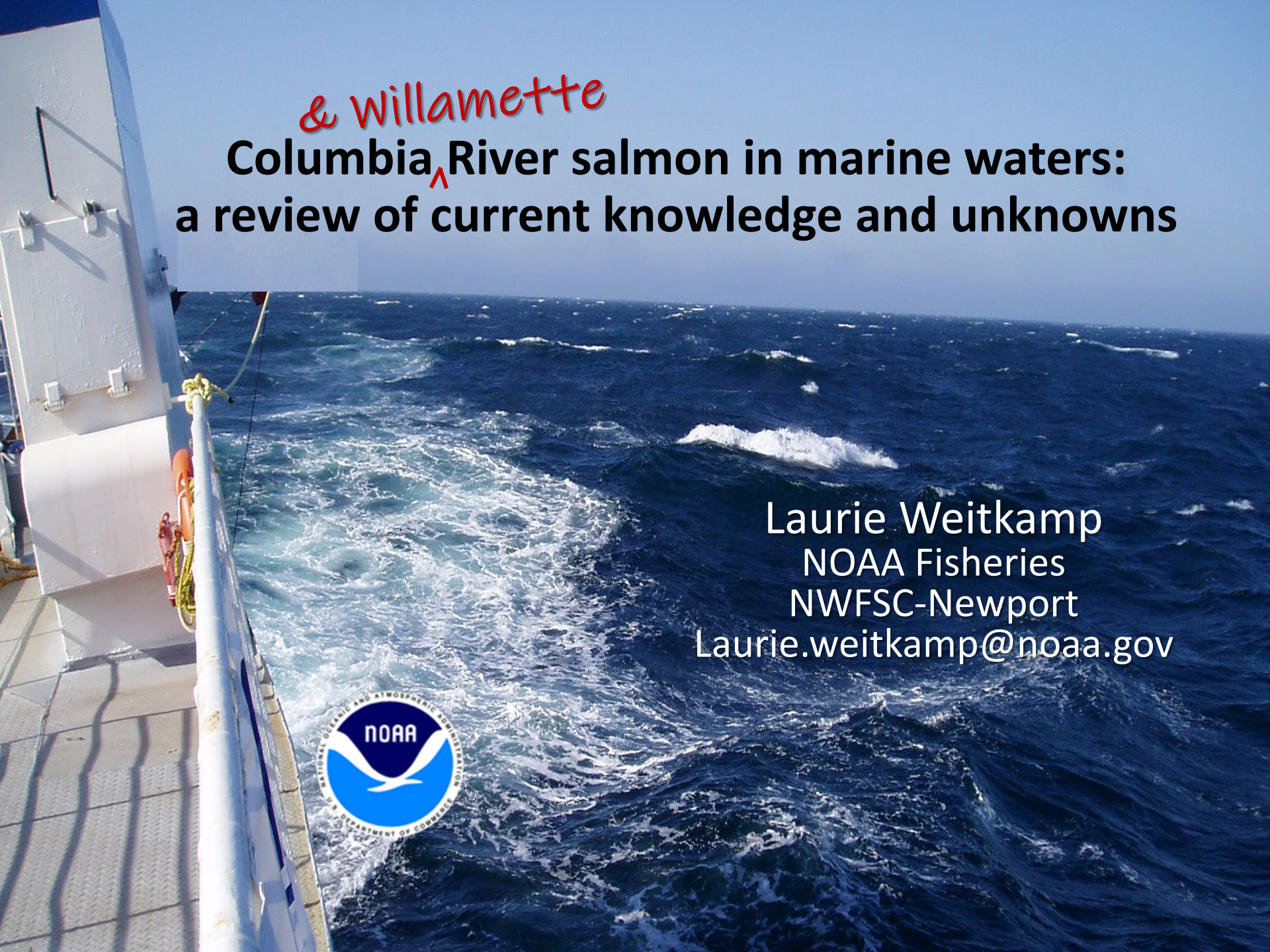

Columbia & Willamette River salmon in marine waters: a review of current knowledge and unknowns

Laurie Weitkamp
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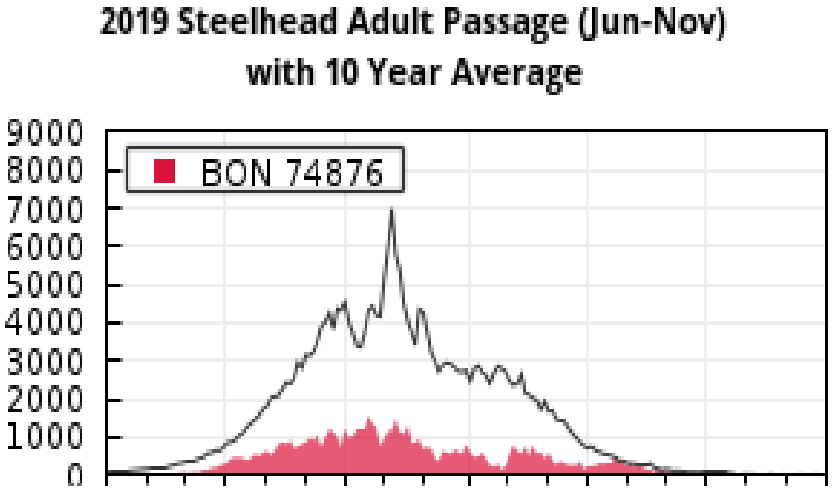
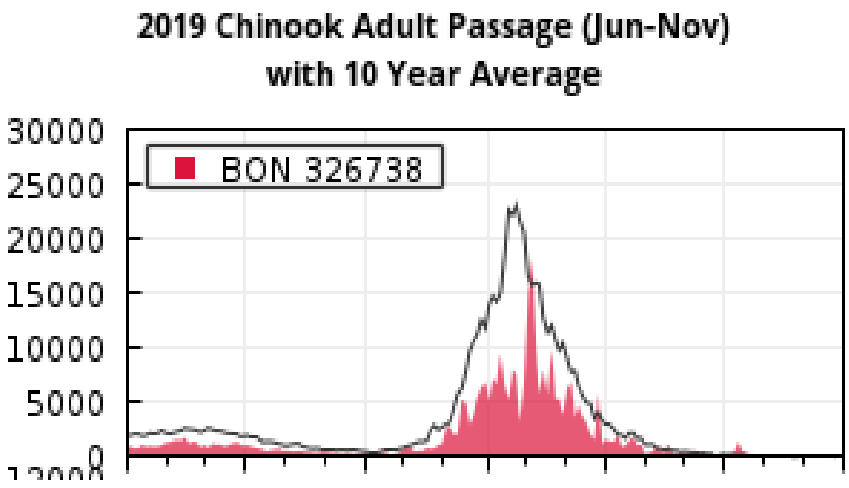
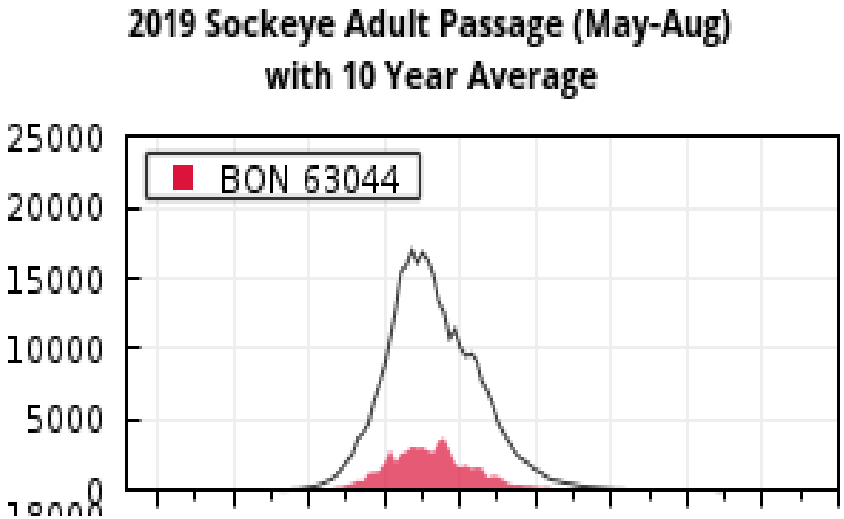
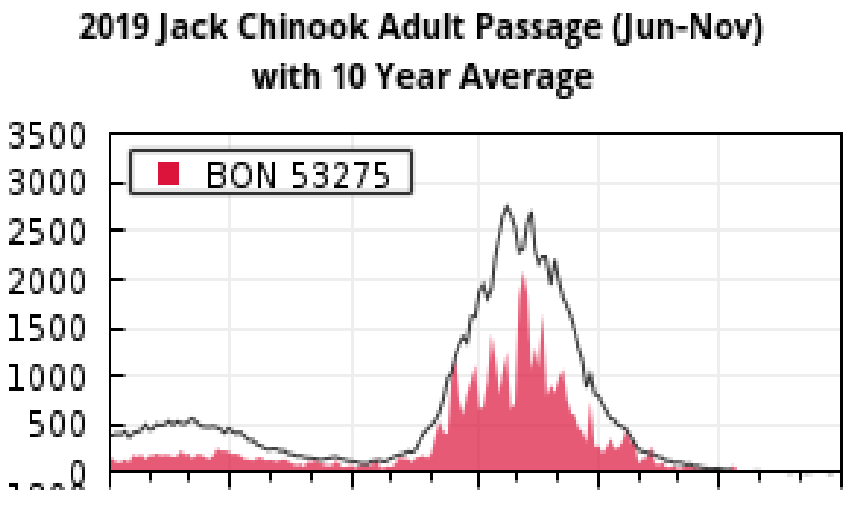
Why should you care about the ocean?





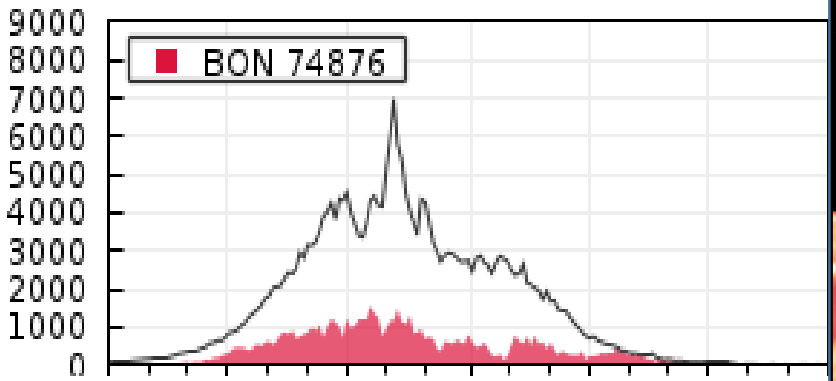




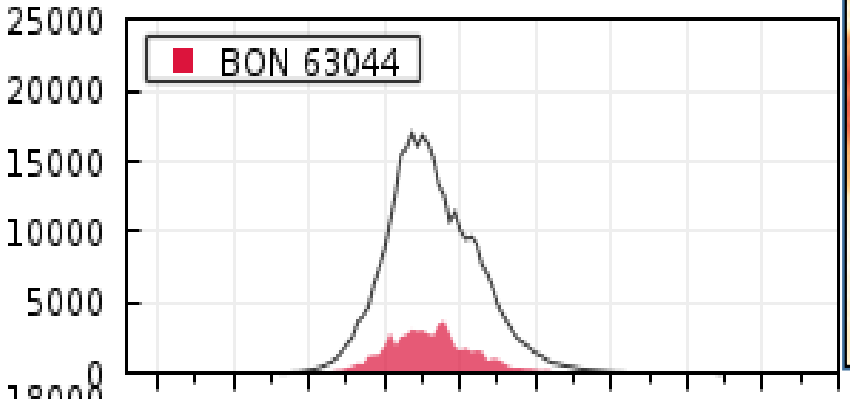
DART website

Why should you care about the ocean?

2019 Steelhead Adult Passage (Jun-Nov)
with 10 Year Average

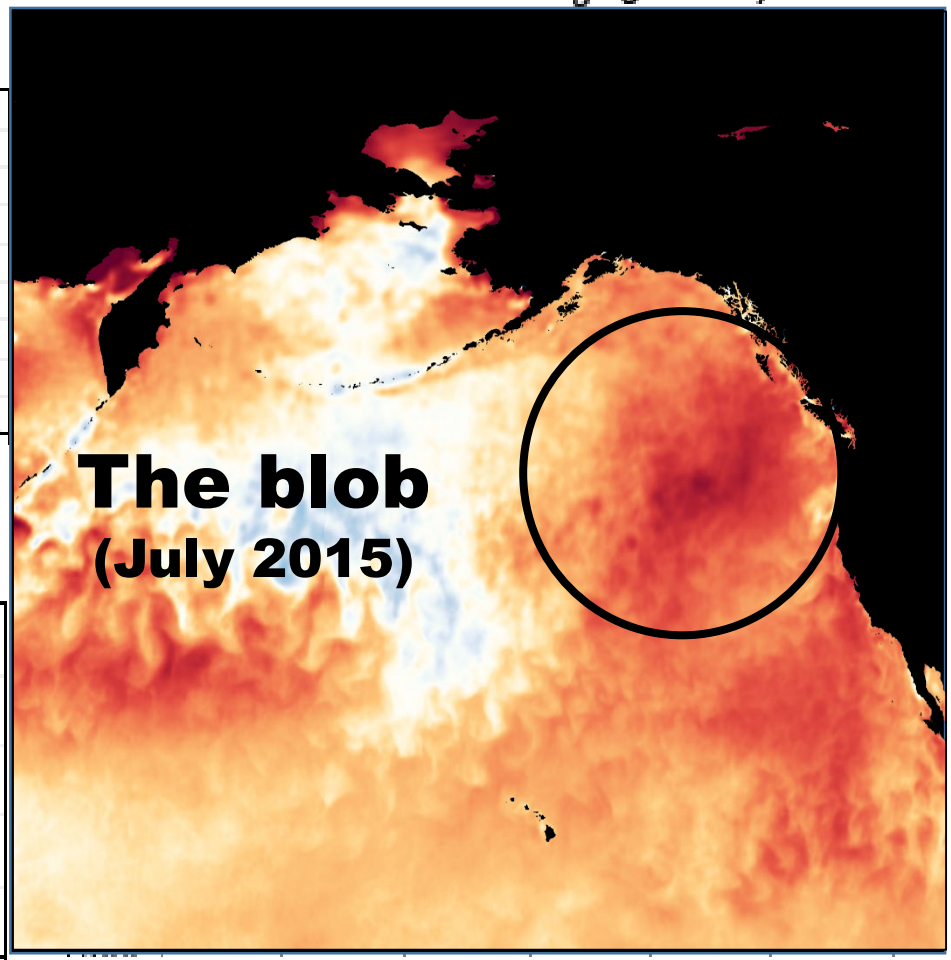


2019 Sockeye Adult Passage (May-Aug)
with 10 Year Average



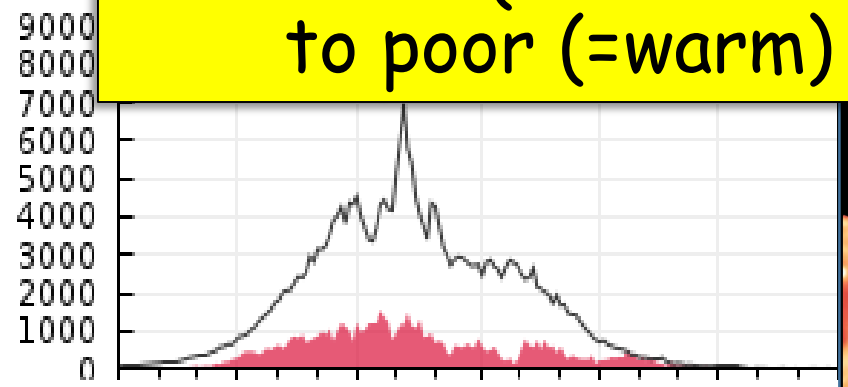
DART website

2019 Chinook Adult Passage (Jun-Nov)

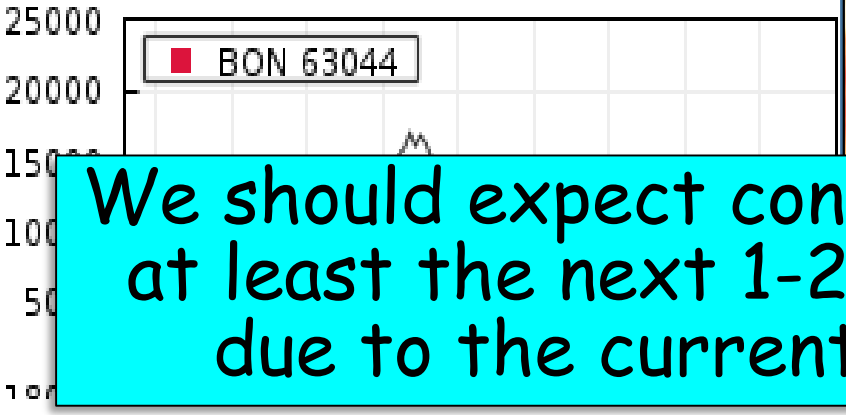


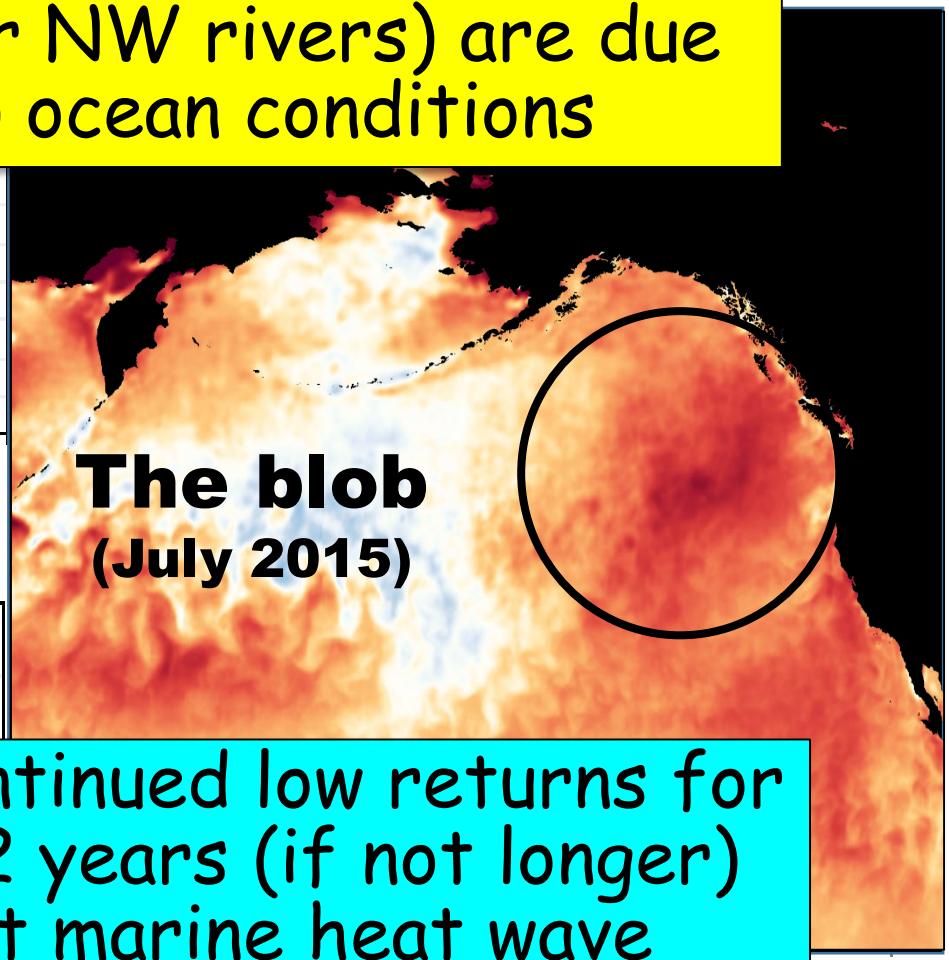
Why should you care about the ocean?

Recent dismal salmon returns to the Columbia (and other NW rivers) are due to poor (=warm) ocean conditions



2019 Sockeye Adult Passage (May-Aug)
with 10 Year Average





We should expect continued low returns for at least the next 1-2 years (if not longer) due to the current marine heat wave

DART website

Why does the marine phase matter?

Marine waters are where:

- salmon spend most of their life
- they gain most of their adult size
- adult abundance is largely determined
- each species does things differently
- we understand the least

Dedicated research around the Pacific Rim in the last 20 years has greatly increased our understanding of salmon in the ocean

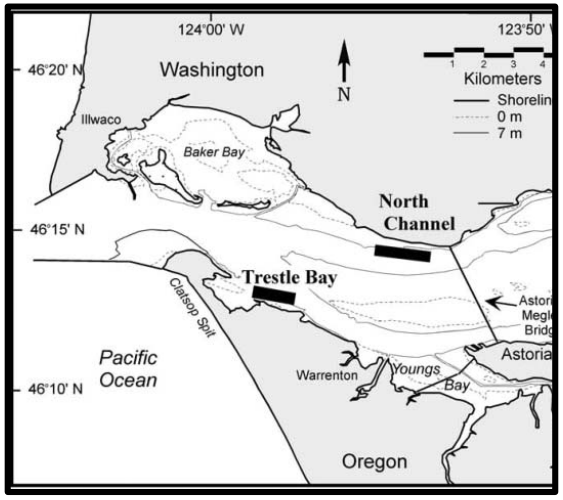
Today's talk

- What is known
  1. Marine distributions
  2. Diets
  3. Depth distributions
  4. Mechanisms influencing survival
  5. What about recent ocean conditions?
- What is not known
- Summary and conclusions

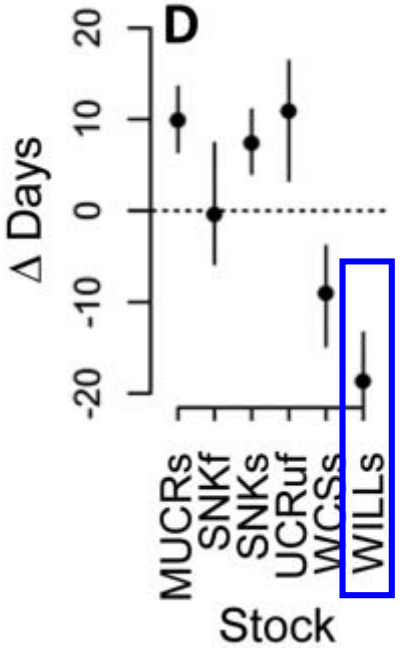
Columbia specific

Salmon in general

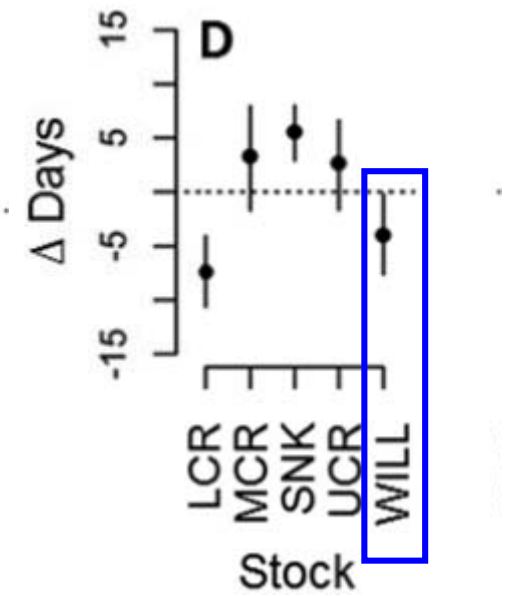
Willamette steelhead and especially Chinook enter marine waters before interior Columbia stocks (Weitkamp et al. 2015, Mar Coast Fish 7:370-392)



Yearling Chinook



Steelhead



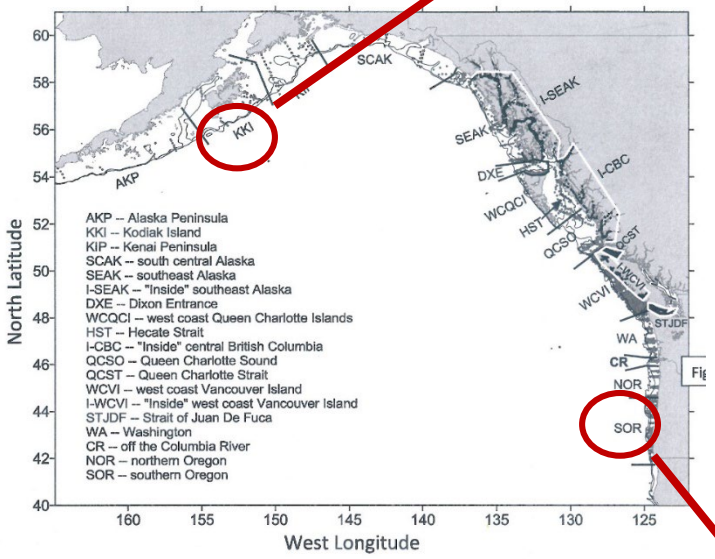
1. Distributions. First summer in the ocean: 3 patterns for Columbia River salmon

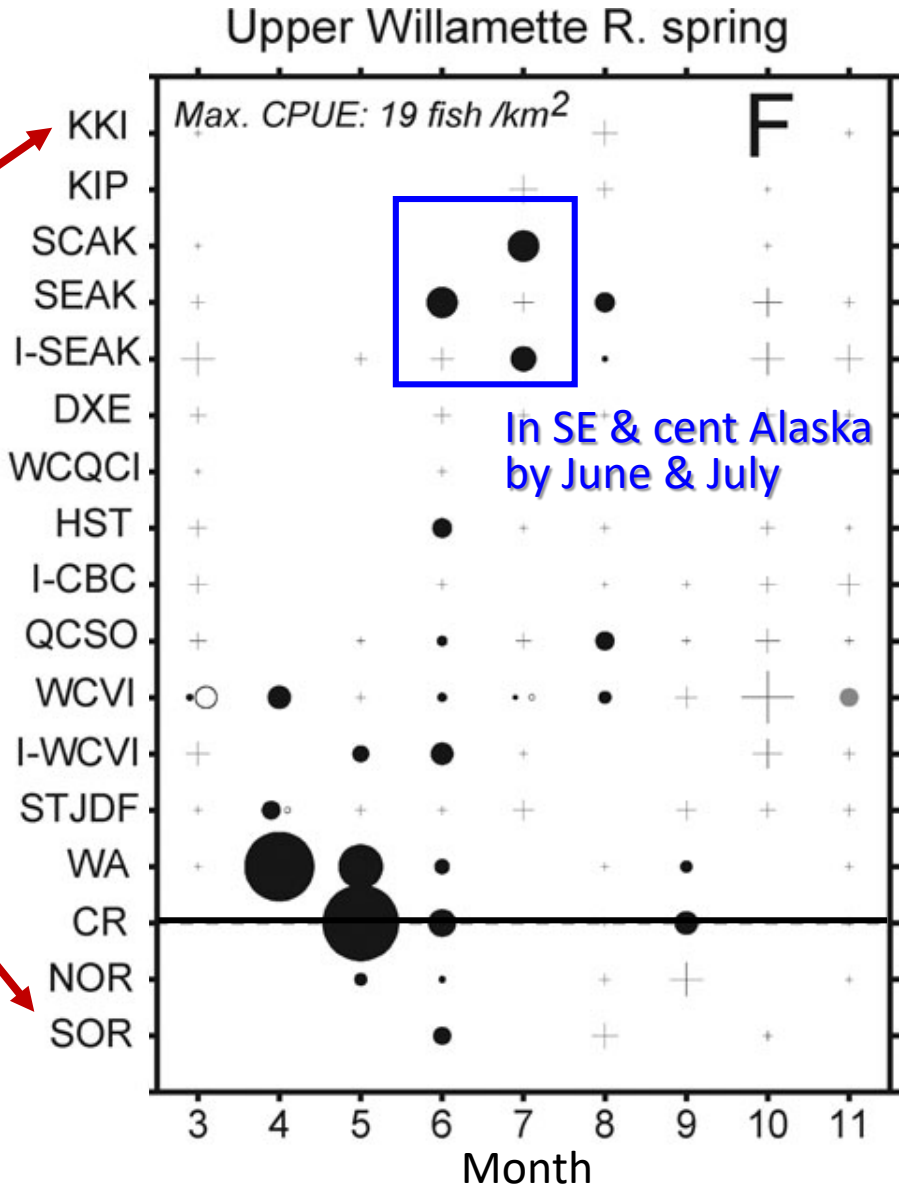
Pattern 1: Rapid north-wards movement on shelf to Gulf of Alaska

Which: Spring Chinook, chum, sockeye, some coho

This is when most marine mortality is thought to occur

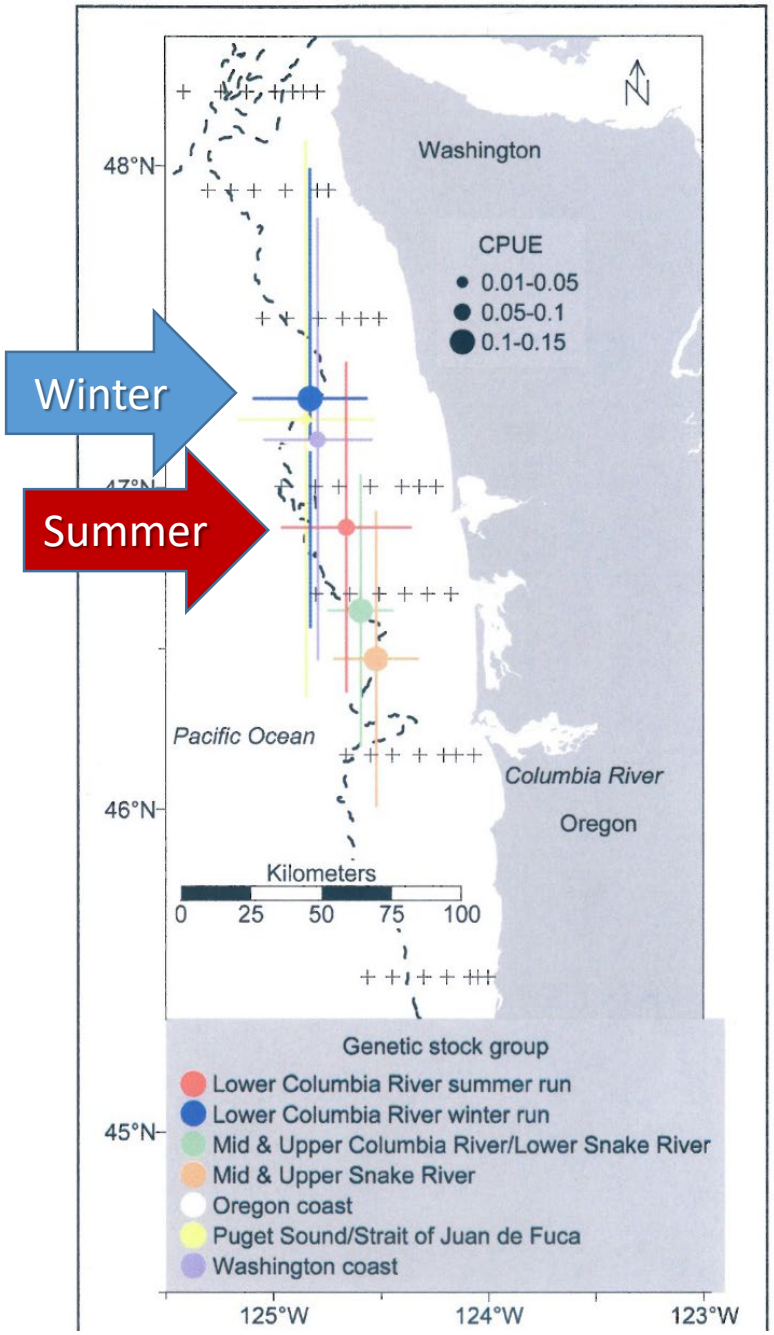
Willamette spring Chinook move rapidly northwards during 1st summer in marine waters (Fisher et al. 2014, TAFS 143:252-272)





Lower Columbia steelhead (which includes Willamette) are caught farther north than interior Columbia steelhead during late May surveys. They attribute this to earlier ocean entry.

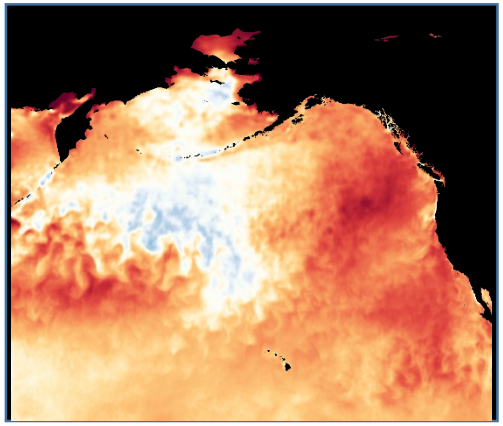
(Van Doornik et al. 2019 Fish Bull. 117:97-106)



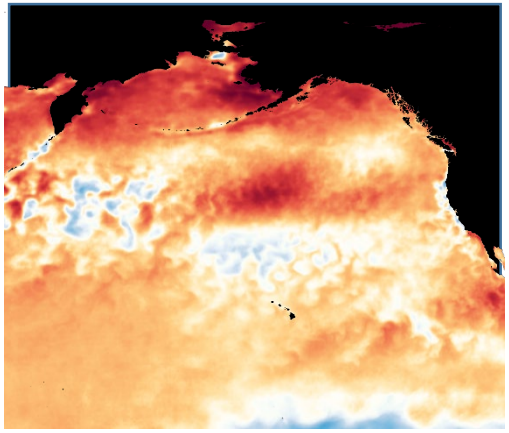
Sea surface temperature anomalies in recent Julys

(shading = monthly sea surface temperature anomalies)

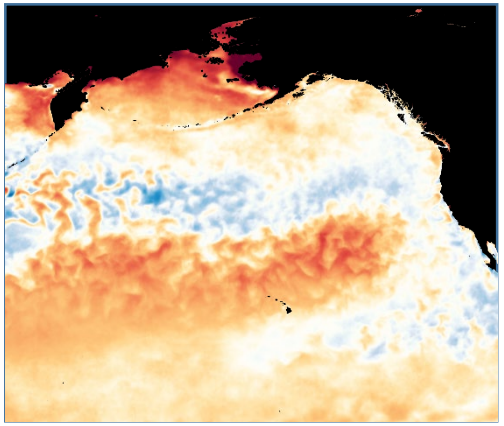
July 2015



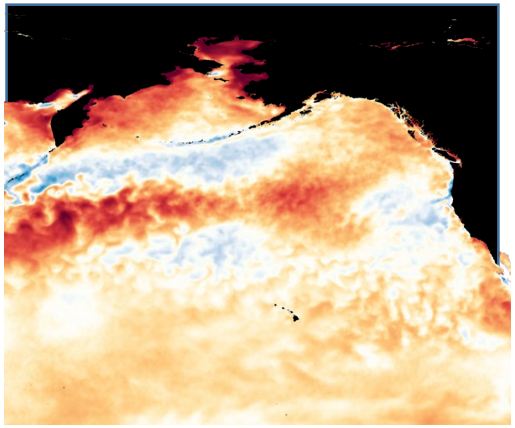
July 2016



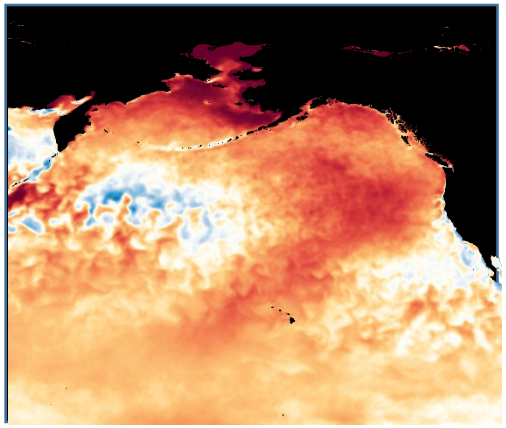
July 2017



July 2018



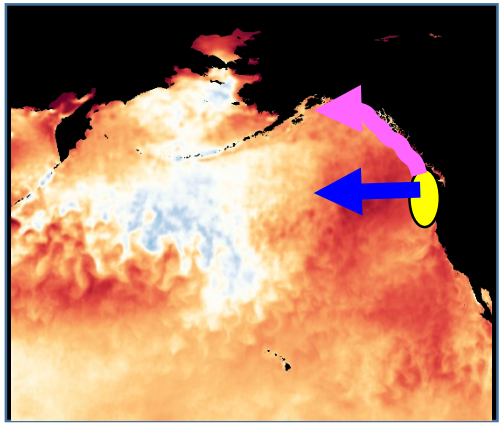
July 2019



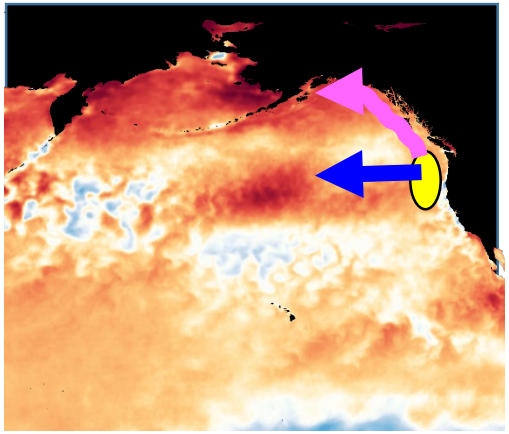
Initial ocean migrations of Columbia River salmon in recent Julys

(shading = monthly sea surface temperature anomalies)

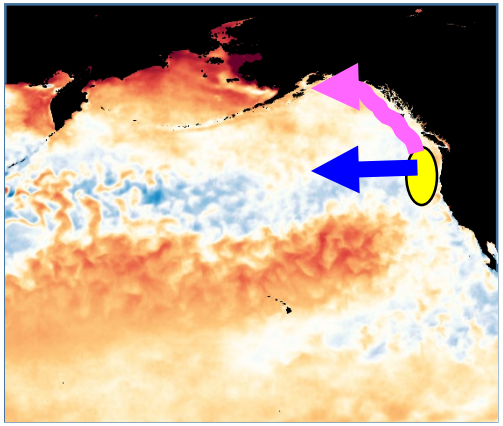
July 2015



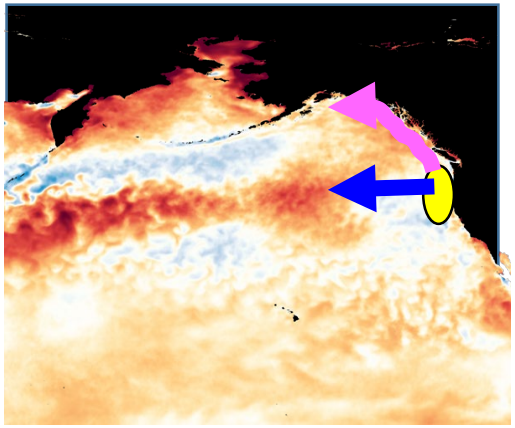
July 2016



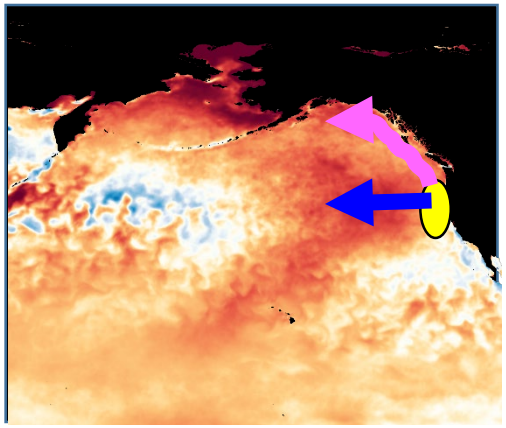
July 2017



July 2018



July 2019



Spring Chinook, sockeye

Steelhead

Fall Chinook, coho

1. Columbia River high seas distributions

We know the least about this phase (where they are, what they're doing)

1. Adults returning to the Columbia: 3 general migration patterns

Pattern 1: Southwards movement along shelf

Which: Fall Chinook, Chum (?), sockeye (?)

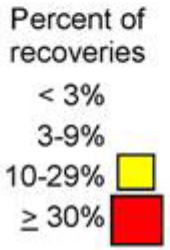
Pattern 2: Northwards along California & Oregon Coasts

Which: Coho

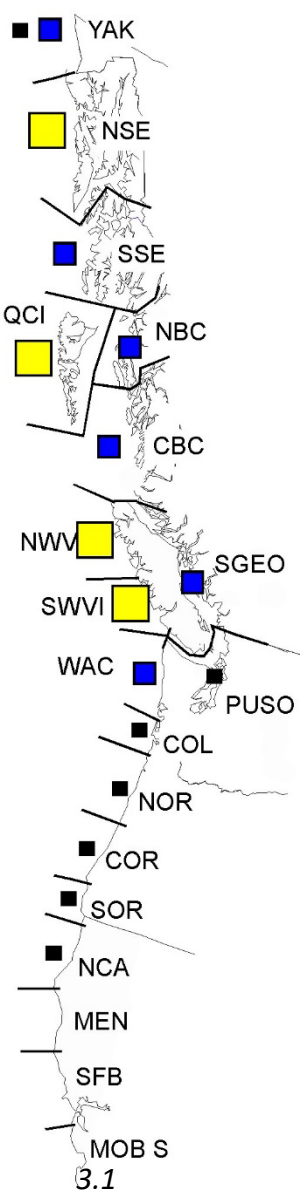
Pattern 3: Move rapidly onshore (or unknown)

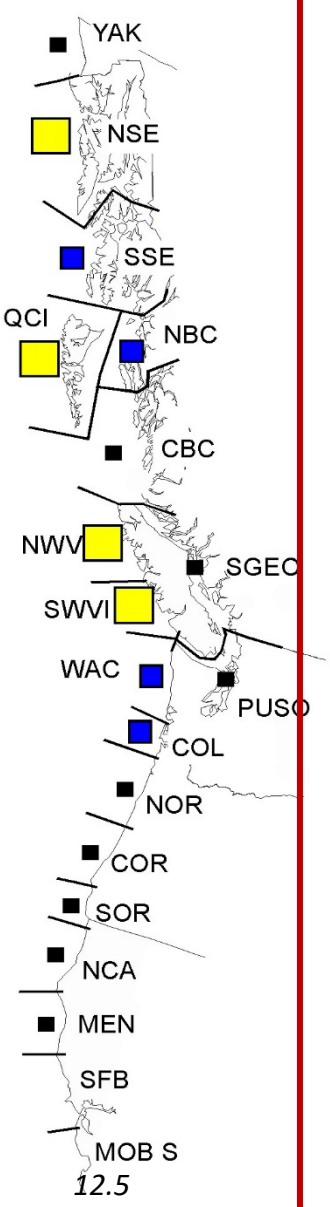
Which: Steelhead, Spring Chinook

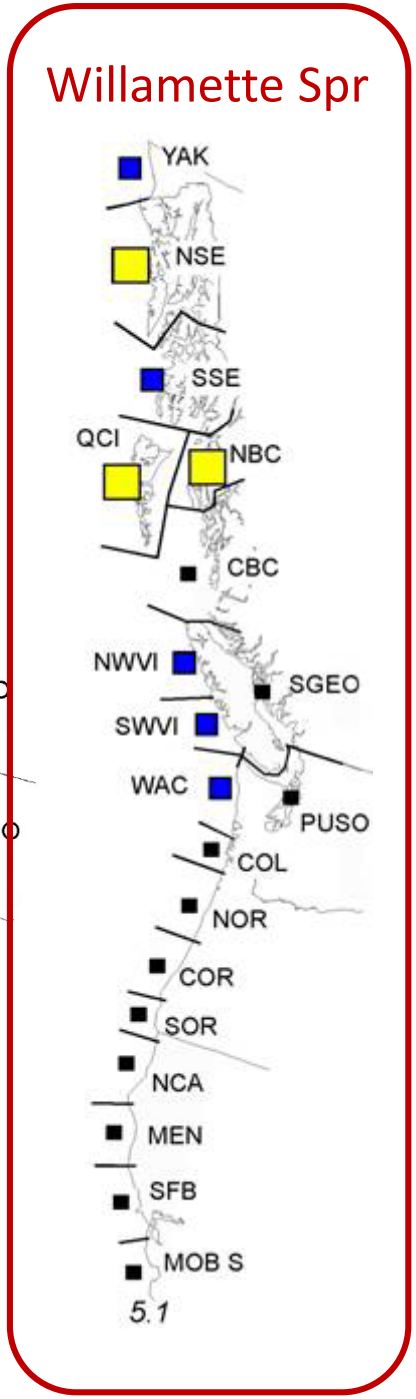
Compared to other Columbia River Chinook, Willamette adults are widely distributed in fisheries.



(Weitkamp 2010, TAFS 139:147-170).







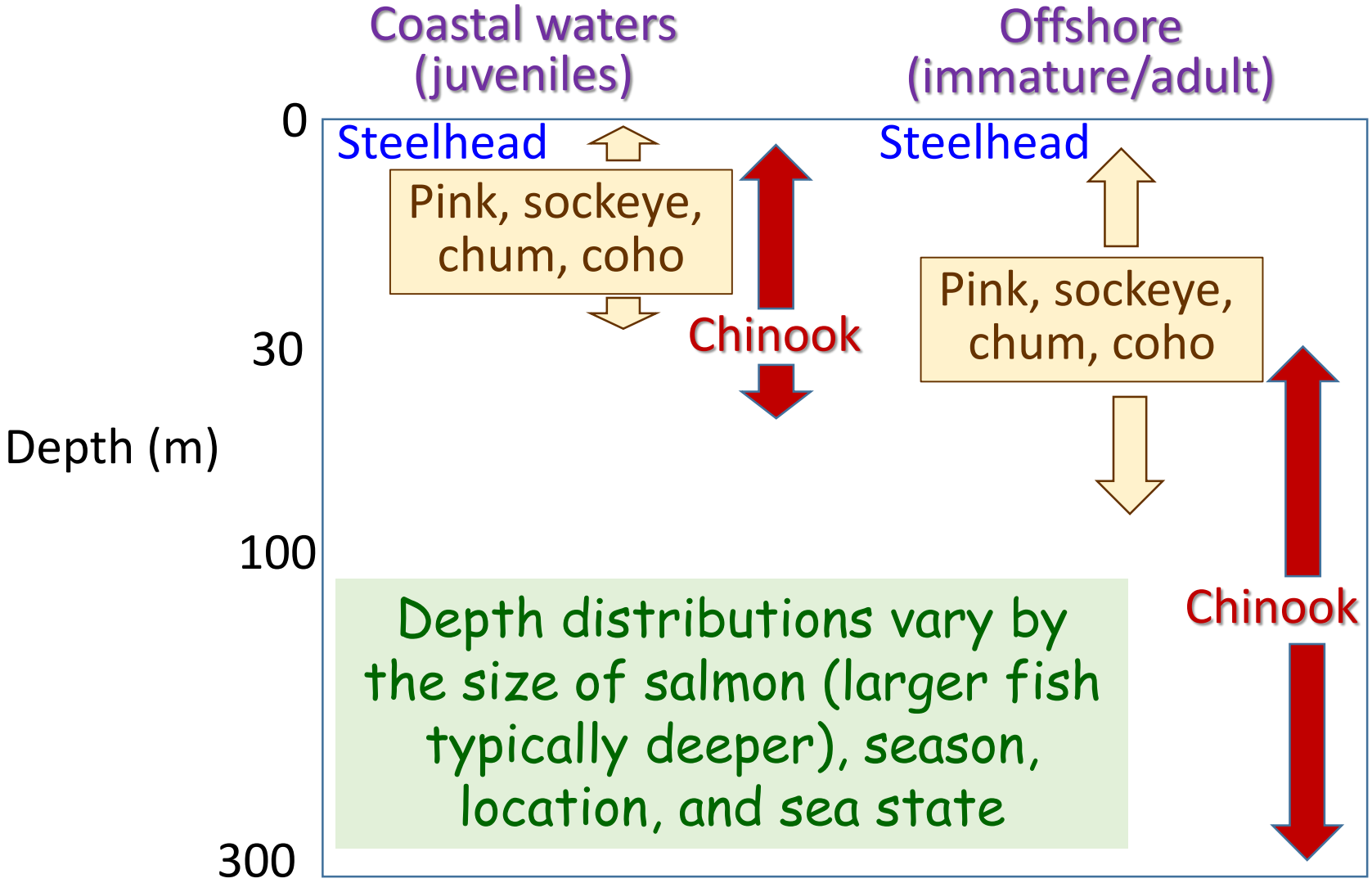
2. General salmon diets in the ocean

Chinook, coho, steelhead

Zooplankton then larger forage fish & squid

Crab larvae

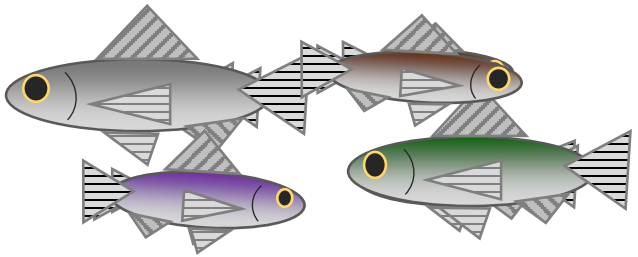
3. Salmon depth distributions



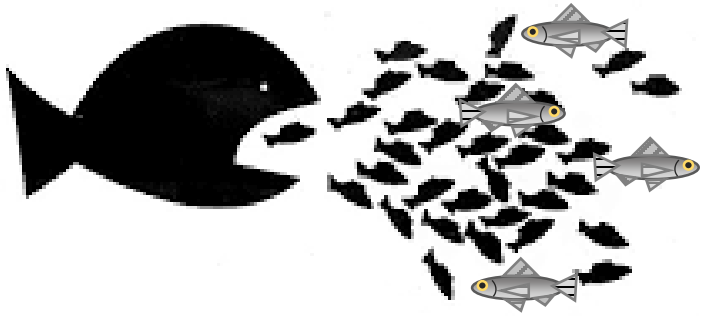
4. Mechanisms influencing survival

Two critical periods for salmon in marine waters

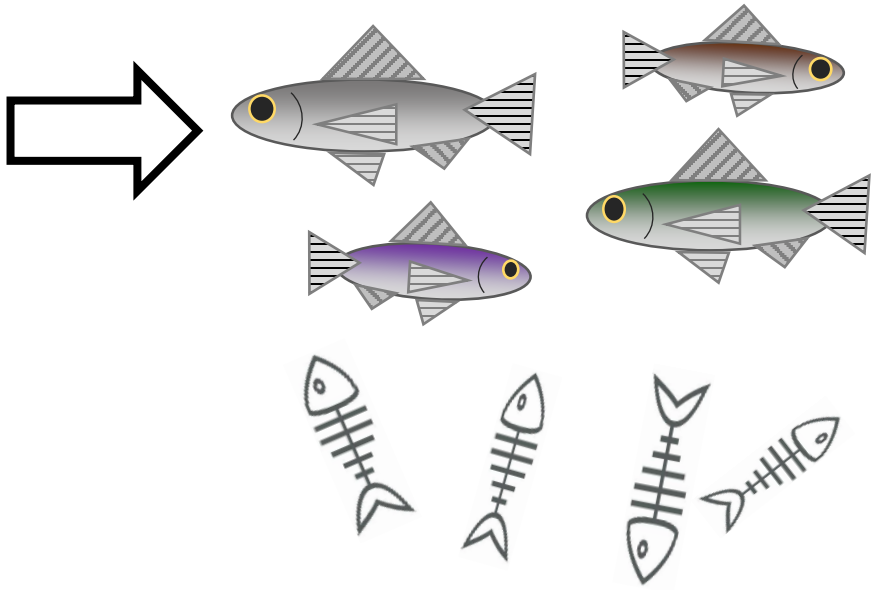
1st summer in ocean:
Rapid growth to escape predation



Lots of alternate prey helps buffer salmon from predation



1st winter in ocean:
Low food, only fish with high energy reserves survive



4. What promotes rapid growth & survival?

Salmon ocean entry year

Year

	Ecosystem Indicators	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Ocean basin	PDO (Sum Dec-March)	18	6	3	13	7	20	12	16	14	9	5	1	15	4	2	8	10	21	19	17	11
	PDO (Sum May-Sept)	10	4	6	5	11	17	16	18	12	14	2	9	7	3	1	8	19	21	20	15	13
	ONI (Average Jan-June)	20																		21	13	5
Physical	46050SST (°C; May-Sept)	16																		18	6	19
	Upper 20 m T (°C; Nov-Mar)	20																		19	18	14
	Upper 20 m T (°C; May-Sept)	17																		15	11	16
	Deep temperature (°C; May-Sept)	21																		13	17	19
	Deep salinity (May-Sept)	19																		8	6	6
Biological	Copepod richness anom. (no. species; May-Sept)	19																		21	16	12
	N. copepod biomass anom. (mg C m^{-3}; May-Sept)	19																		21	18	7
	S. copepod biomass anom. (mg C m^{-3}; May-Sept)	21	2	5	4	3	14	15	20	13	10	1	7	16	9	8	6	11	18	19	17	12
	Biologicaltransition (day of year)	18	8	5	7	9	14	13	19	12	2	1	3	16	6	10	4	11	21	21	17	15
	Ichthyoplankton biomass (mg C 1,000 m^{-3}; Jan-Mar)	21	12	3	8	10	19	18	15	17	16	2	13	5	14	11	9	20	6	7	1	4
	Ichthyoplankton community index (PCO axis 1 scores; Jan-Mar)	10	13	2	7	5	11	20	18	3	12	1	14	15	8	4	6	9	19	21	17	16
	Chinook salmon juvenile catches (no. km^{-1}; June)	19	4	5	16	8	12	17	20	11	9	1	6	7	15	3	2	10	13	18	21	14
	Coho salmon juvenile catches (no. km^{-1}; June)	19	8	13	6	7	3	16	20	17	5	4	10	11	15	18	1	12	9	14	21	2
	Mean of ranks	17.9	7.2	6.0	7.3	6.1	13.0	15.9	17.1	11.3	9.2	2.7	8.6	12.8	8.1	6.6	7.7	12.8	16.7	17.2	14.4	11.6
	Rank of the mean rank	21	5	2	6	3	15	17	19	11	10	1	9	13	8	4	7	13	18	20	16	12

Colors indicate state of indicators influencing survival:

Green good for salmon

Yellow neutral for salmon

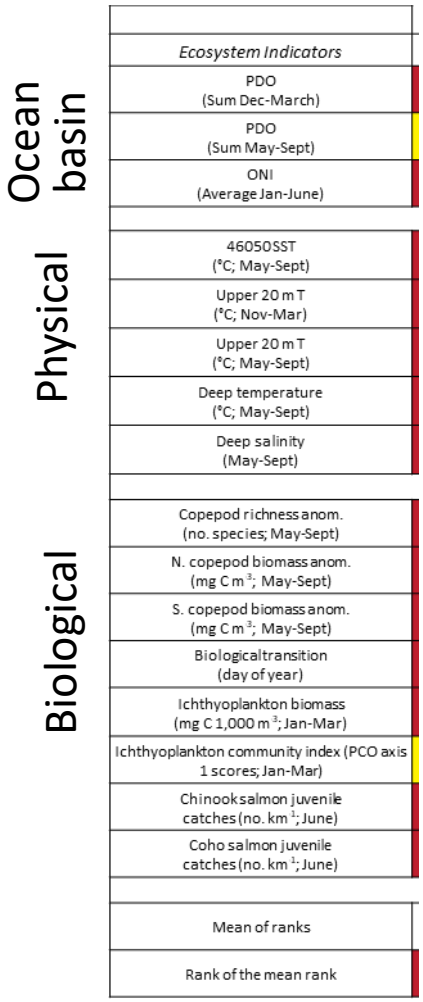
Red bad for salmon

www.nwfsc.noaa.gov/research/hottopics/salmon_forecasts.cfm

4. What promotes rapid growth & survival?

Indicators

"Good" conditions



<u>Ocean-basin scale</u>
Seasonal Pacific Decadal Oscillation (PDO)
=NE Pacific SST
El Niño index

Cold water along West Coast before/after spring outmigration, no El Niño

<u>Physical indicators</u>
Seasonal sea surface temp
Deep temps & salinity

Cold & salty water locally (off Newport, OR)

<u>Biological</u>
Copepods (zooplankton)
Ichthyolankton (=salmon food)
Juvenile salmon catches

Lots of lipid-rich copepods & good salmon prey, early onset of upwelling, **lots** of juvenile salmon in June

5. Wh… pred…eturns?

Bad for salmon

Good for salmon

Salmon ocean entry year

	Ecosystem Indicators	1998	999	2000	2001	2002	2003	2004	2005	006	200	2008	2009	2010	2011	2012	2013	014	2015	2016	2017	2018	2019
Ocean basin	PDO (Sum Dec-March)	19	6	3	13	7	21	12	17	14	9	5	1	16	4	2	8	10	22	20	18	11	15
	PDO (Sum May-Sept)	10	4	6	5	11	17	16	18	12	1	2	9	7	3	1	8	20	22	21	15	13	19
	ONI (Average Jan-June)	21	1	1	7	14	16	15	17	9	1	3	11	18	4	6	8	10	19	22	13	5	20
Physical	SST NDBC buoys (°C; May-Sept)	17	6	8	4	5	11	22	12	2	1	1	10	3	7	9	16	20	19	18	13	15	21
	Upper 20 m T (°C; Nov-Mar)	21	11	8	10	6	15	16	13	12	5	1	9	18	4	3	7	2	22	20	19	14	17
	Upper 20 m T (°C; May-Sept)	16	11	13	4	1	3	22	19	8	1	2	5	17	7	6	18	20	9	14	12	15	21
	Deep temperature (°C; May-Sept)	22	6	8	4	1	10	12	16	11	5	2	7	14	9	3	15	21	19	13	18	20	17
	Deep salinity (May-Sept)	21	3	11	4	5	18	19	12	7	1	2	16	20	15	14	13	22	17	9	8	6	10
Biological	Copepod richness anom. (no. species; May-Sept)	20	2	1	7	6	15	14	19	16	1	8	9	18	4	5	3	11	21	22	17	13	12
	N. copepod biomass anom. (mg C m^{-3}; May-Sept)	20	15	11	12	4	17	14	21	16	1	7	10	9	1	3	5	6	18	22	19	8	2
	S. copepod biomass anom. (mg C m^{-3}; May-Sept)	22	2	5	4	3	15	16	21	14	1	1	7	17	9	8	6	11	19	20	18	13	12
	Biological transition (day of year)	19	11	6	7	8	15	12	20	14	3	1	2	17	4	9	5	10	21	21	18	13	15
	Nearshore Ichthyoplankton (mg C 1,000 m^{-3}; Jan-Mar)	17	3	11	6	1	21	22	15	8	1	3	13	2	7	5	10	19	14	15	12	9	20
	Nearshore & offshore Ichthyoplankton community index (PCO axis 1 scores; Jan-M…)	11	6	5	9	8	13	16	20	1	1	3	12	15	4	2	7	10	18	21	22	17	19
	Chinook salmon juvenile catches (no. km^{-1}; June)	20	4	5	17	8	12	18	21	13	1	1	6	7	16	2	3	10	14	19	22	15	9
	Coho salmon juvenile catches (no. km^{-1}; June)	20	8	14	6	7	3	17	21	18	4	5	10	11	16	19	1	13	9	15	22	2	12
	Mean of ranks	18.5	6.2	7.3	7.4	5.9	13.9	16.4	17.6	0.9	9.	2.9	8.6	13.1	7.1	6.1	8.3	3.4	17.7	18.3	16.6	11.8	15.1
	Rank of the mean rank	22	4	6	7	2	15	17	19	11	1	1	9	13	5	3	8	14	20	21	18	12	16

www.nwfsc.noaa.gov/research/hottopics/salmon_forecasts.cfm

5. What do indicators predict for salmon returns?

Salmon ocean entry year

	Ecosystem Indicators	2014	2015	2016	2017	2018	2019
Ocean basin	PDO (Sum Dec-March)	10	22	20	18	11	15
	PDO (Sum May-Sept)	20	22	21	15	13	19
	ONI (Average Jan-June)	10	19	22	13	5	20
Physical	SST NDBC buoys (°C; May-Sept)	20	19	18	13	15	21
	Upper 20 m T (°C; Nov-Mar)	2	22	20	19	14	17
	Upper 20 m T (°C; May-Sept)	20	9	14	12	15	21
	Deep temperature (°C; May-Sept)	21	19	13	18	20	17
	Deep salinity (May-Sept)	22	17	9	8	6	10
Biological	Copepod richness anom. (no. species; May-Sept)	11	21	22	17	13	12
	N. copepod biomass anom. (mg C m^{-3}; May-Sept)	6	18	22	19	8	2
	S. copepod biomass anom. (mg C m^{-3}; May-Sept)	11	19	20	18	13	12
	Biological transition (day of year)	10	21	21	18	13	15
	Nearshore Ichthyoplankton (mg C 1,000 m^{-3}; Jan-Mar)	19	14	15	12	9	20
	Nearshore & offshore Ichthyoplankton community index (PCO axis 1 scores; Jan-Mar)	10	18	21	22	17	19
	Chinook salmon juvenile catches (no. km^{-1}; June)	10	14	19	22	15	9
	Coho salmon juvenile catches (no. km^{-1}; June)	13	9	15	22	2	12
	Mean of ranks	13.4	17.7	18.3	16.6	11.8	15.1
	Rank of the mean rank	14	20	21	18	12	16

Forecast based on ocean conditions in ocean entry year 2019:

2020: Poor returns of adult coho, some steelhead

2021: Poor returns of adult Chinook, some steelhead, sockeye

www.nwfsc.noaa.gov/research/hottopics/salmon_forecasts.cfm

Big unknowns of salmon marine ecology

- Is predation **the** major source of mortality?
  - Who are predators, when does it occur, are all fish equally vulnerable (i.e., size-selective)?
  - How does forage fish abundance and quality affect the magnitude of predation on salmon?
- What is the actual mechanism regulating survival every year and when does it occur?
- Where are salmon on the high seas, what are they doing?
  - Especially steelhead!
- Do salmon interact or compete with each other (stocks, H/W) or other species in the ocean?
- How will salmon fare with changing ocean conditions?

Summary and conclusions

- The marine phase for Pacific salmon determines the number and size of returning adults each year
  - Largely determined during 1st summer & winter in ocean
- Each species/stock uses the ocean differently, resulting in differences in marine survival
  - Where they go, what they eat, depth distributions
  - Know the least about steelhead, which have a very different ocean distribution (head straight offshore, at surface)
- Recent and current warm ocean waters have and will continue to result in poor returns of Pacific Northwest salmon
  - Returns becoming less predictable, more variable
- Salmon managers need to rethink actions as ocean conditions continue to be unfavorable
  - Allowable fisheries impacts
  - Rules on broodstock collection for hatcheries
  - Consider captive broodstocks for critically low stocks?


Questions?