Ocean Conditions, Salmon, and Climate Change

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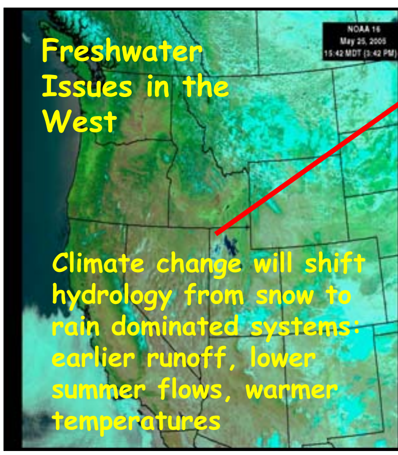
Topics

- Effects of climate change in freshwater on salmon
- Effects of climate change in the ocean on salmon
- Life-cycle modeling (tying it all together)
- Ocean acidification
- Recommendations……



Freshwater Issues in the West

Climate change will shift hydrology from snow to rain dominated systems: earlier runoff, lower summer flows, warmer temperatures

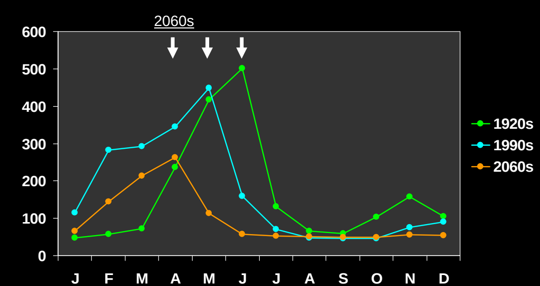
Today: > 30 salmon stocks listed under ESA

Future:

1. Human population growth

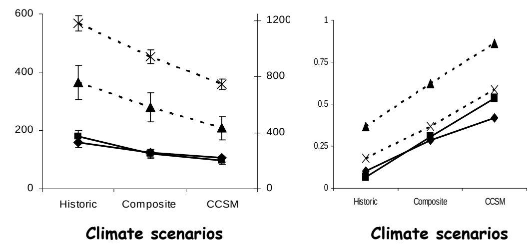
2. Increased demand for water, power resources

Runoff regimes are shifting: Spring runoff will be less and earlier

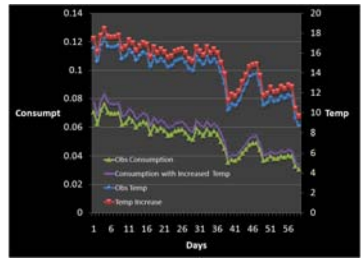


Effects of future (IPCC) climate scenarios: Salmon River Idaho

1. Salmon abundance decreases: **2. Extinction risk increases:**



Responses are not linear - how will increasing temperatures affect fish consumption?



With a 1 degree C increase in air temperature, juvenile Chinook salmon consumption rates increase by 9%. With climate change, Chinook feeding will need to increase in an already food limited system.

Chittaro, P., K. Haught, B. Sanderson and R. Zabel

Key management questions

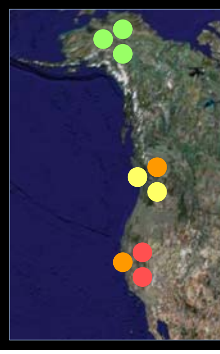
- Where should we invest in salmon protection across their range?
- Do climate change predictions alter restoration plans?
- What restoration strategies can increase salmon resilience to climate change?

So which populations are sensitive?

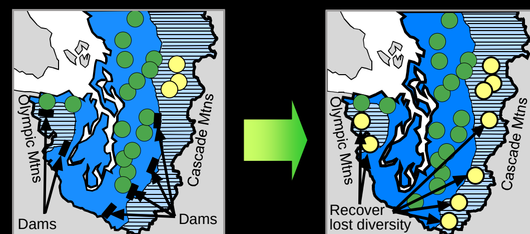
North: mostly better

PNW: some better, some worse

South: mostly worse



Restore access to diverse habitats



Rainfall/transitional hydrologic regime

Ocean-type Chinook population

Snowmelt hydrologic regime

Stream-type Chinook population

Waples et al. 2008

Do climate change predictions alter restoration plans?

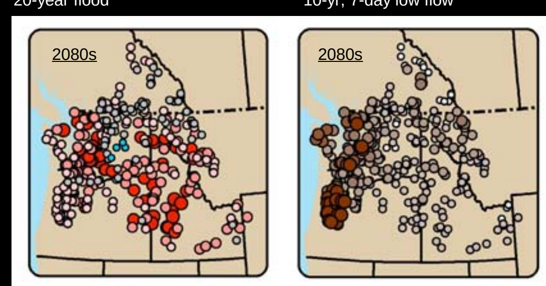
What will climate change do here?

How will restoration actions respond to those changes?

Predicted change in extreme flows

20-year flood

10-yr, 7-day low flow



>50% increase in flow

<50% of current flow

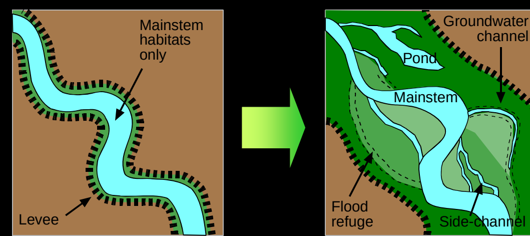
Tohver and Hamlet 2010

Restoration techniques and climate change

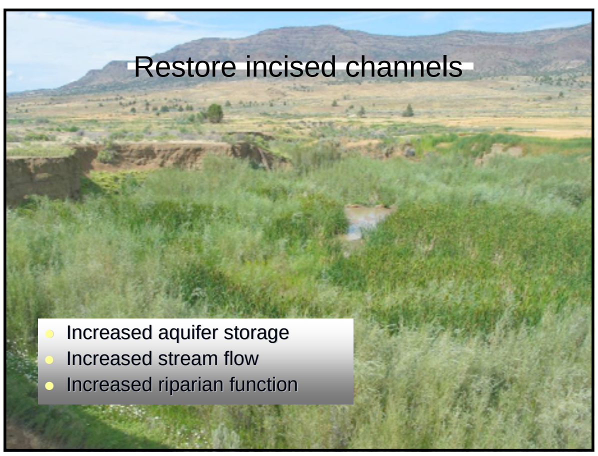
Restoration technique	Does technique ameliorate climate change effect?		
	Temperature increase	Low flow decrease	Peak flow increase
Road rehabilitation	N	N	N/Y
Riparian rehabilitation	Y	N/Y	N
Floodplain connectivity	Y	N	Y
Restore in-stream flow	Y	Y	N
In-stream habitat	N	N	N
Nutrient enrichment	N	N	N
Restore incised channel	Y	Y	Y

Summary table by Jen Greene

Increase habitat diversity



Waples et al. 2008



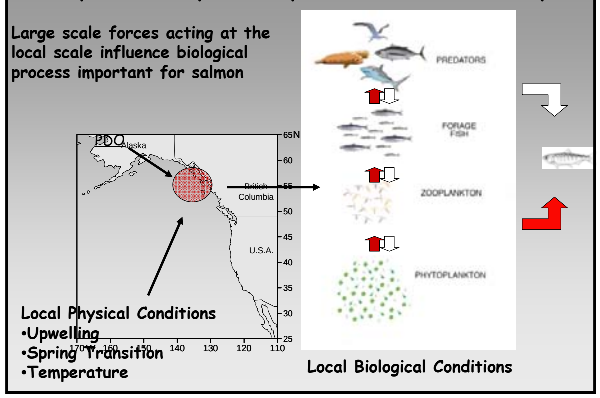
Summary

- Salmon vulnerability to climate change
  - Most severe in the south, getting better northward
- Does climate change alter restoration plans?
  - Depends on where you are
  - Depends on what you're trying to do
- Restoration strategies to increase resilience
  - Increase habitat diversity
  - Restore flow regimes

2. Ocean productivity sets salmon recruitment into adult life stages

- Return rates can vary >10x with similar freshwater conditions/survival
- Trends displayed at multiple scales:
  - Annual
  - Decadal
  - 60-100 years
  - Millennia

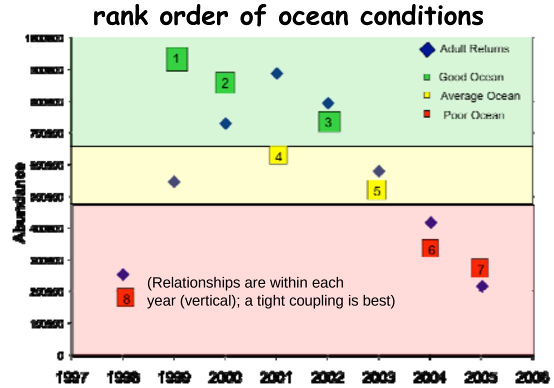
We have developed a suite of physical and biological indices to predict ecosystem response to climate variability



Environmental Variables	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
PDO (December-March)	11	4	2	8	5	12	7	10	9	6	3	1
PDO (May-September)	9	2	3	4	6	11	10	12	8	7	1	5
MEI Annual	12	1	3	5	11	10	8	9	6	4	2	7
MEI Jan-June	12	2	3	5	8	10	7	11	4	9	1	6
SST at 46050 (May-Sept)	10	8	3	4	1	6	12	9	5	11	2	7
SST at NH 05 (May-Sept)	8	2	1	4	6	7	12	11	5	9	3	10
SST winter before going to sea	12	7	5	6	4	8	11	10	9	3	1	2
Physical Spring Trans (Logerwell)	8	7	2	1	4	10	9	12	10	3	6	5
Upwelling (Apr-May)	7	1	11	3	6	10	9	12	7	2	4	5
Deep Temperature at NH 05	12	5	6	3	1	8	9	10	11	4	2	7
Deep Salinity at NH05	12	5	6	4	3	10	11	8	7	1	2	9
Length of upwelling season	7	3	2	10	1	11	9	12	6	5	8	4
Copepod richness	12	2	1	5	3	9	8	11	10	6	4	7
N.Copepod Anomaly	12	9	3	6	2	10	7	11	8	5	1	4
Biological Transition	11	5	4	7	6	10	8	12	9	2	1	3
Copepod Community structure	12	3	4	6	1	8	9	11	10	7	2	5
Catches of salmon in surveys												
June-Chinook Catches	11	2	3	9	6	8	10	12	7	5	1	4
Sept-Coho Catches	9	2	1	4	3	5	10	11	7	8	6	12
Mean of Ranks of Environmental D	10.4	3.9	3.5	5.2	4.3	9.1	9.2	10.8	7.7	5.4	2.8	5.7
RANK of the mean rank	11	3	2	5	4	9	10	12	8	6	1	7

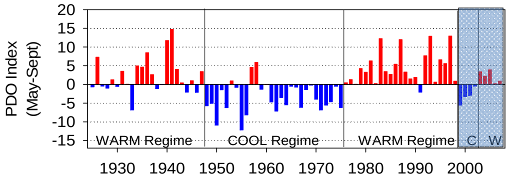
"Stop-light" figure summarizing ocean indicators over the past 12 years. Based on rank order we predict adult salmon returns 1-2 years into future.

Returns of Columbia River fall Chinook vs. rank order of ocean conditions



Variability may be increasing?

(PDO: May-Sep Average, 1925-2007)

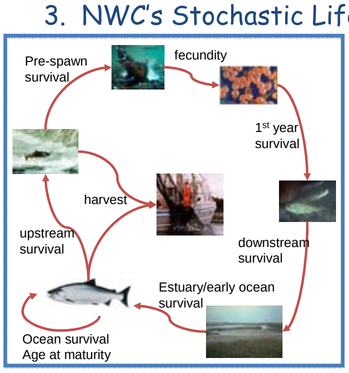


- We have had two shifts of four years duration recently: 1999-2002 and 2003-2006.
- Is this the future?

How do we use this information?

- View FW actions in context of marine ecosystem variability & integrate with marine productivity:
  - Adjust flow, hatchery release timing to match marine productivity
  - Scale hatchery production to marine productivity
- Increase salmon population diversity and complexity to buffer effects of climate change (including estuary habitat)

3. NWC's Stochastic Life-Cycle Model

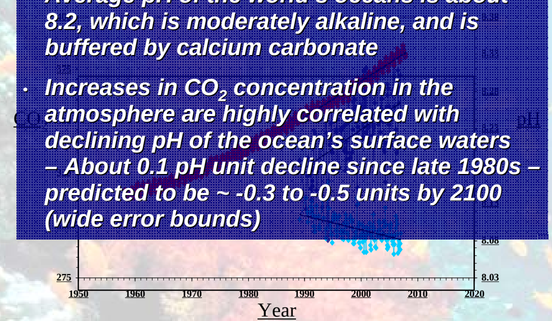


Future directions under the FCRPS BiOp Adaptive Management Implementation Plan (AMIP):

- Additional populations
- Enhanced climate modeling
- Spatial connectivity and correlation among populations
- Dam breaching scenarios
- Hatchery impacts
- Near-term population forecasts
- Inter-specific interactions
- Effects of habitat actions
- Life history diversity

4. Ocean Acidification: Global Warming's *Evil Twin*

- *Average pH of the world's oceans is about 8.2, which is moderately alkaline, and is buffered by calcium carbonate*
- *Increases in CO_2 concentration in the atmosphere are highly correlated with declining pH of the ocean's surface waters – About 0.1 pH unit decline since late 1980s – predicted to be ~ -0.3 to -0.5 units by 2100 (wide error bounds)*



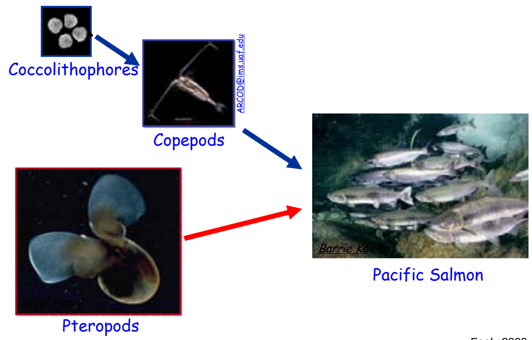
Adapted from Feely 2009

Concern for Many Marine Organisms and Ecosystems

- Reduced calcification rates
- Significant shift in key nutrient and trace element speciation
- Shift in phytoplankton diversity
- Reduced growth, production and life span of adults, juveniles & larvae
- Reduced tolerance to other environmental fluctuations
- Changes to fitness and survival
- Changes to species biogeography
- Changes to key biogeochemical cycles
- Changes to food webs
- Changes to ecosystem & their services
- Uncertainities great – research required

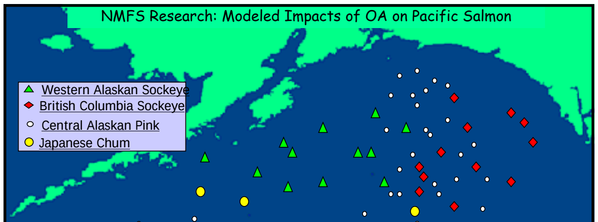
Feely 2009

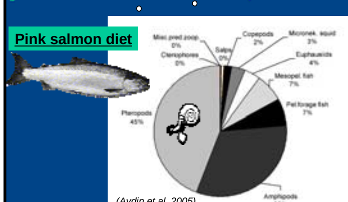
Potential Effects on Open Ocean Food Webs



Feely 2009

NMFS Research: Modeled Impacts of OA on Pacific Salmon





(Aydin et al. 2005)

Predicted effect of climate change on pink salmon growth:

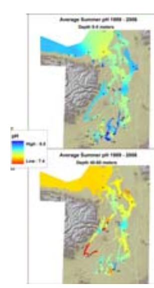
•10% increase in water temperature leads to 3% drop in mature salmon body weight (physiological effect).

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

Feely 2009

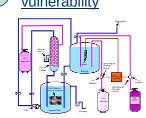
NMFS Research: Predicting ecological effects of OA

1 Patterns of acidification

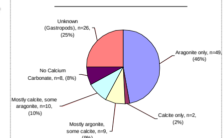


e.g. Puget Sound pH maps

2 Estimating species vulnerability

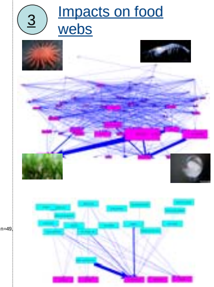


e.g. Treatment experiments



e.g. Survey of mineralogy of Puget Sound mollusks

3 Impacts on food webs



e.g. Complete and bivalve-centric Puget Sound food webs

Collaboration topics to consider…

- Designing specific habitat restoration strategies?
- Are there key populations we need to protect?
- Snake River spring/summer Chinook – how do we recover stocks in wilderness in the face of climate change?
- Klamath, Rogue, Umpqua – do we treat these rivers as refugia for recolonization?
- Can the rate of climate change swamp phenotypic plasticity?