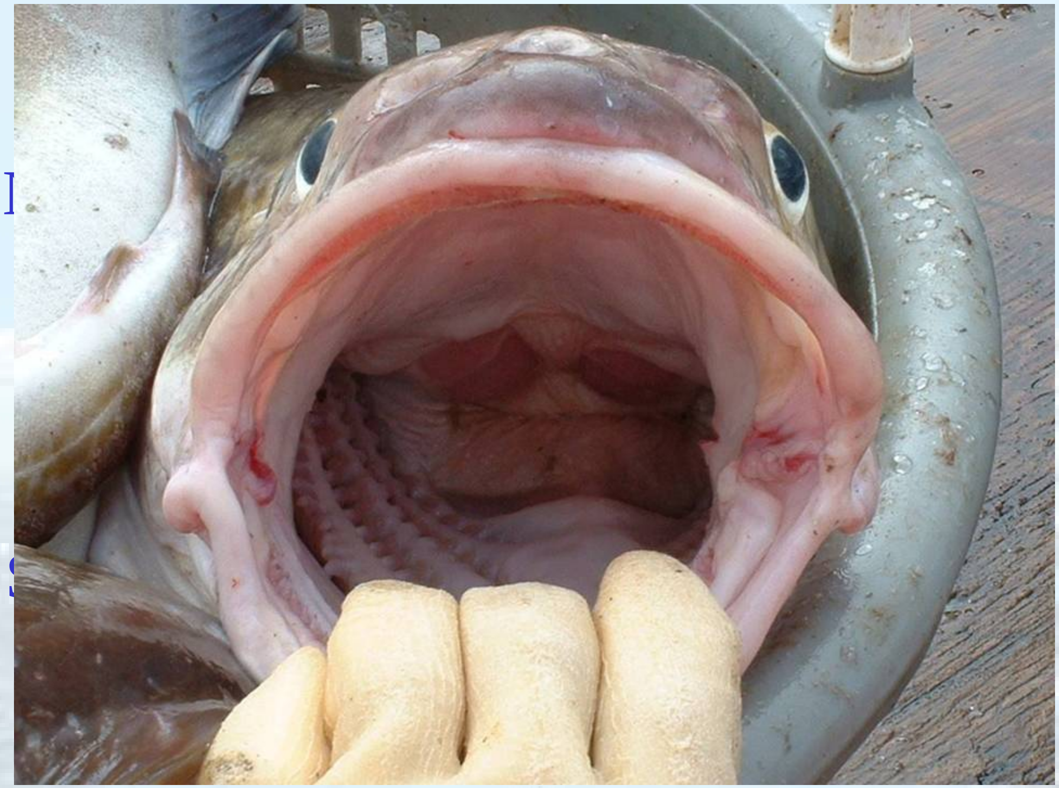
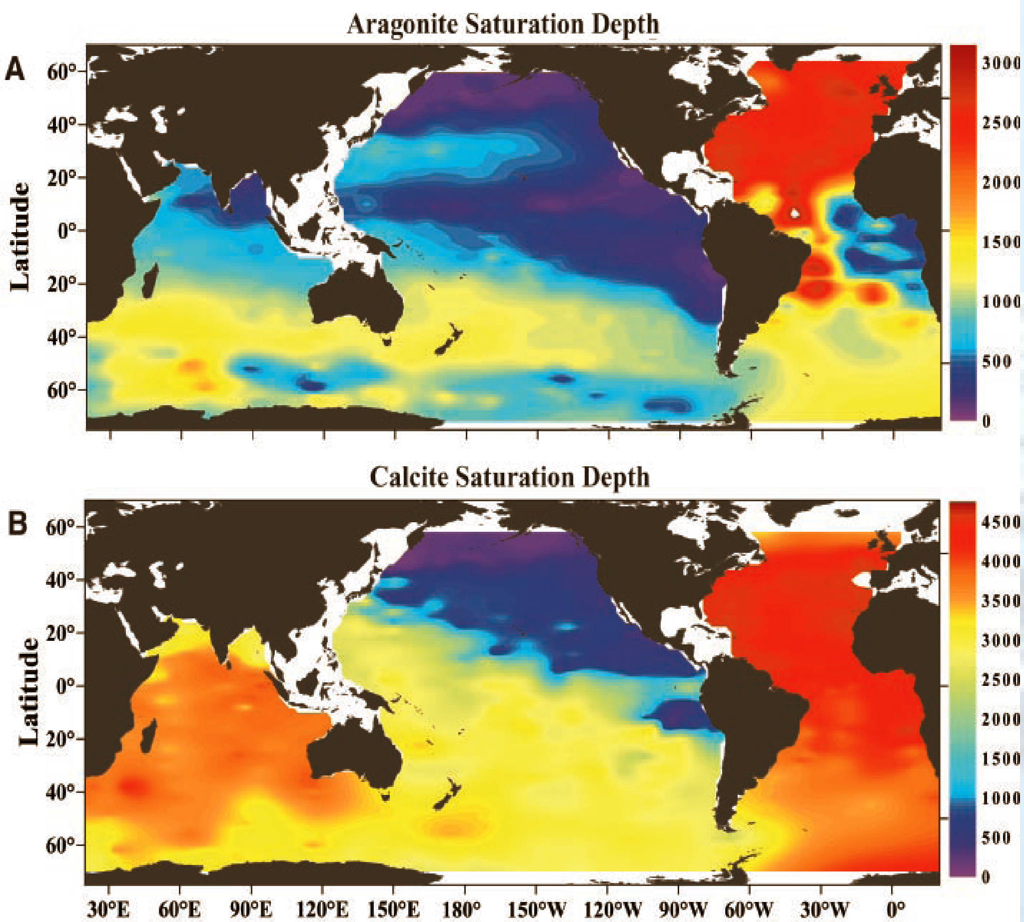
Fisheries Impacts of Ocean Acidification – Focus on Alaskan waters

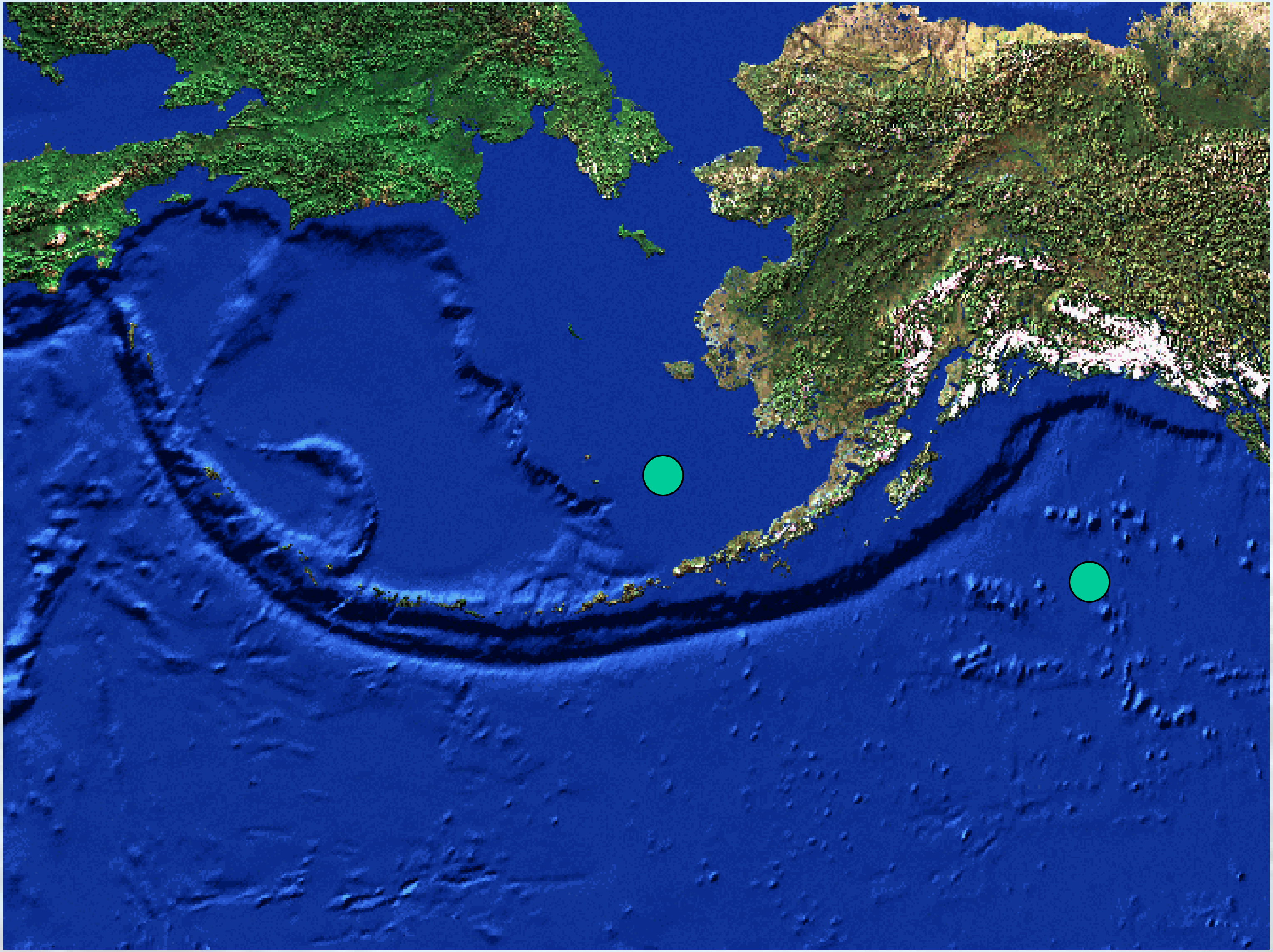


Sentinel Region

North Pacific Ocean, where carbonate saturation depth is relatively shallow.

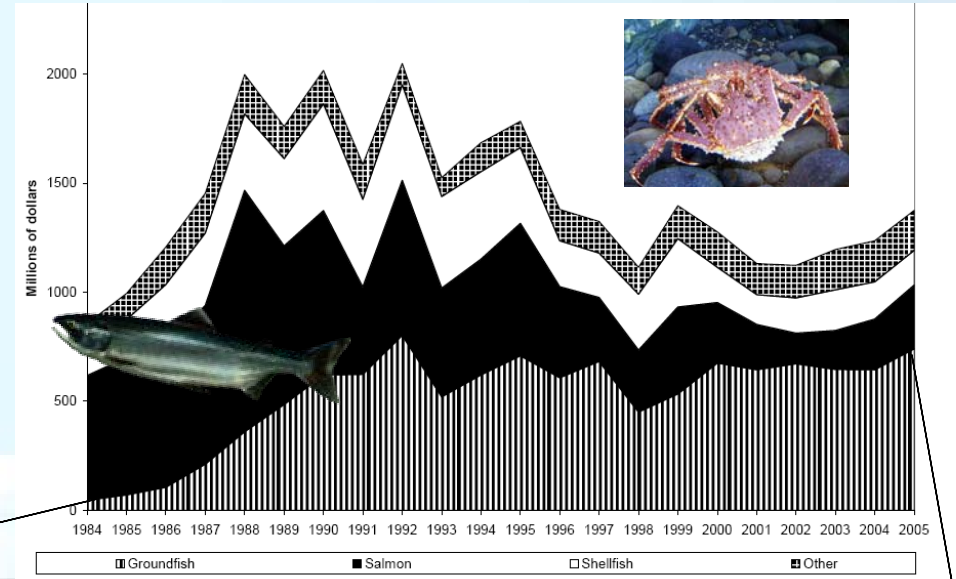


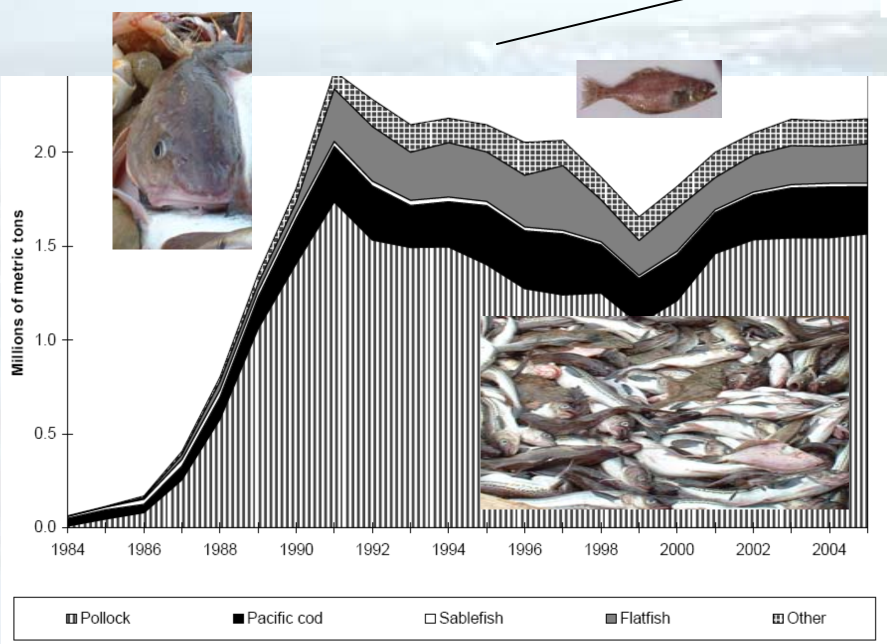
Feely et al. 2004. Impact of anthropogenic CO_2 on the $CaCO_3$ in the oceans. Science 305: 362-366.

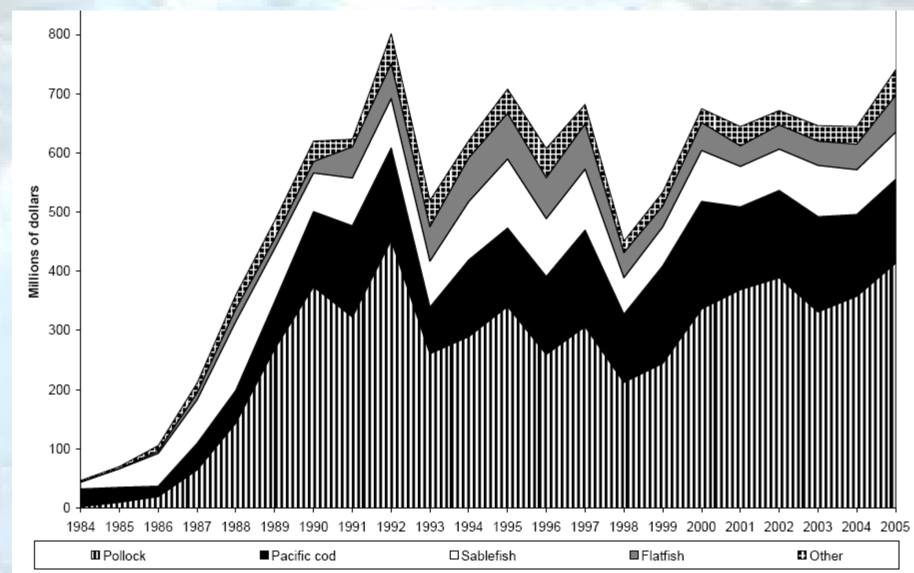


Highly productive shallow shelves, productive offshore regions (rearing and growth area for salmon)

Components of Alaskan fisheries







2006 Alaska Commercial Salmon Harvest Ex-vessel Values

Species	Avg. wt (lbs.)	Avg. Price/lb.	No. of Fish (thousands)	Lbs. of Fish (thousands)	Estimated Value USD (thousands)
Chinook	15.71	3.03	645	10,126	30,721
Sockeye	5.71	0.76	41,649	237,716	180,610
Coho	7.24	1.04	4,428	32,065	33,447
Pink	3.70	0.16	72,808	269,613	43,372
Chum	8.44	0.32	21,532	181,836	58,299
Totals			**141,062**	**731,355**	**346,449**

From http://www.cf.adfg.state.ak.us/geninfo/finfish/salmon/salmoncatch.php accessed 9/28/07

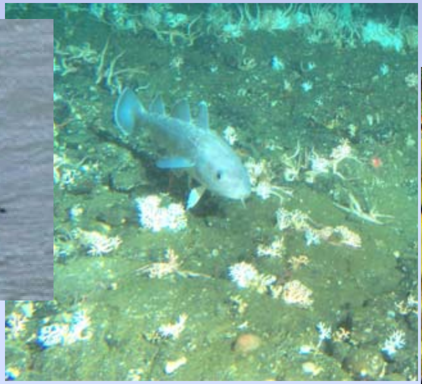
Does not include recreational value, or data from Japan, Russia, Canada, or Wa-Or-Ca

Rich biological relationships

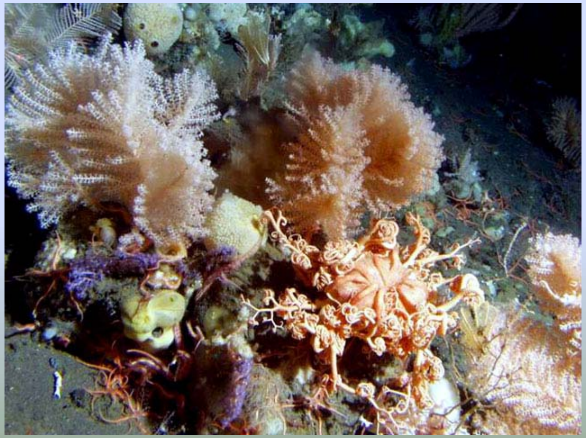






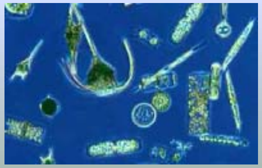




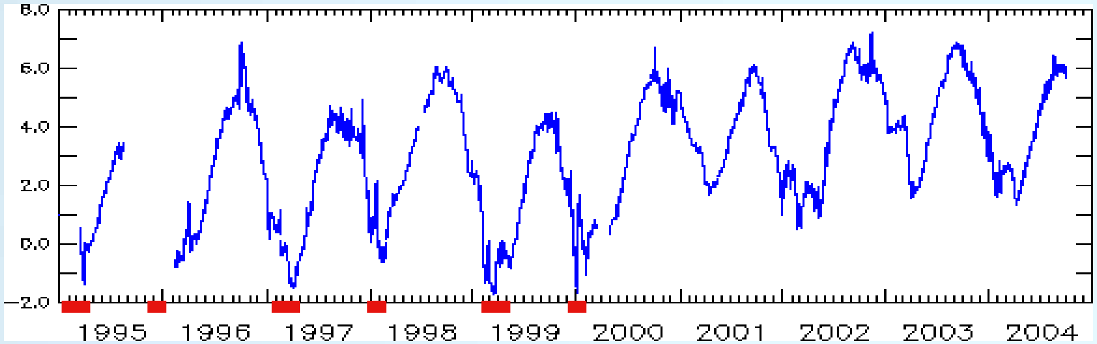




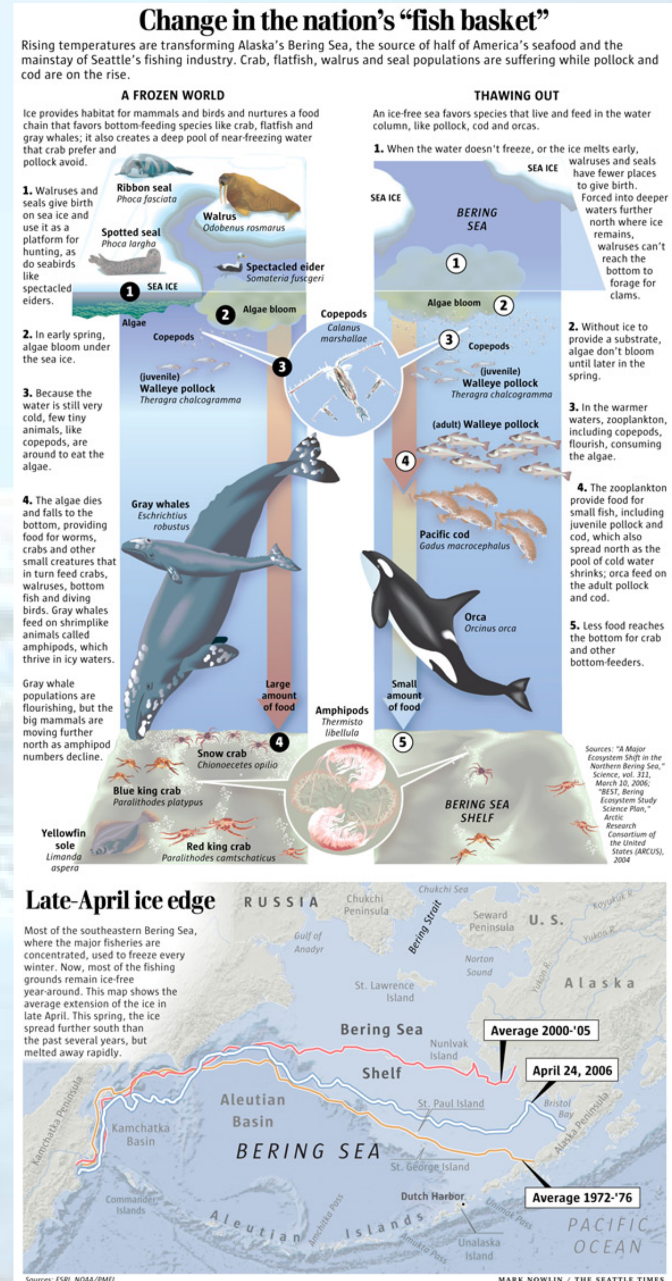




Temperature and ice versus acidity?



- Temperature
  - Direct temperature effects
  - Ice-related productivity
  - Winners and losers
- Acidity…any winners?



Acidity

- Direct stress
  - Crabs
  - Physiological effects on fish

- Habitat stress
  - Corals, effects on sheltering fish
- Trophic stress
  - Salmon dependent on pteropods
  - Shifting pathways in food web

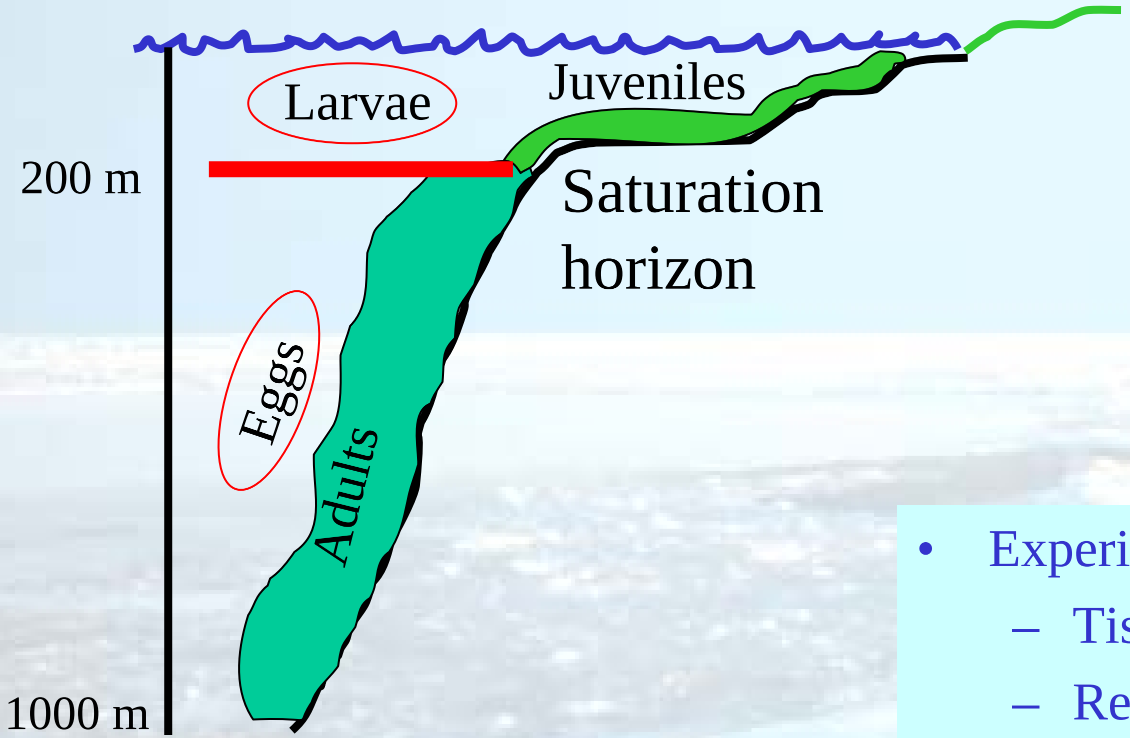
Ocean Acidification - Shellfish

- Larval blue king crab, Kodiak Alaska, pilot experiment, 2006.
- Tested range of projected global ocean pH change over the current century.
- Reduced growth and survival.


Photo: B. Stevens, NOAA Alaska Fisheries Science Center

- Contact: Bob Foy, AFSC Kodiak

Finfish in a Low Carbonate Environment – many do live.

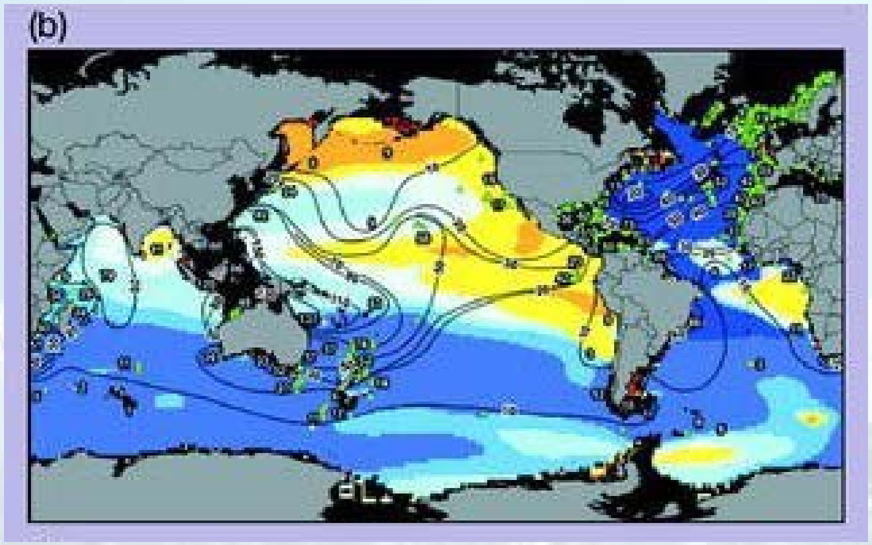


Alaska Sablefish

- Experimental effects
  - Tissue acidosis
  - Reproduction
- Experimental concentrations generally higher than considered reasonable given projected CO_2 concentrations
- Considerable planning on further experiments – Mike Sigler

Ocean Acidification - Corals

Deep-sea bioherm forming corals



Guinotte, JM, J. Orr, S. Cairns, A. Freiwald, L. Morgan, and R. George. 2006. Will human-induced changes in seawater chemistry alter the distribution of deep-sea scleractinian corals? Front. Ecol. Environm. 4:141-146. Green triangles are locations of deep-sea bioherm forming corals.

Depth distribution of Aleutian corals.

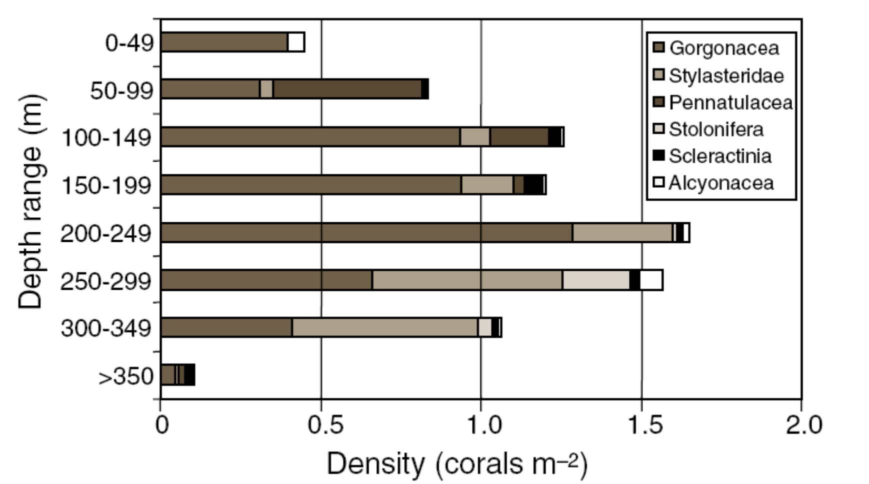


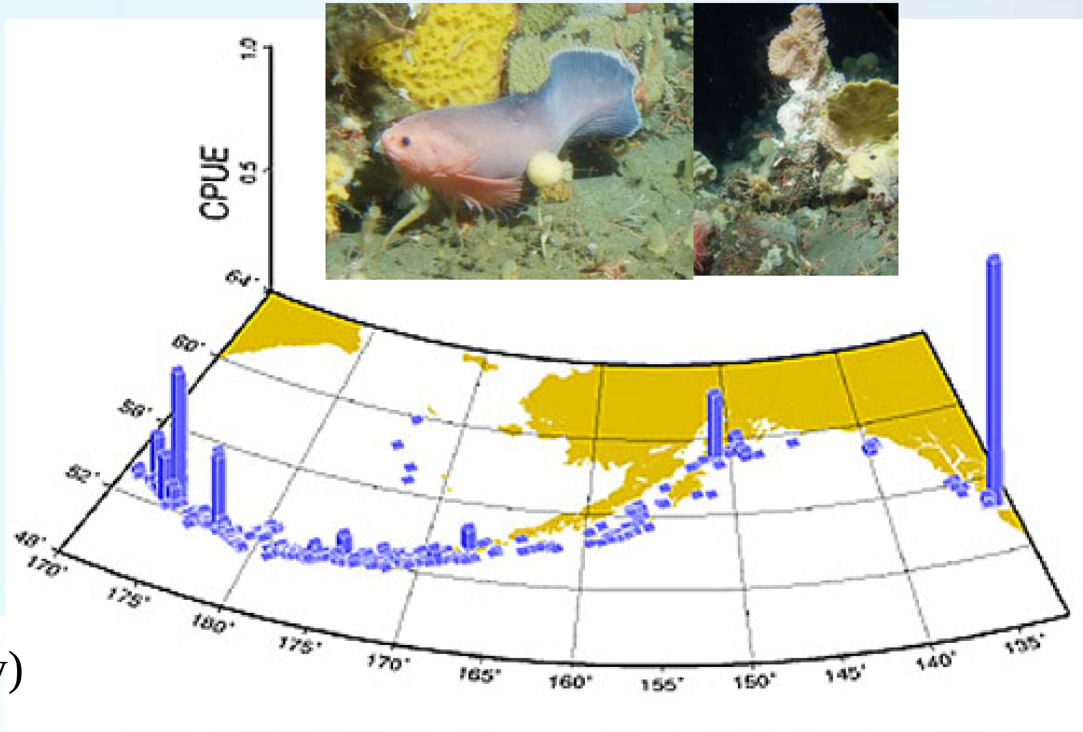
Fig. 3 Density of corals observed in 50-m depth zones with the submersible '*Delta*'

Stone, R. P. 2006. Coral habitat in the Aleutian Islands off Alaska: Depth distribution, fine-scale species associations, and fisheries interactions. Coral Reefs 25:229-238.

Coral gardens

- Shelter for juvenile rockfish

(Jonathan Heifetz, Auke Bay Laboratory)

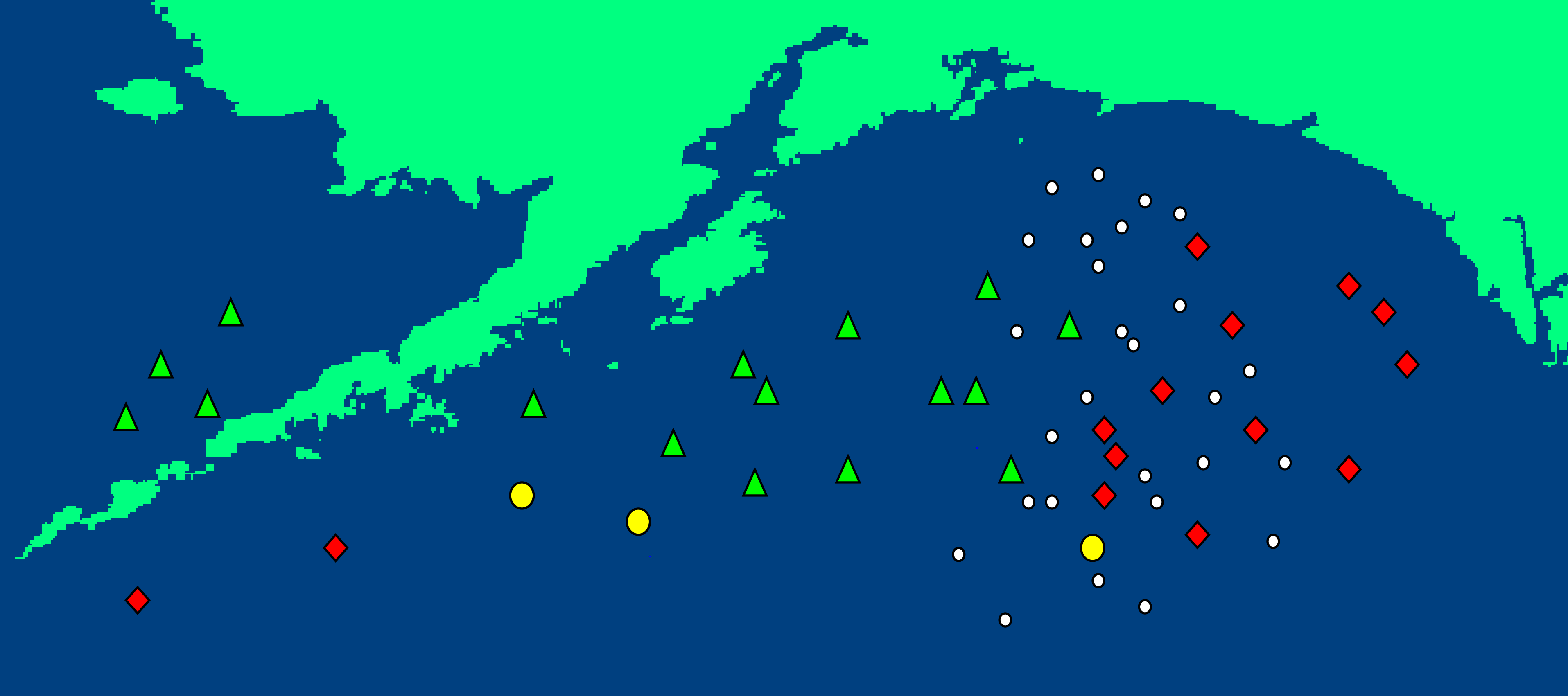


Ocean Acidification - Calcareous plankton, the base of the food web.

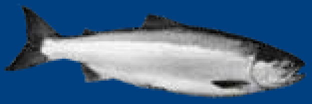
Pteropods (snail)

Coccolithophores (phytoplankton)

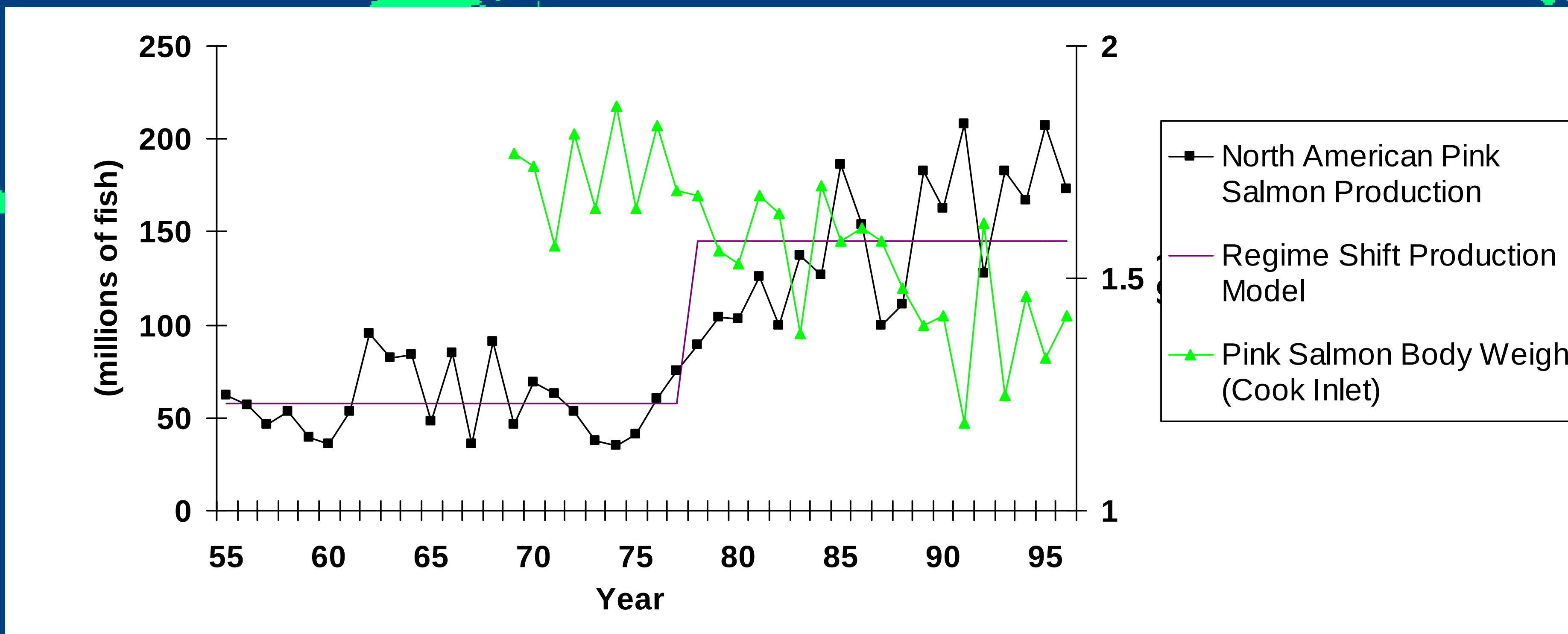
Foraminifera
(protist)



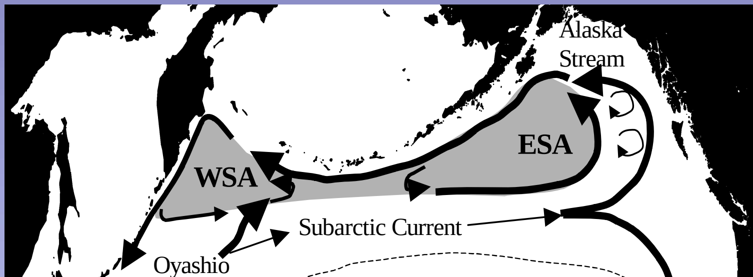
Pacific Salmon Carrying Capacity



- Stock competition
- Salmon may be forage limited
- Habitat linked to water temperature

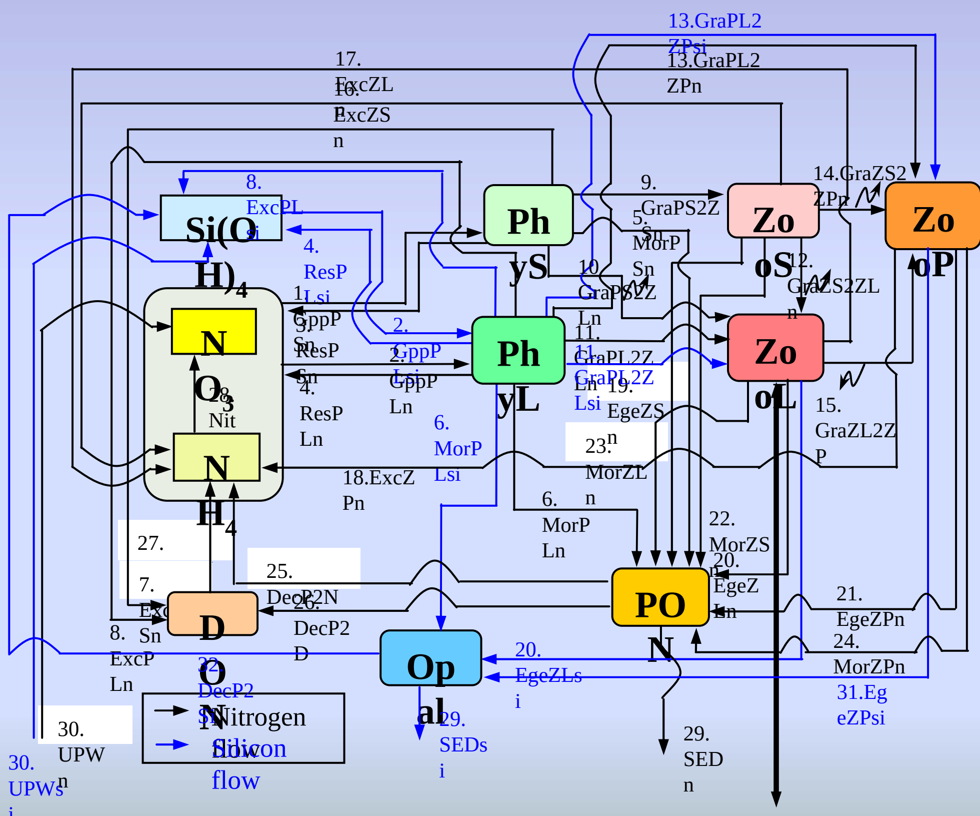


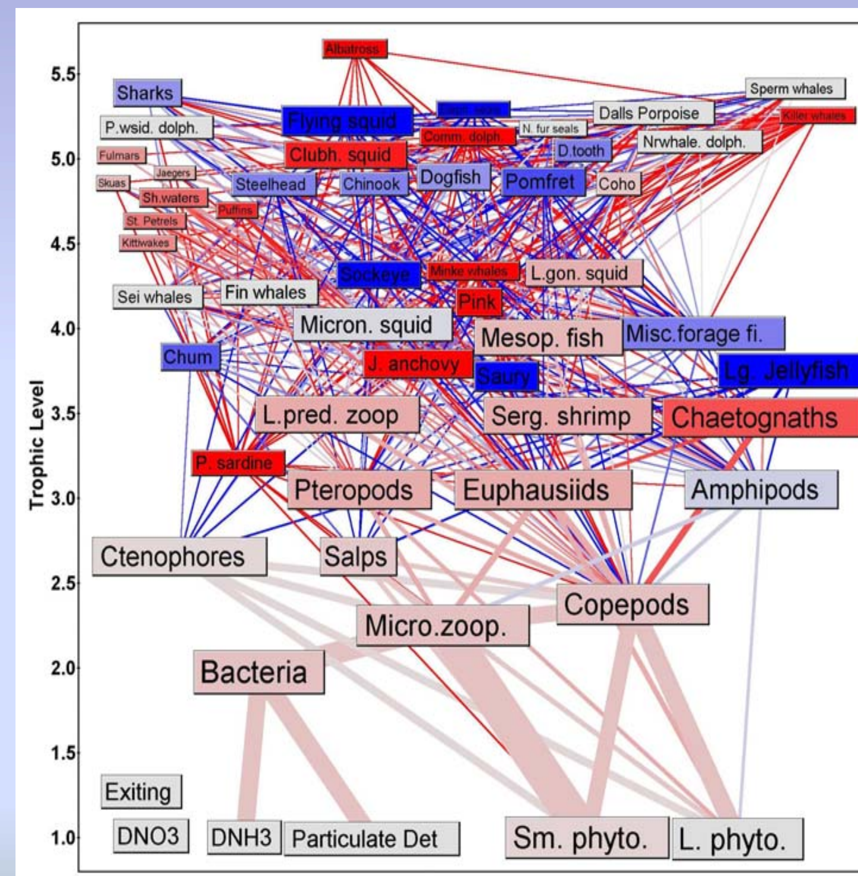
Trends in production and growth



An example of model linkages

Aydin et al. (Ecosim, food web)
Megrey et al. (NEMURO, NPZD)





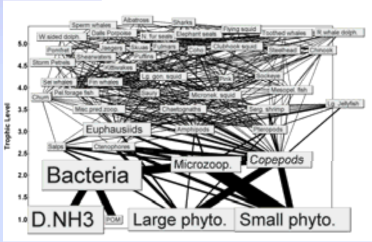
NEMURO contans 1-D vertical migration, Ecosim is “entire pelagic mixed layer.”

Model linkages

Pink salmon bioenergetics model, predicts daily pink salmon growth and numerical mortality based on input ration.

Pink salmon body weight and numbers used to set Ecosim biomass for predator and prey equations in next timestep.

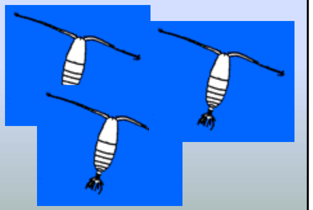
Consumption and mortality rates for Pink salmon based on predator and prey biomass.



Ecosim (ecosystem biomass dynamics model), run on a daily timestep.

No direct feedback to NEMURO: Ecosim parameters for predatory zooplankton (euphausiids) tuned to match NEMURO predictions for same species.

Daily biomass density of phytoplankton, microzooplankton, large zooplankton



NEMURO (nutrient-phytoploankton-zooplankton-detritus): 1-dimensional water column model integrated on an hourly timestep.

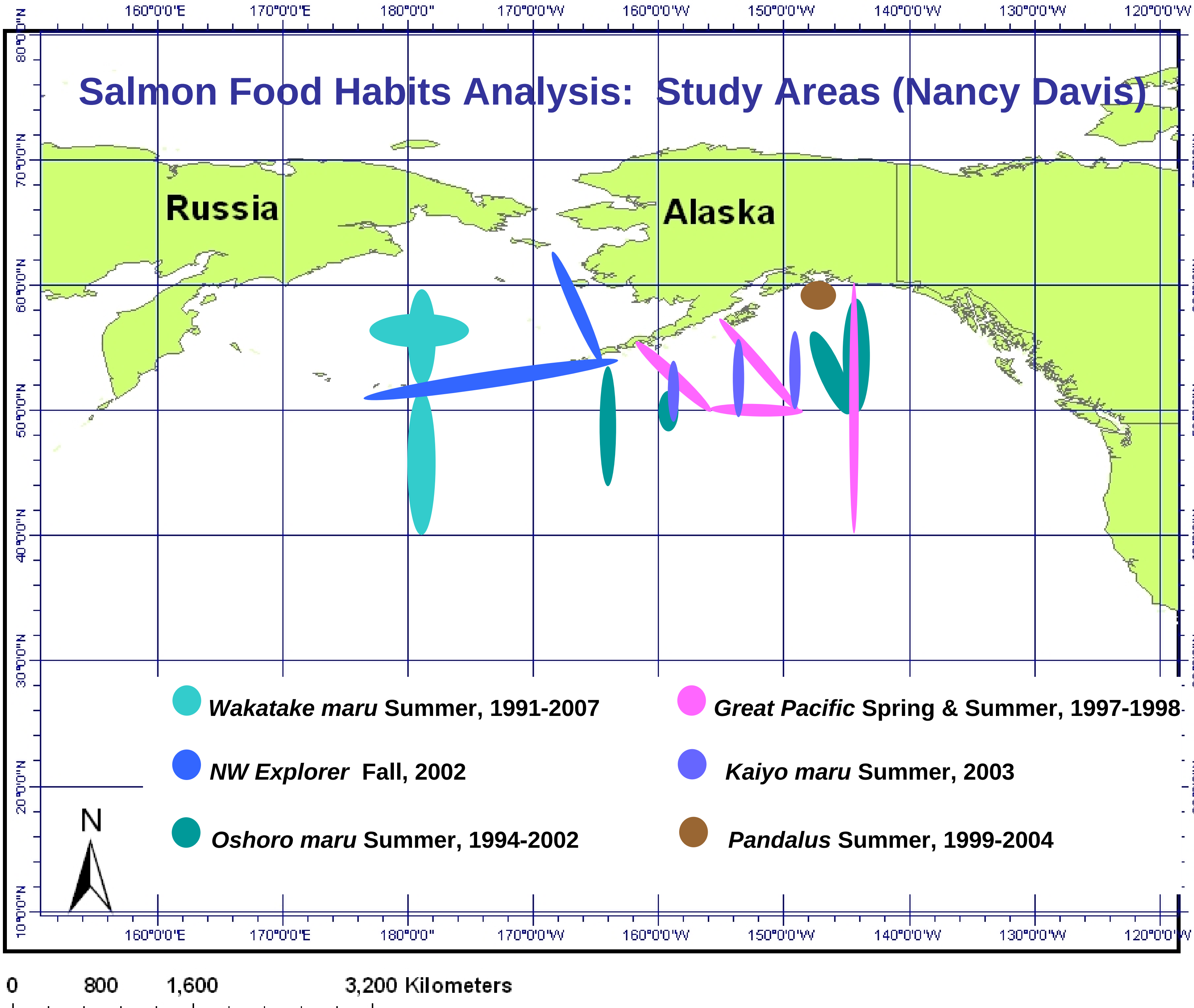
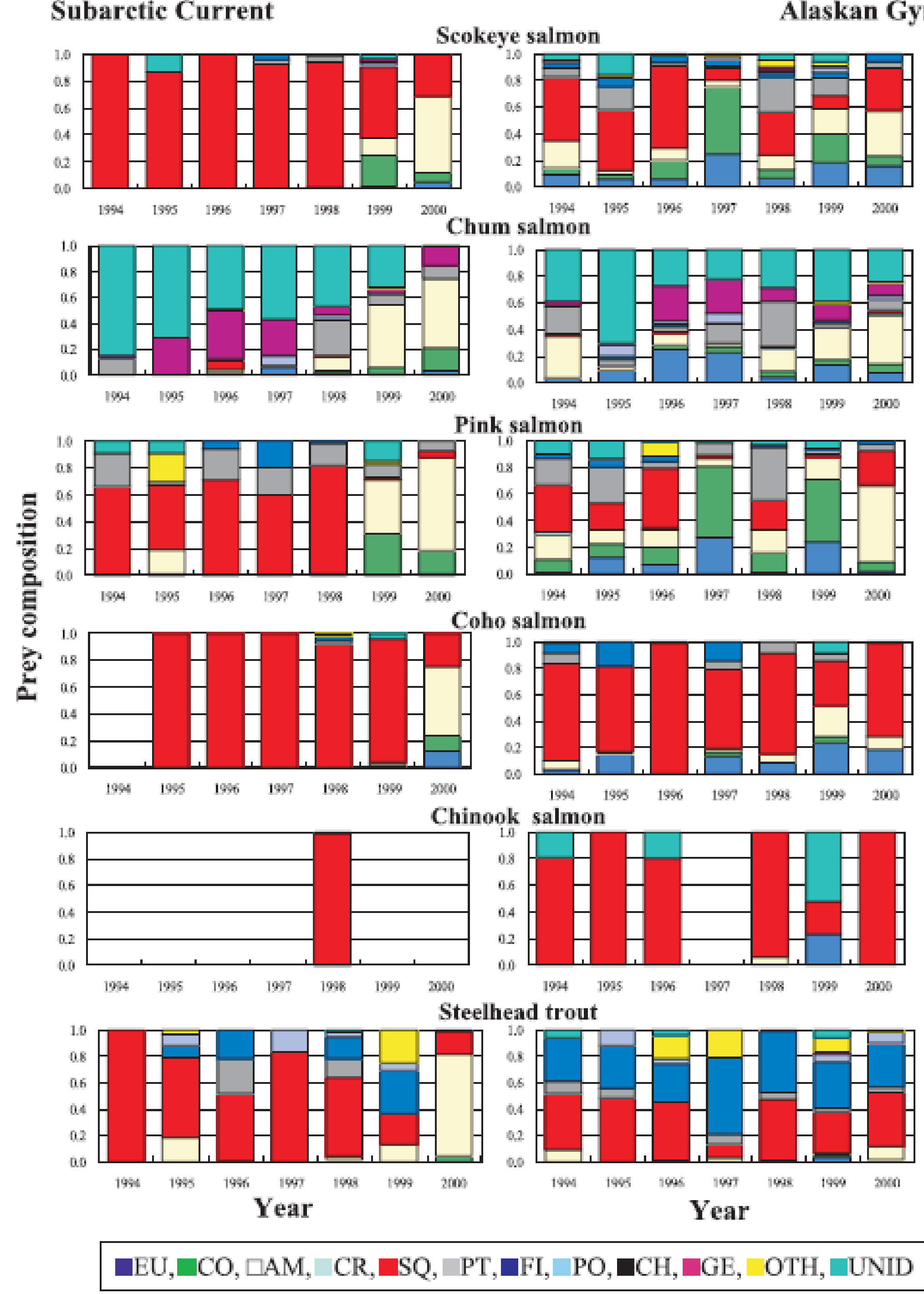

Salmon Food Habits Analysis: Study Areas (Nancy Davis)
Russia
Alaska
Wakatake maru Summer, 1991-2007
NW Explorer Fall, 2002
Oshoro maru Summer, 1994-2002
Great Pacific Spring & Summer, 1997-1998
Kaiyo maru Summer, 2003
Pandalus Summer, 1999-2004
N
160°0'0"E
170°0'0"E
180°0'0"
170°0'0"W
160°0'0"W
150°0'0"W
140°0'0"W
130°0'0"W
120°0'0"W
80°0'0"N
70°0'0"N
60°0'0"N
50°0'0"N
40°0'0"N
30°0'0"N
20°0'0"N
10°0'0"N
0 800 1,600 3,200 Kilometers

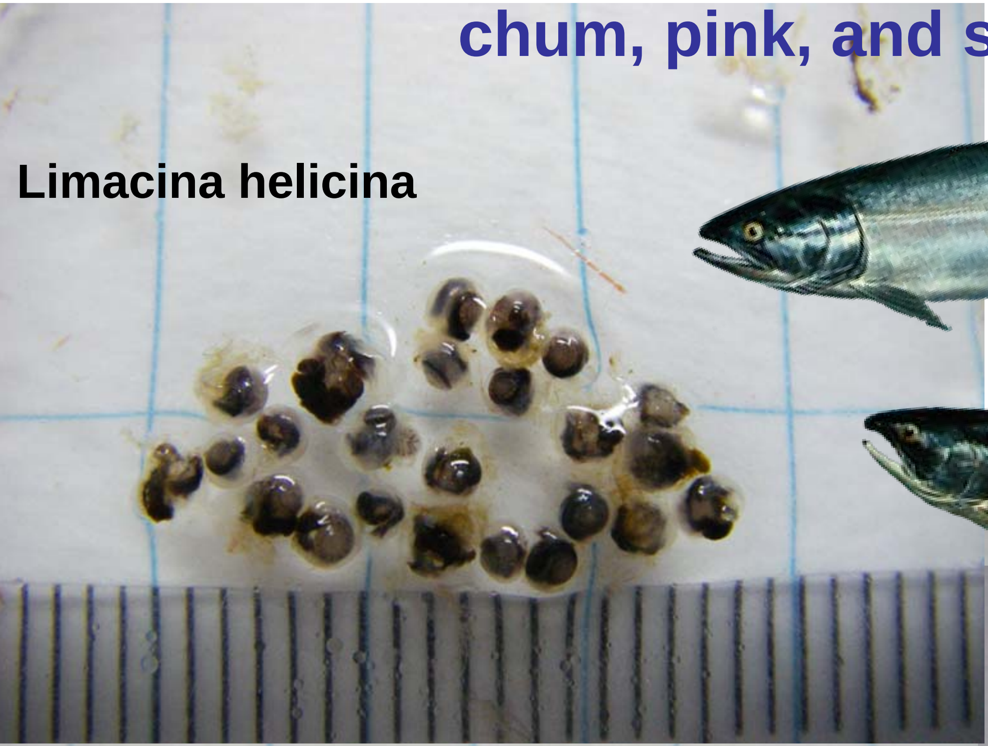
Table 1. Prey animals and food items of Pacific salmon in the Gulf of Alaska.

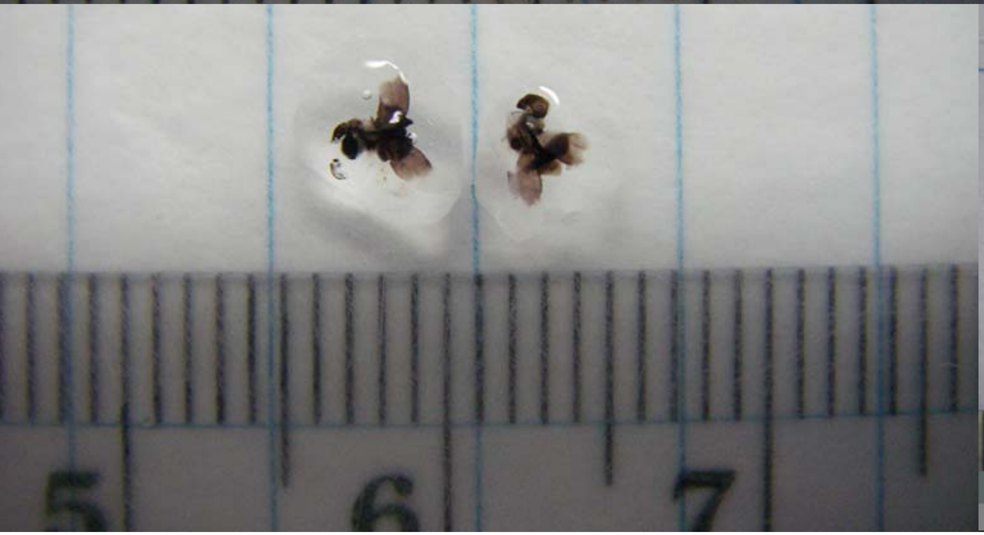
Food items	Species
Euphausiids (EU)	*Thysanoessa longipes*
	Thysanoessa inermis
	Thysanoessa spp.
	Euphausia spp.
	Other euphausiids
Copepods (CO)	*Neocalanus cristatus*
	Eucalanus bungii
	Other copepods
Amphipods (AM)	*Hyperia medusarum*
	Hyperia spp.
	Themisto pacifica
	Themisto japonica
	Themisto spp.
	Primno macropa
	Phronima sedentaria
	Other amphipods
Decapods (DE)	Decapods
Squids (SQ)	*Berryteuthis anonychus*
	Gonatus middendorffi
	Other squids
Pteropods (PT)	*Limacina* spp.
	Clio spp.
	Clione spp.
Fishes (FI)	*Anoplopona fimbria*
	Myctophids
	Other fish eggs and larvae
Polychaetes (PO)	Polychaetes
Chaetognaths (CH)	Chaetognaths
Gelatinous zooplankton (GE)	Coelenterates
	Ctenophores
	Salps
Otheranimals (OT)	Halocyprids
	Cumacea
	Octopoda
	Ostracods
	Barnacles
	Debris
UI	Unidentified material



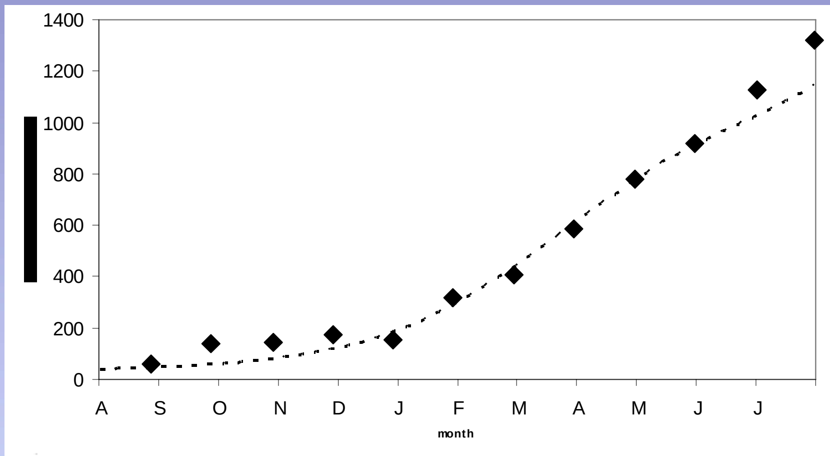
Kaeriyama et al. 2004

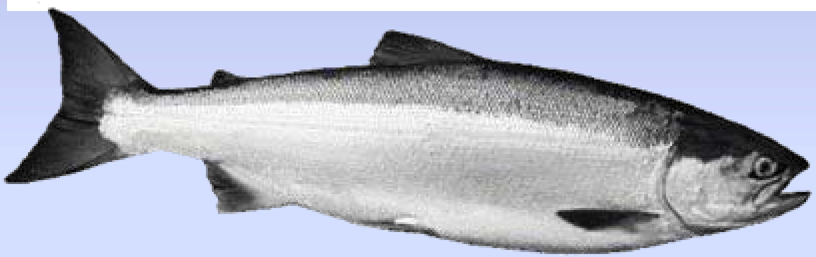
Pteropods are consumed by juvenile, immature, and maturing chum, pink, and sockeye salmon



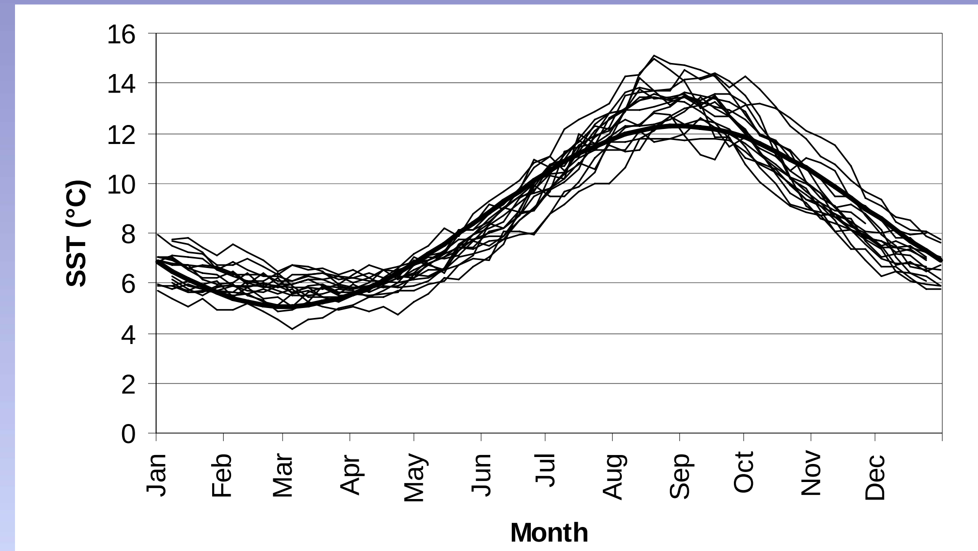


Additional data





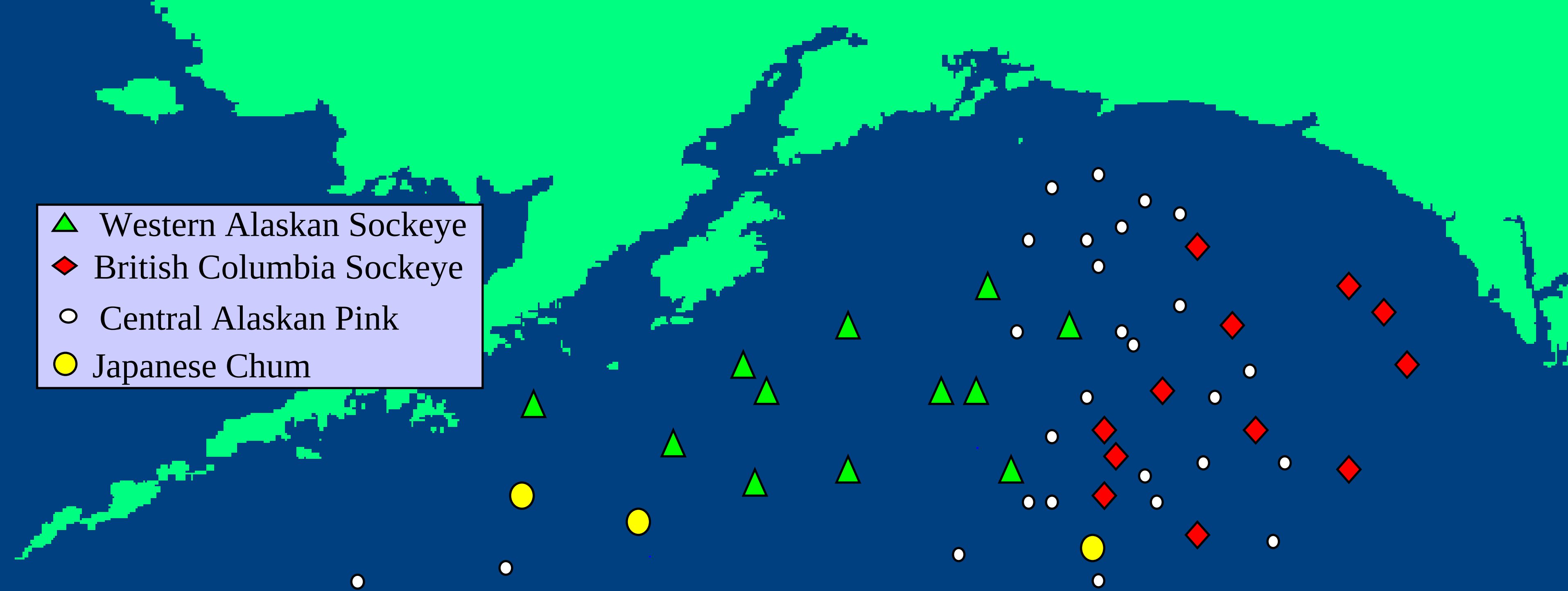
OSP temperature



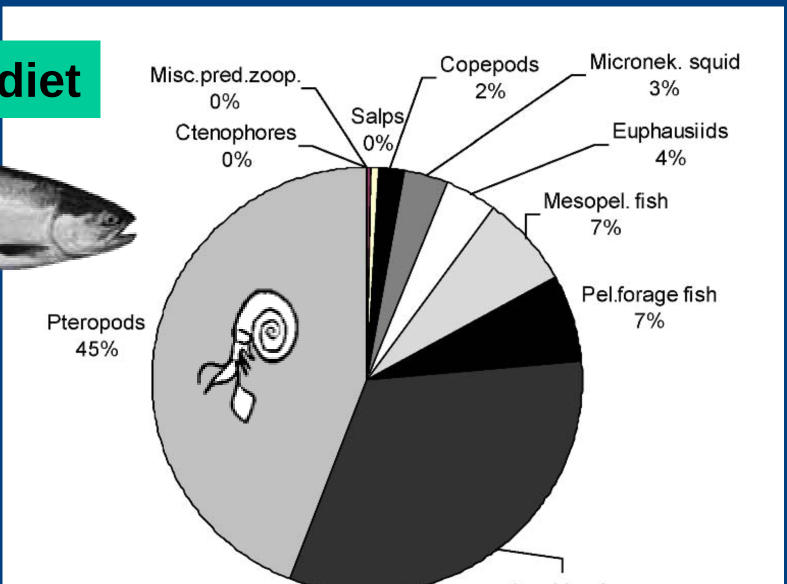
Prey quality

Prey group	cal / g wet weight	species and range
Copepods	700	*Neocalanus cristatus*, 627-748
Euphausiids	1000	*Thysanoessa* spp., *Euphausia* spp., 840-1050
Pteropods	650	*Limacina helicina*; 624-940
Amphipods	800	*Parathemisto pacifica*; 852-1010
Ctenophores	50	*Beroe* sp., 47
Salps	36	*Salpa* sp., 36
Chaetognaths	450	*Sagitta elegans*; 455-488
pelagic forage fish	1200	*Gasterosteus aculeatus*; 1166-1533
mesopelagic forage fish	2000	*Stenobrachius leucopsarus; Tarletonbeania crenular* *Leuroglossus schmidti*; 2041-2365 (Bering Sea)
Micron. squid	1500	*Berryteuthis anonychus*; 1307-1737 (increases with increasing mantle length).

Mixed-layer dynamics



Pink salmon diet



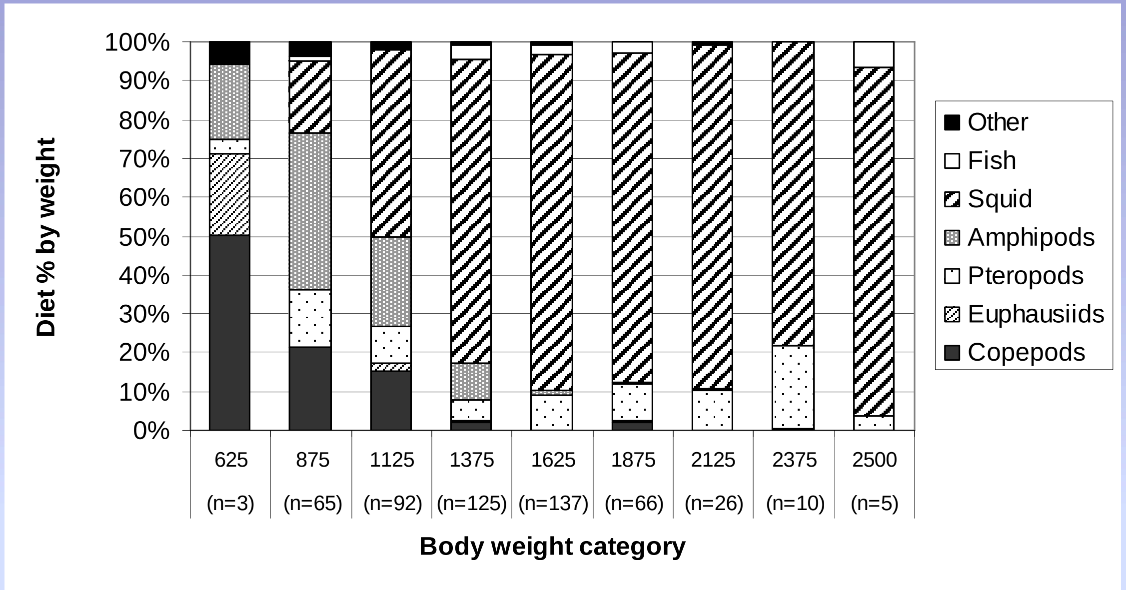
(Aydin et al. 2005)

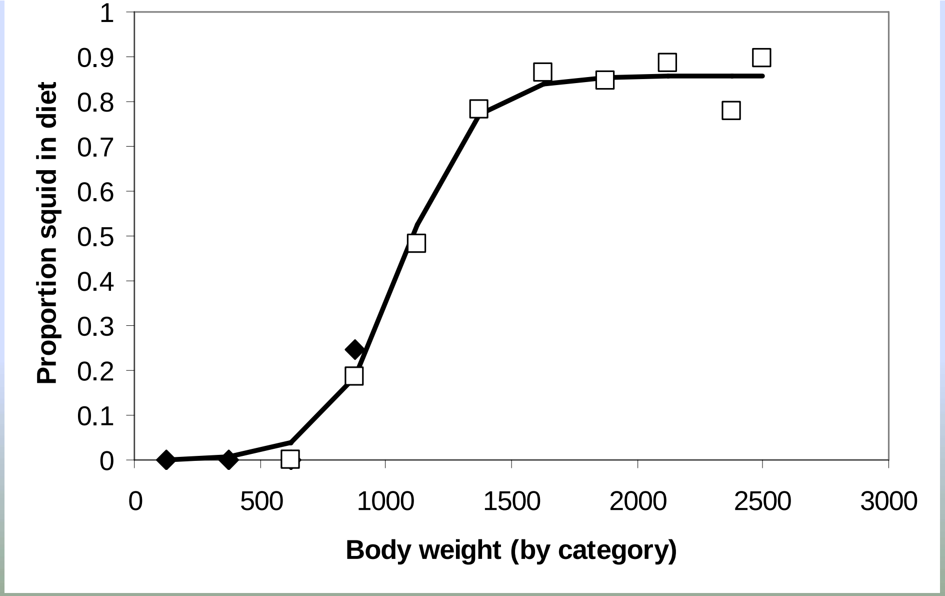
Predicted effect of climate change on pink salmon growth:

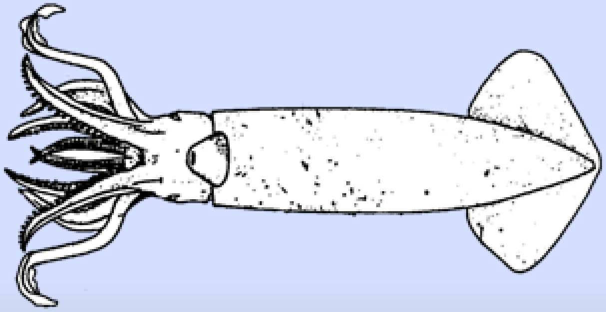
•10% increase in water temperature leads to 3% drop in mature salmon body weight (physiological effect).

•10% decrease in pteropod production leads to 20% drop in mature salmon body weight (prey limitation).

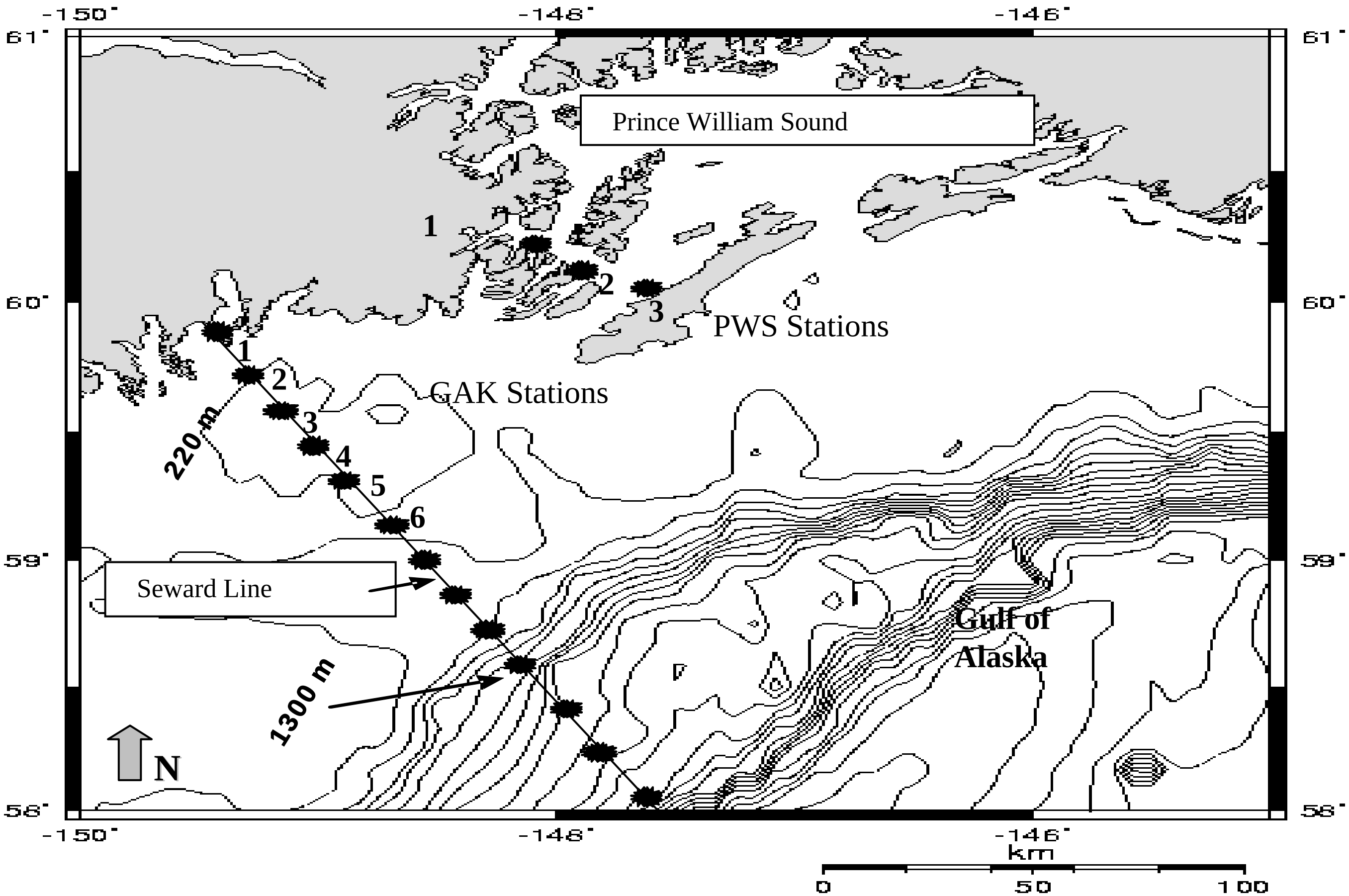
Diet switching?





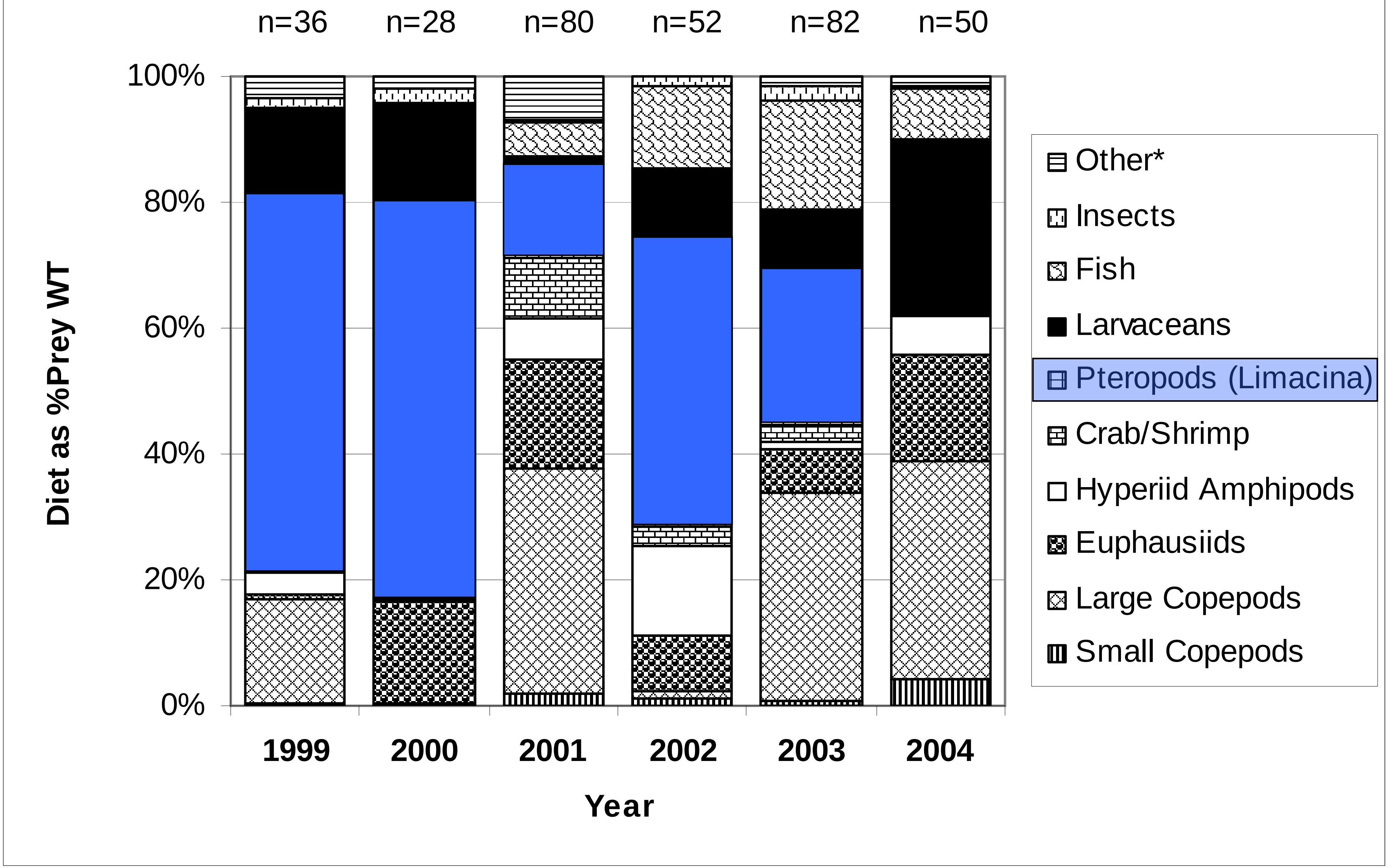


Prince William Sound and northern GOA (Seward Line) sample sites for collection of juvenile pink salmon 1999-2004

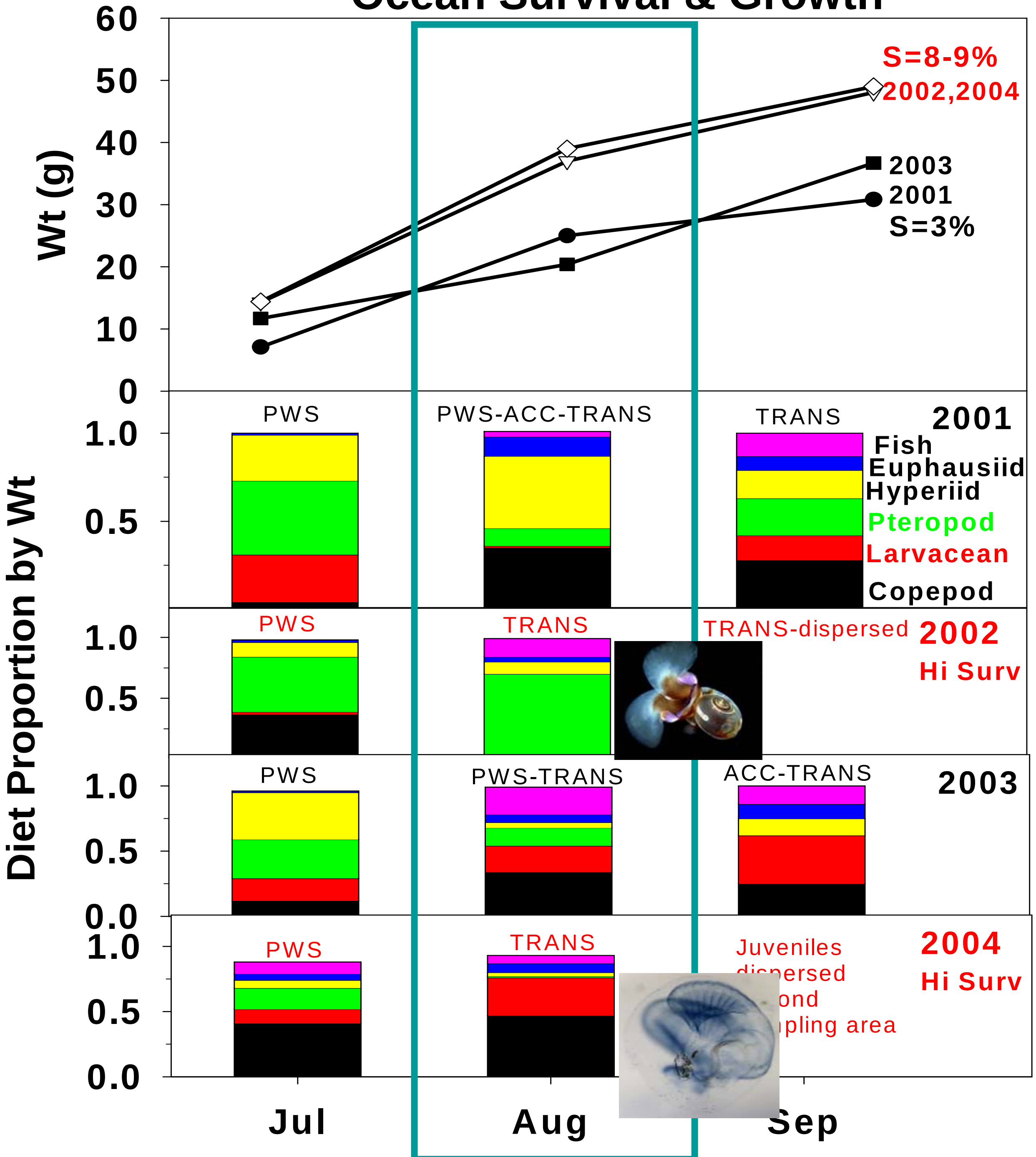


Juvenile Pink Salmon

Interannual Diet Comparison: August GAK 1-6



Ocean Survival & Growth

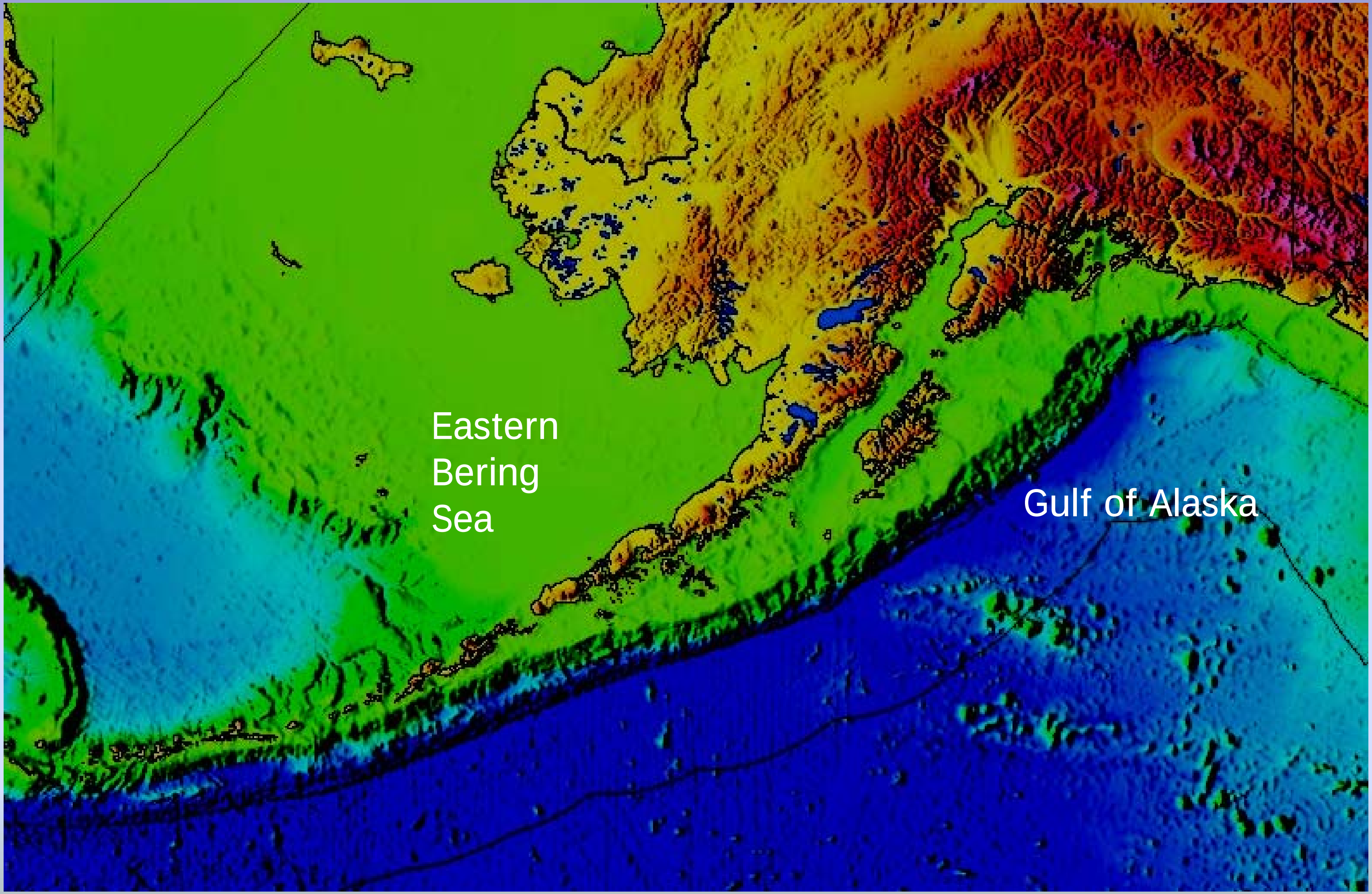


GROWTH:
Higher survival associated with Larger juveniles

DISTRIBUTION:
Higher survival associated with Earlier, wider dispersal during Aug-Sep

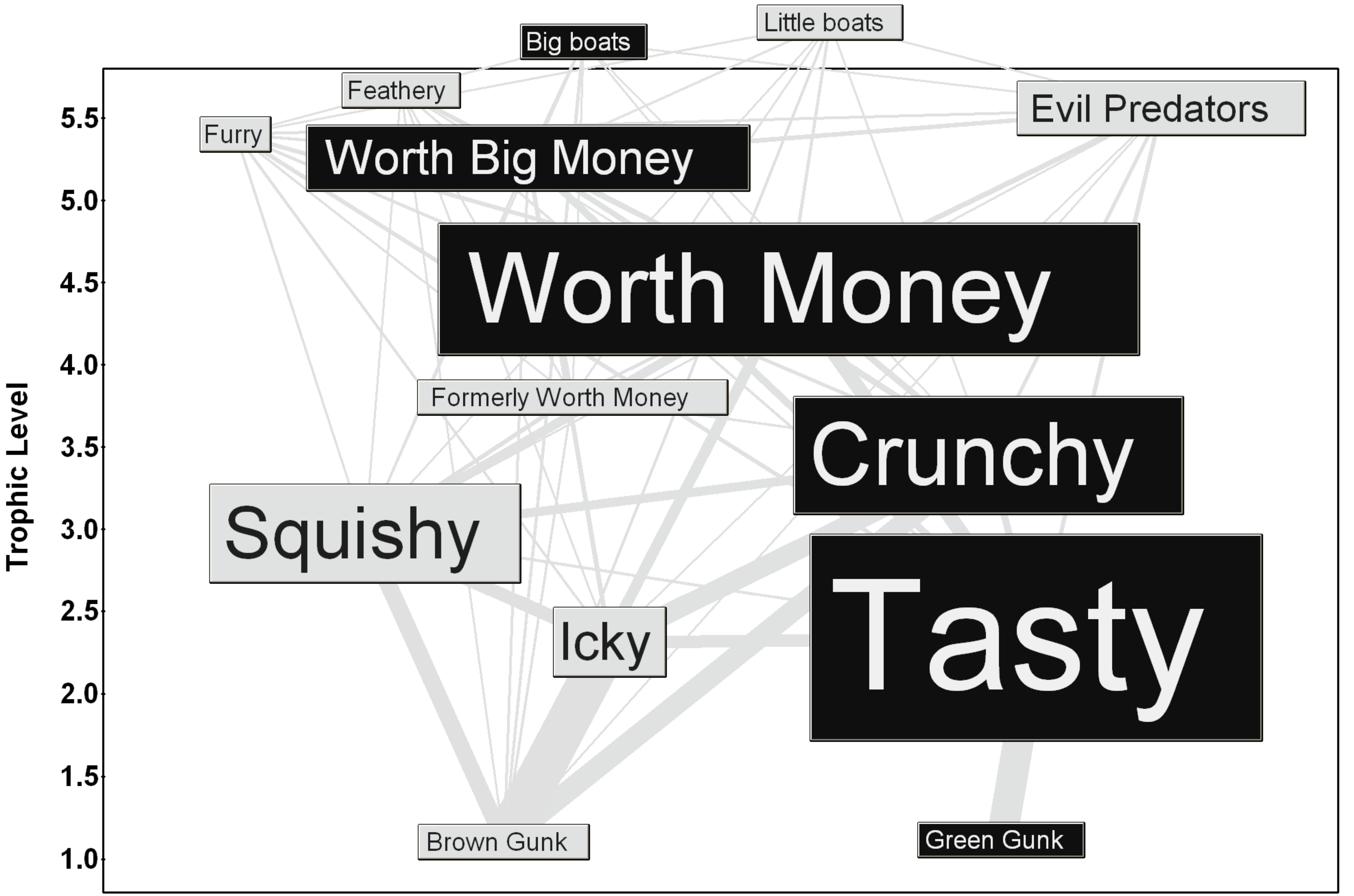
DIET:
Diet composition Highly variable Among months & Years.
Non-Crustaceans Important during Critical period in August

FOOD WEB EFFECTS

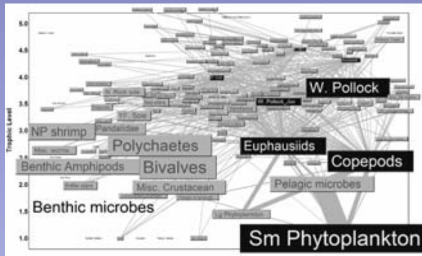


Rich biological relationships

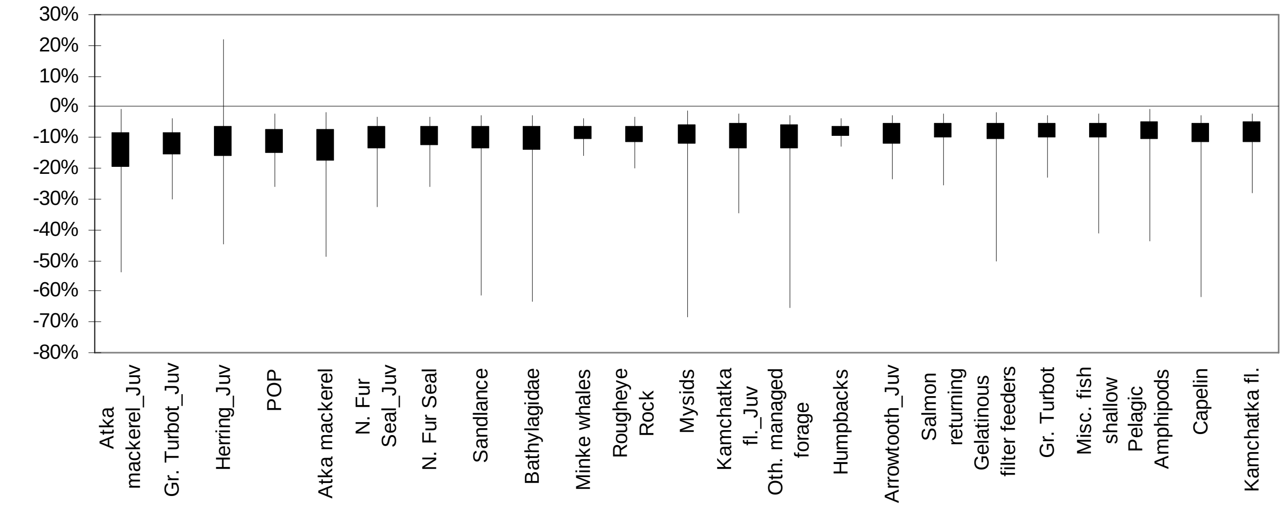
Complexity vs. management reality



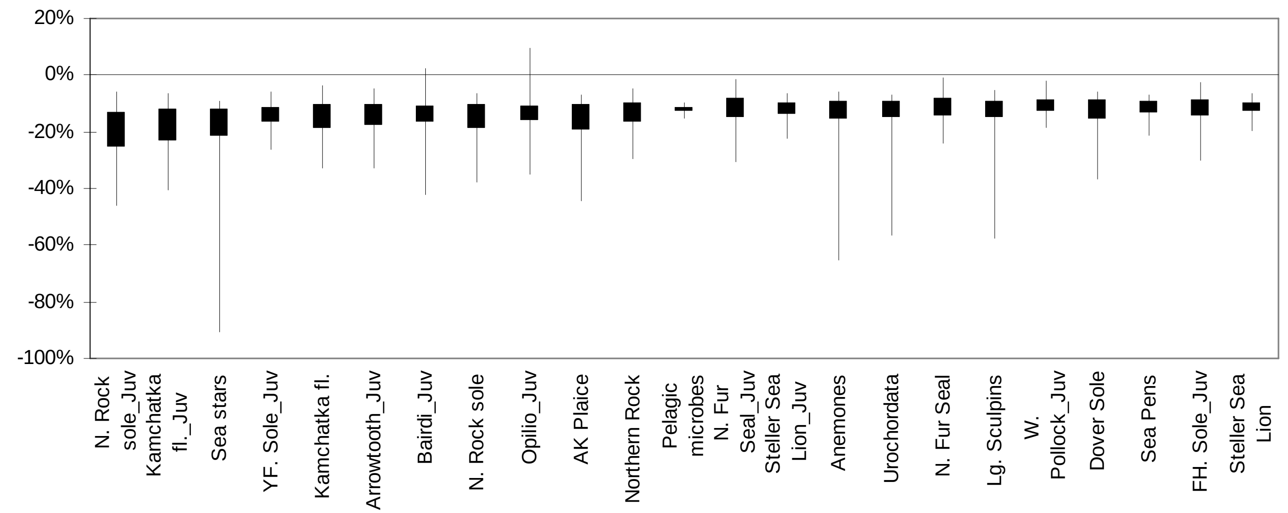
FOOD WEB EFFECTS - simulated



Decrease in large phytoplankton



Decrease in micro-phytoplankton



A key to upper trophic levels is THRESHOLD effects

- *Current data (summer-dominated) indicates that pteropods are a relatively low percentage of fish diets.*
- *HOWEVER* (for example), during fall BASIS surveys, *L. helicina* comprised up to 25% of prey wet weight for age-0 pollock in oceanic influenced waters that move through the Aleutian passes into the SE Bering Sea (L. Eisner pers. comm.).

Research Goals for Understanding Biological Impacts – Alaska Fisheries Science Center

M. Jones, NMFS

- Measure species-specific physiological responses
- Understand impacts on fish, marine mammals and seabirds
- Forecast fisheries and subsistence impacts

- Contact: Mike.Sigler@noaa.gov