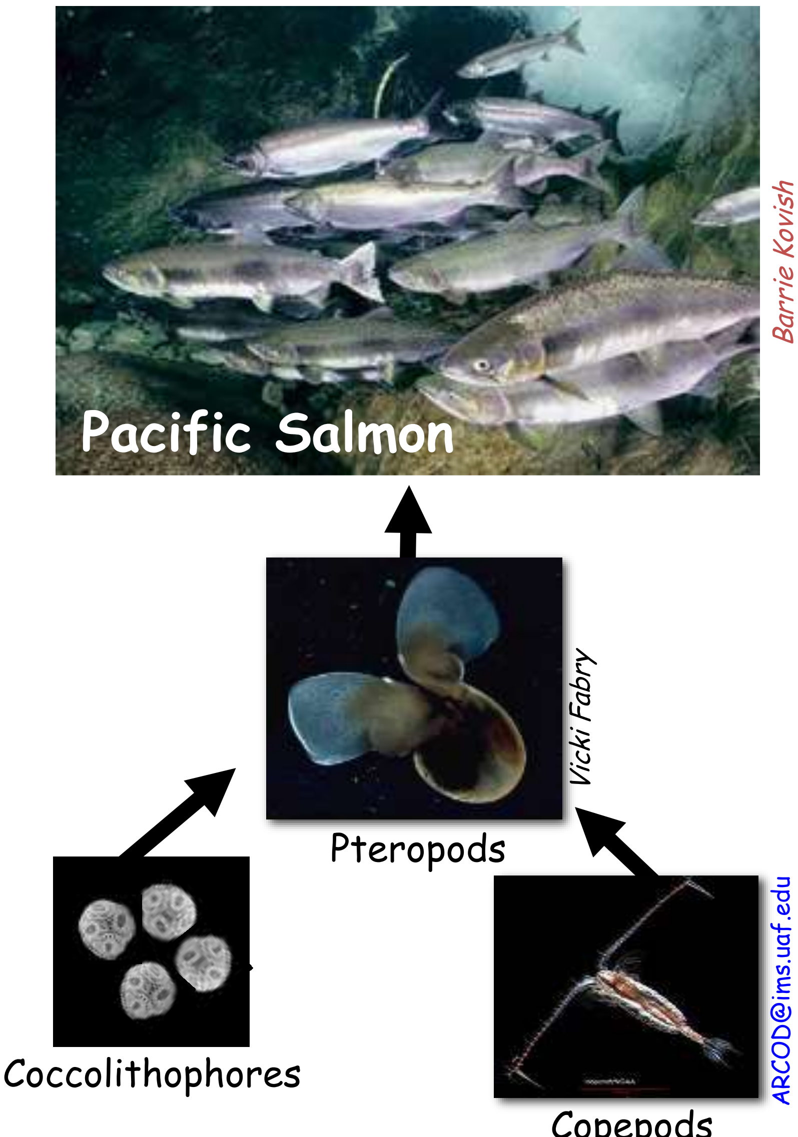
Projected changes in sea surface temperatures indicate loss of most summer thermal habitat of king salmon by the end of the century



86% loss of 1-10°C (34-50°F) habitat by 2080s

Data from Abdul-Aziz et al. 2011

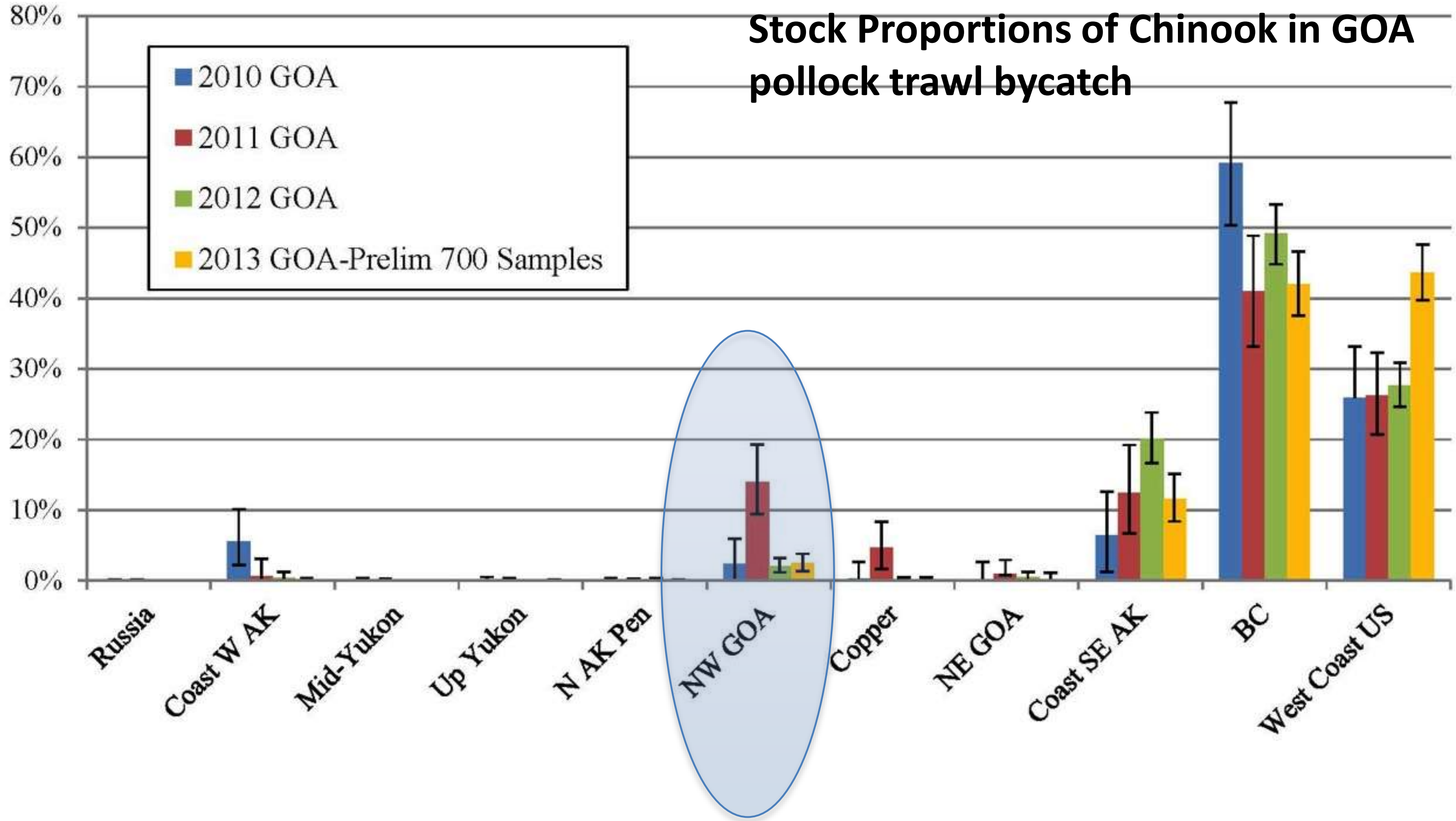
What are the biological implications of ocean acidification?



- Reduced calcification rates for calcifying (hard-shelled) organisms
- physiological stress
- Shifts in phytoplankton diversity and changes in food webs
- Reduced tolerance to other environmental fluctuations
- ***Potential for changes to fitness and survival, but this is poorly understood***

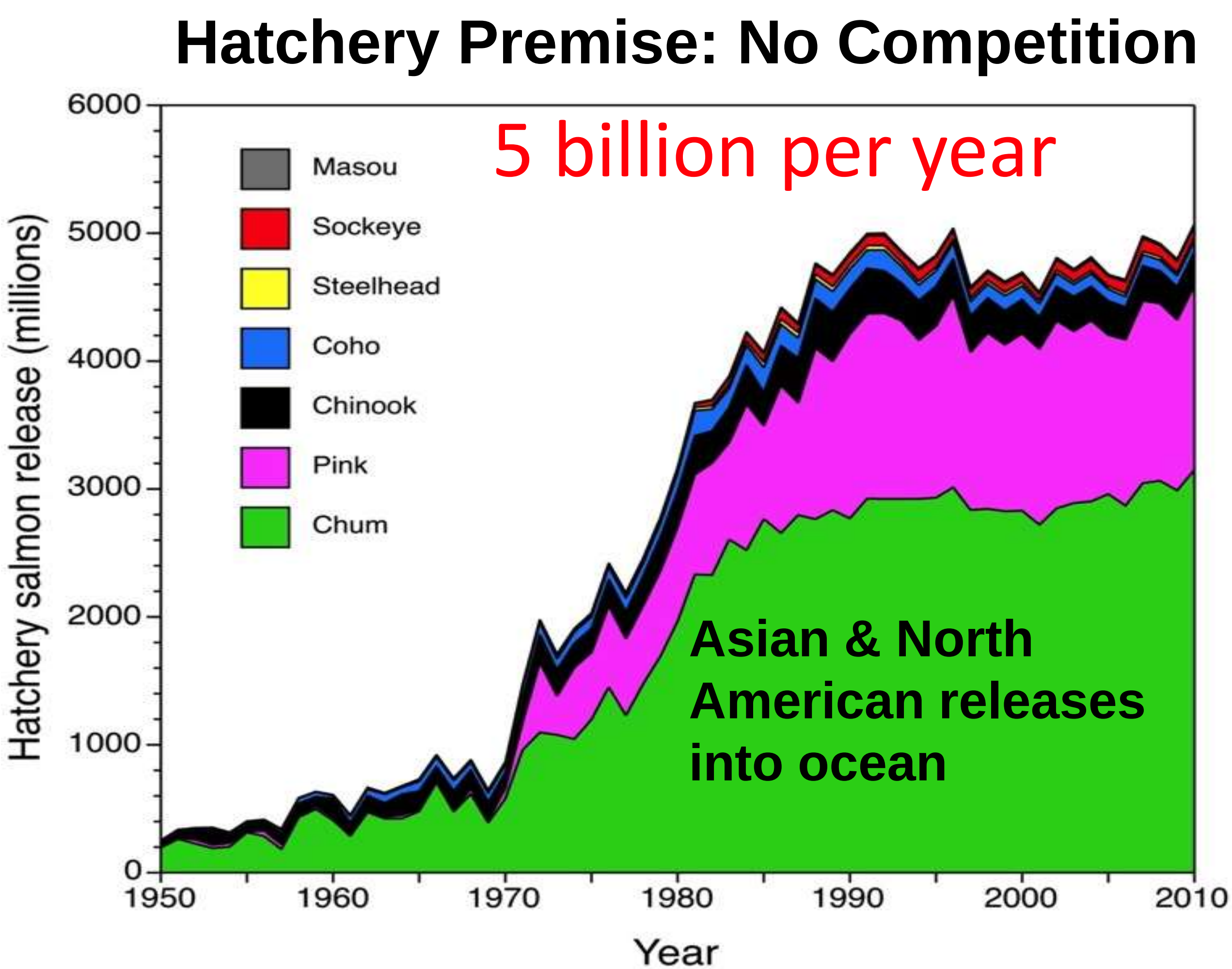
(Slide provided by Dick Feely, NOAA)

Ocean Fishing: What are the combined impacts of catch, bycatch, dropout mortality, and ecological interactions by commercial fisheries Gulf of Alaska and Bering Sea?



Guyon et al. 2014

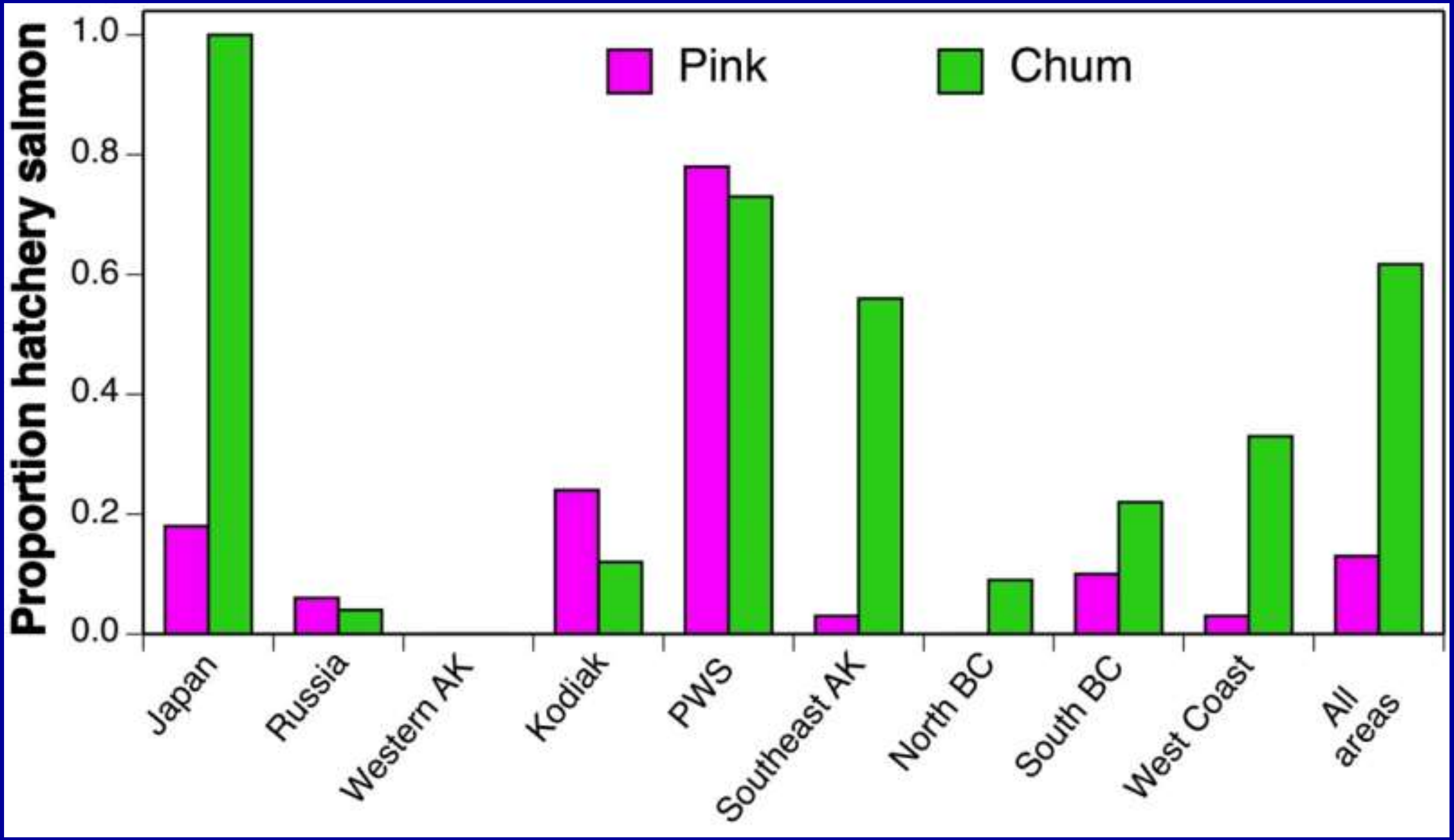
Do interactions with hatchery salmon in the ocean affect productivity of wild Mat-Su salmon?



Data Source: npafc.org

Regional Wild vs. Hatchery Abundance

Some “pristine” regions have high hatchery production, 1990-2005; Data source: Ruggerone et al. 2010



Marine pollution example: Potential Mechanisms of Juvenile Salmon Mortality Due to Plastic Marine Debris

Direct Mortality

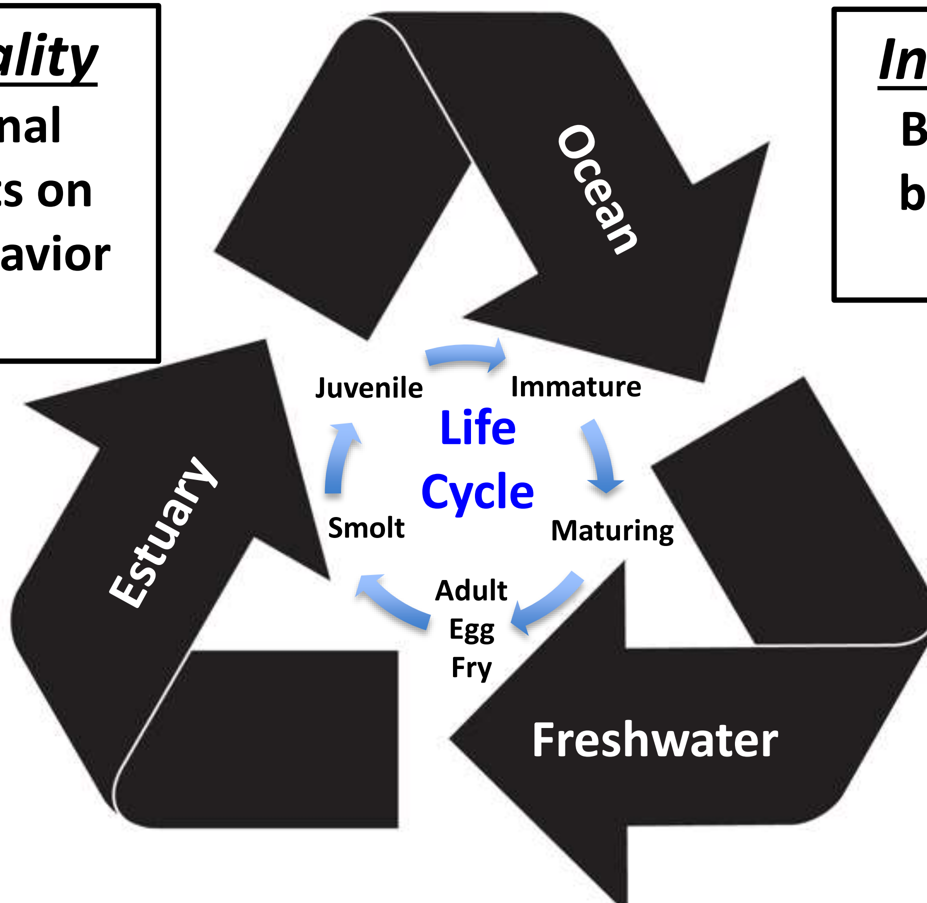
Mechanical injury, starvation, toxicity

Indirect Mortality

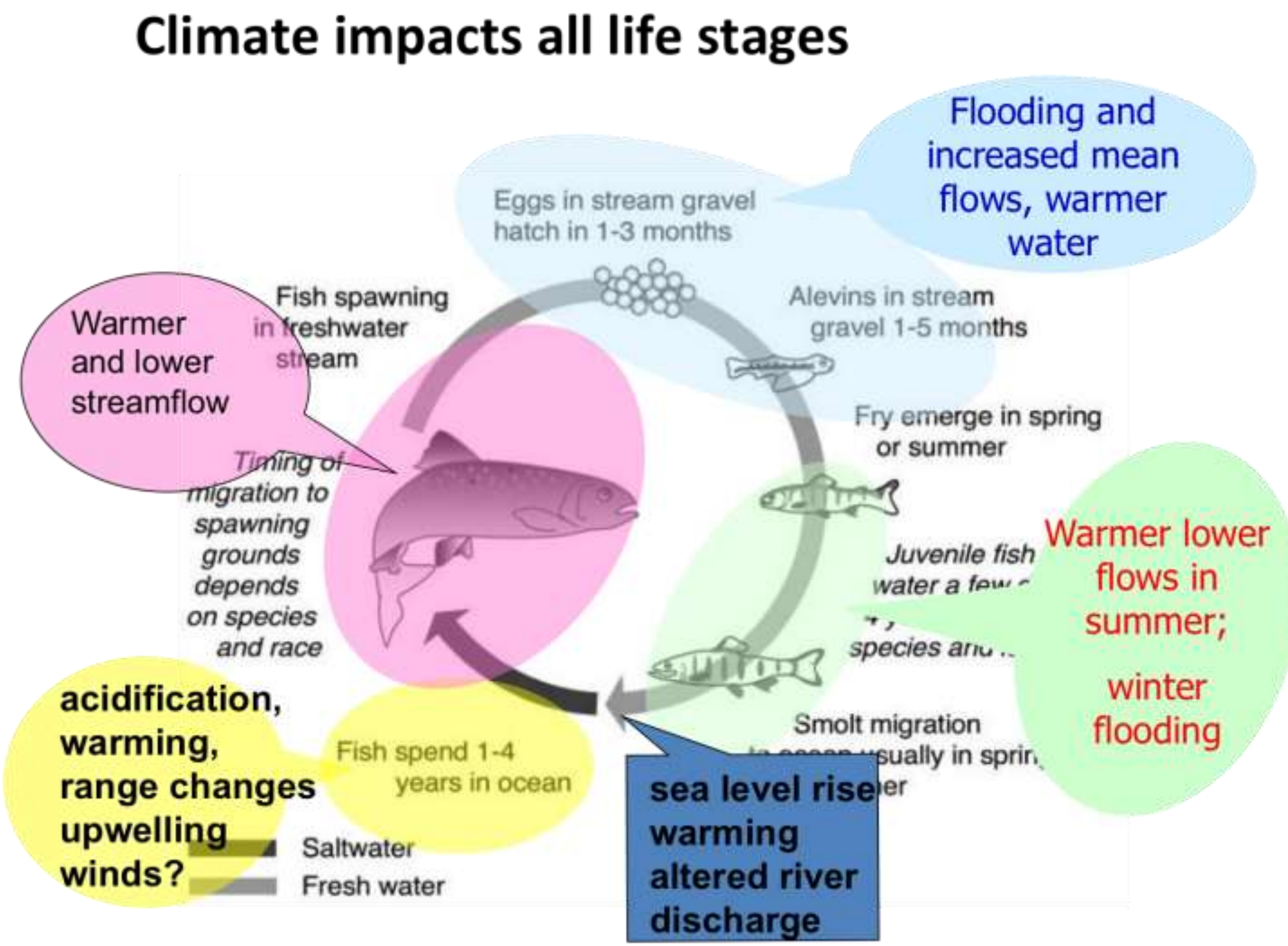
Transgenerational epigenetic effects on physiology & behavior

Indirect Mortality

Biomagnification & bioaccumulation of toxic chemicals



Hypotheses linking changes in FW and Marine Habitats to recent declines



Slide provided by Nate Mantua, NOAA

1. Critical size and period hypothesis

Year class strength is set during 1st year at sea

Critical Periods

First Spring

Faster growing Chinook escape predation

First Winter

Larger and more energetic Chinook survive winter

Slide provided by Ed Farley, NOAA/AFSC/Auke Bay Lab

2. Match Mismatch Hypothesis:

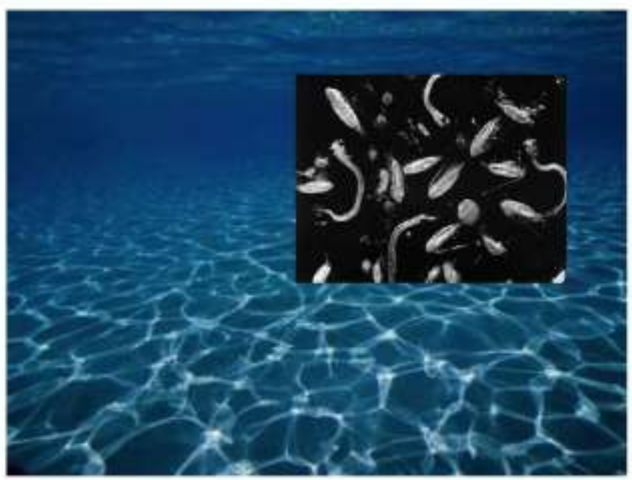
smolts are entering the ocean earlier

Slide provided by Ed Farley, NOAA/AFSC/Auke Bay Lab

Possible outcomes for earlier outmigration

Physiology

Smoltification stress – transition from freshwater to saltwater



Growth/Survival

Reduced survival - Smolt enter during a period of lower ocean productivity

Slide provided by Ed Farley, NOAA/AFSC/Auke Bay Lab

3. Declining adult size reduces productivity

Reduced Fecundity

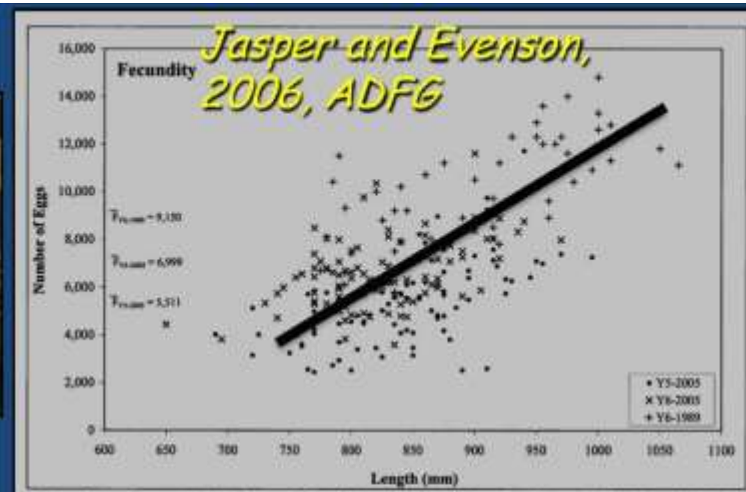


Figure 5.–Fecundity versus length (mideye to tail fork) of Yukon River Chinook salmon from Districts 5 and 6 in 2005, and District 6 in 1989, Yukon Area.

Reduced Access to Spawning Habitat

Bigger salmon:
- Power through faster currents
- Leap over higher water falls or barriers
- Spawn in habitat that contains coarser substrate

Modified from slide provided by Ed Farley, NOAA/AFSC/Auke Bay Lab

Suggestions for next steps

- **Proceed with recommended ADFG Chinook stock assessment & research plan (ADFG 2013)**
- **Develop a plan for local marine research, monitoring, & evaluation of juvenile salmon & their nearshore habitats in Cook Inlet**
- **Support/collaborate with NOAA's juvenile salmon ecosystem monitoring & assessment in shelf habitats of the Bering Sea & Gulf of Alaska**
- **Cooperate with treaty organizations addressing these issues in international waters (high seas) - North Pacific Anadromous Fish Commission (npafc.org) and North Pacific Marine Science Organization (pices.int)**