Climate Effects and Oregon Coast Coho Salmon:
A multi-ecosystem approach

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Outline

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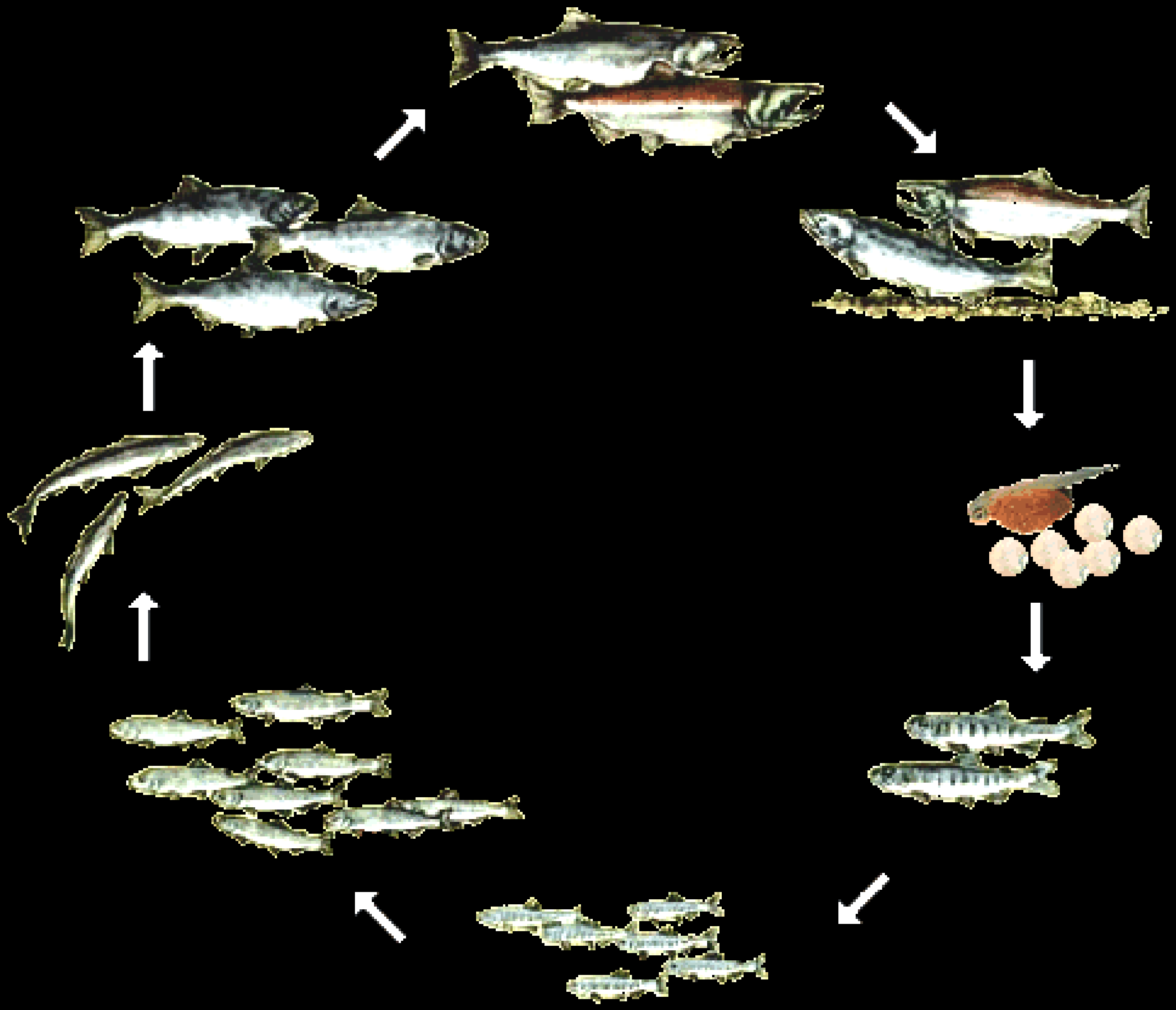
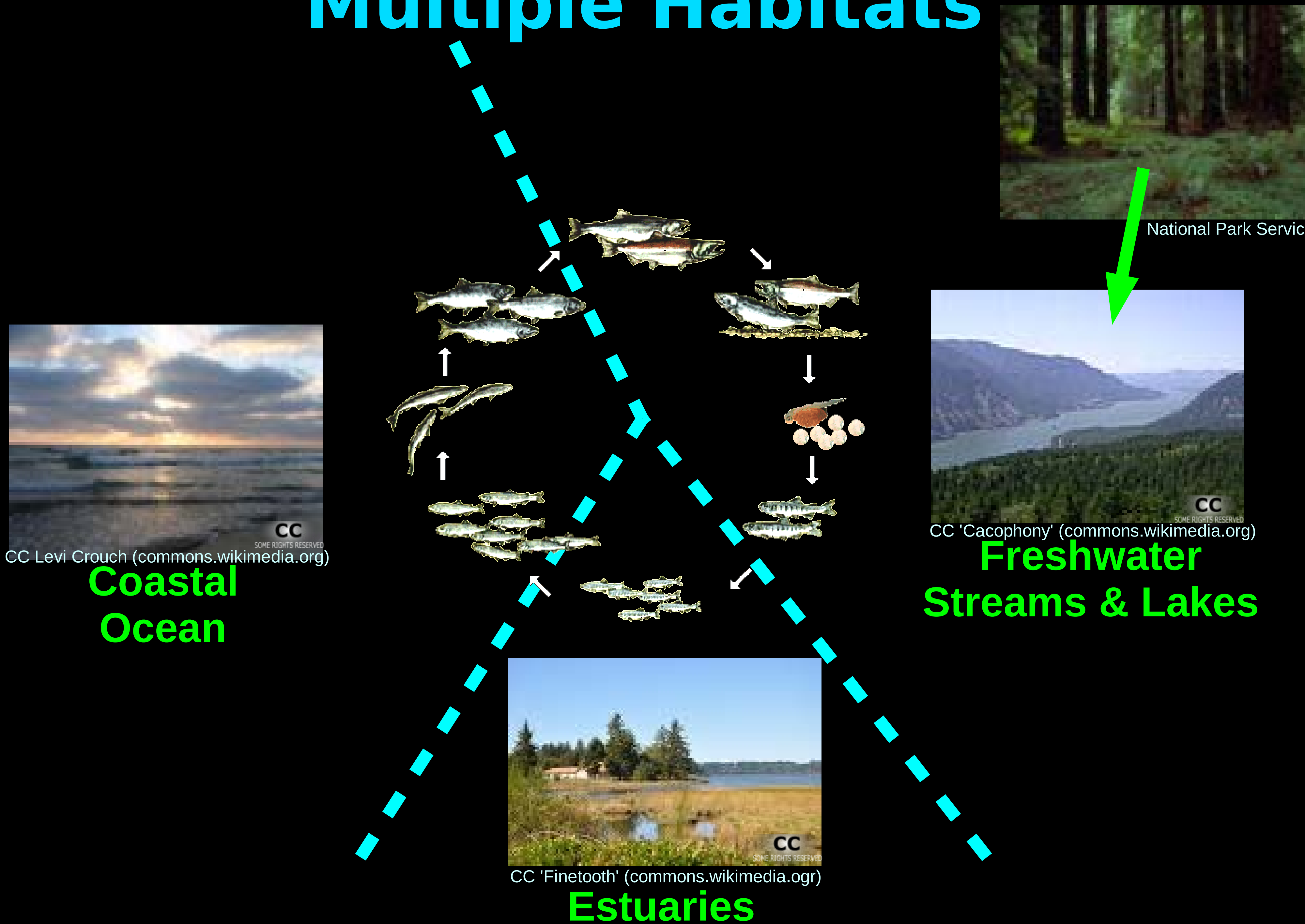
  - Salmon Life Cycle & Habitats
  - Oregon Coast Coho Salmon
- Climate Links to Salmon
  - Primary Links
  - Pathways
- Predicting Effects
  - Approach
  - Results
    - Physical/Chemical Pathways
    - Effects on Salmon
- Conclusions

Salmon Life Cycle

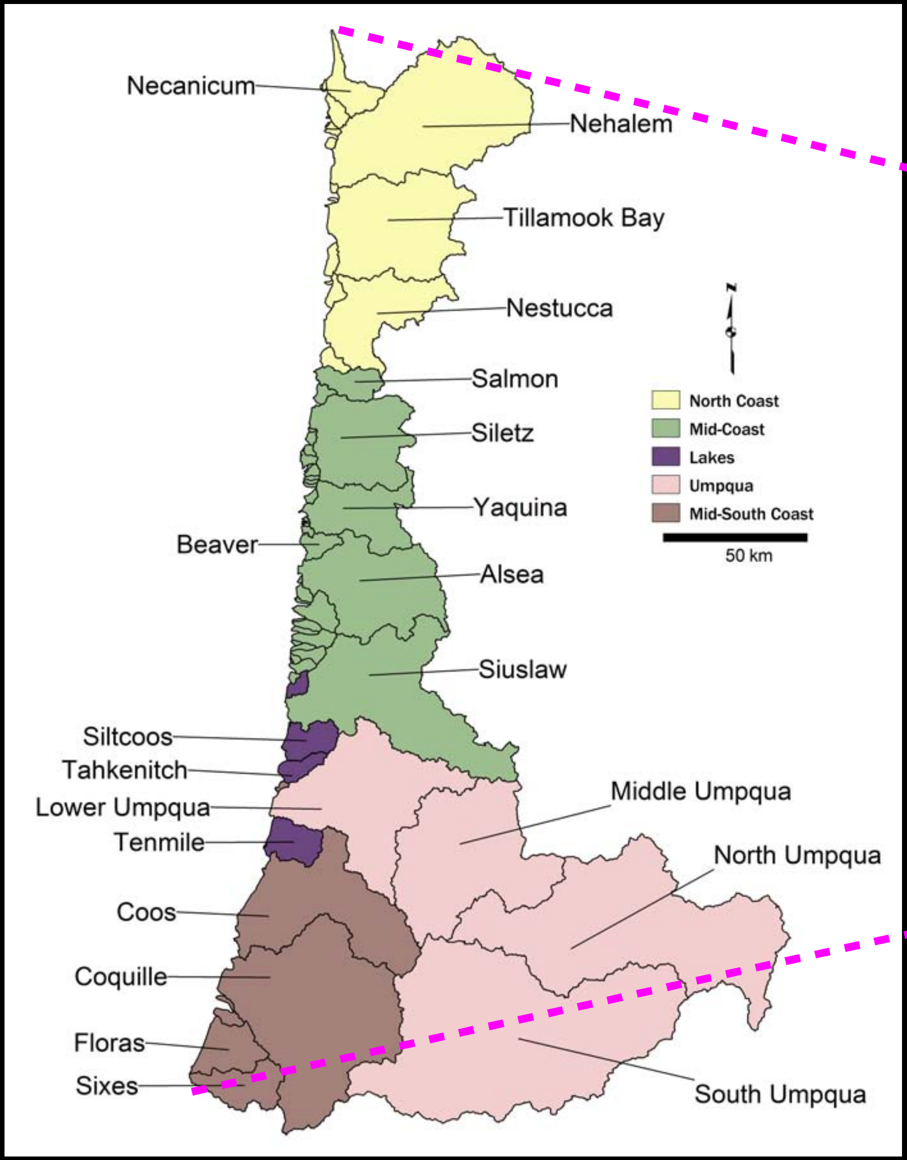


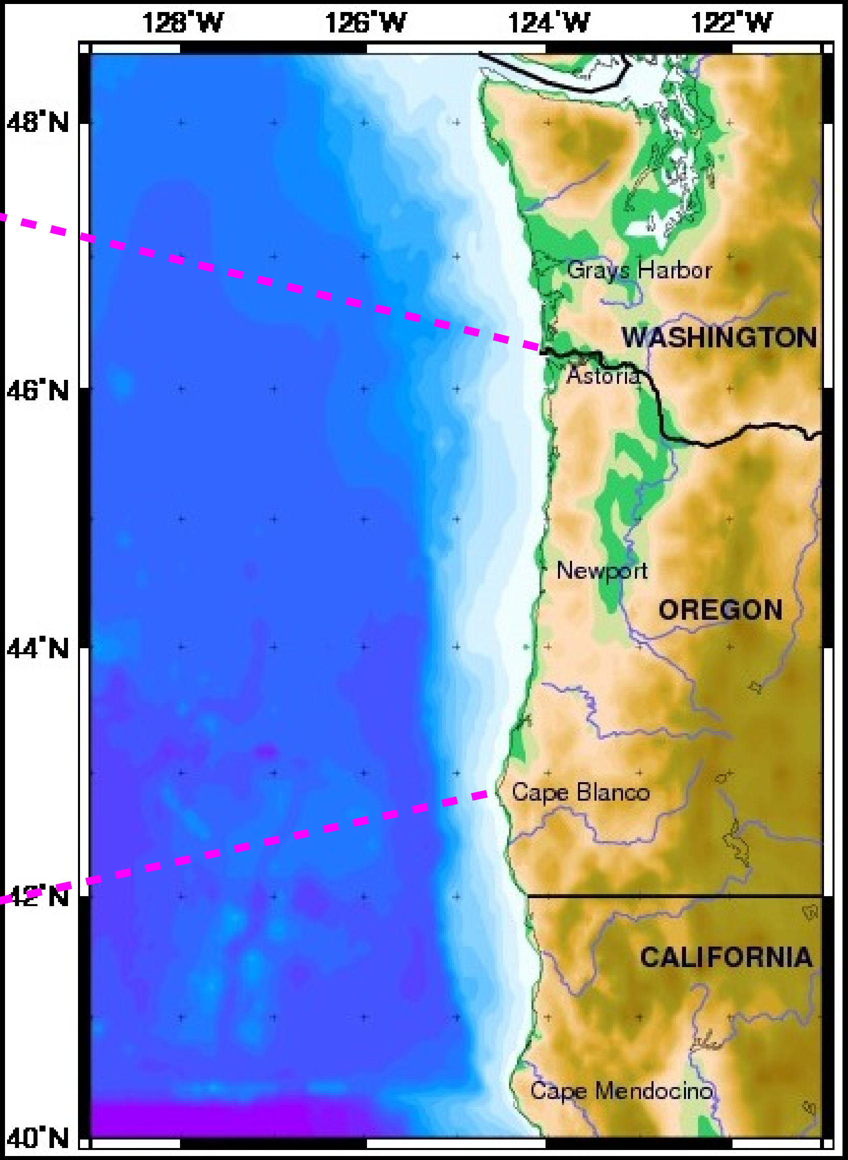
modified from Capital Region District, BC (www.crd.bc.ca)

Multiple Habitats

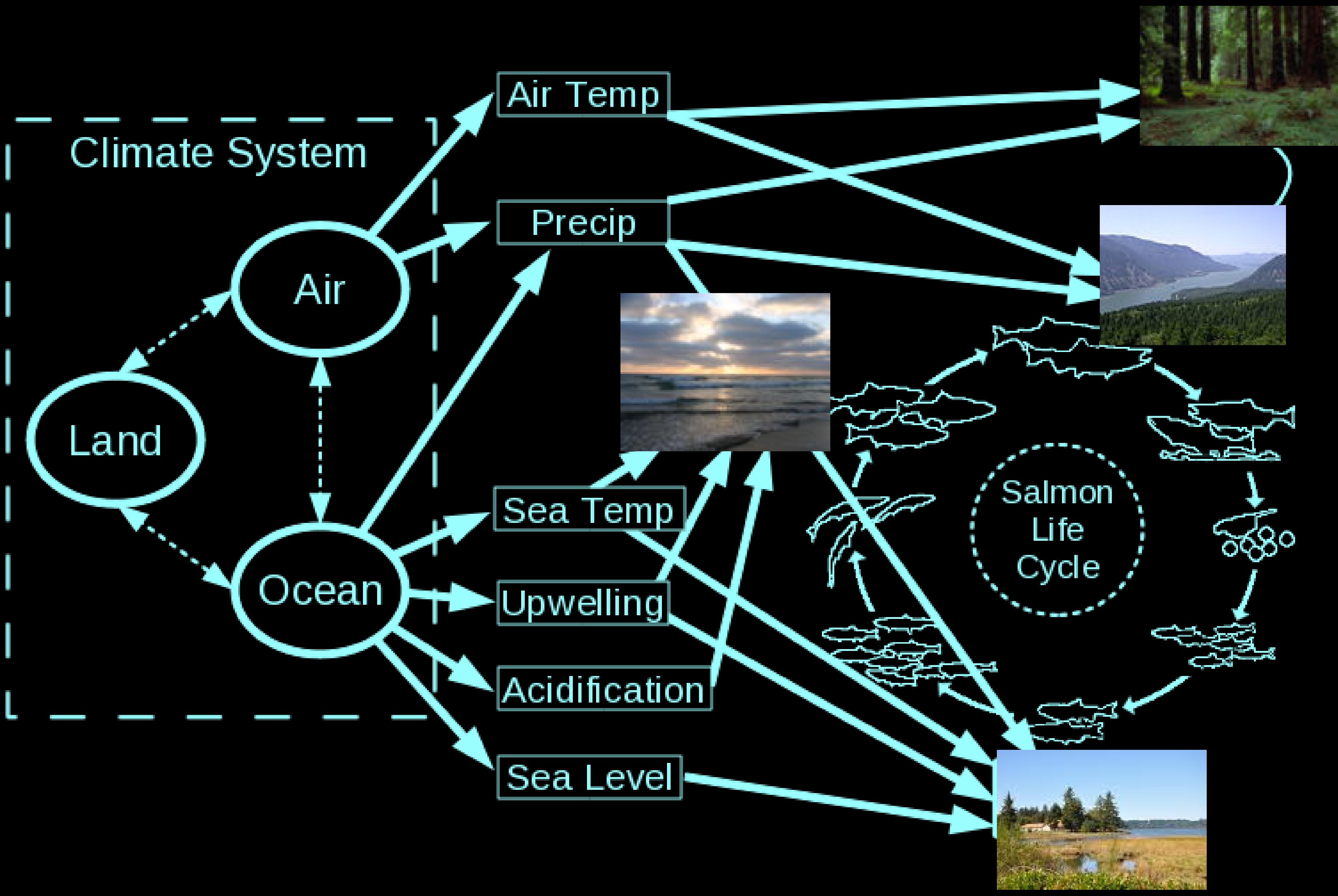


Oregon Coast Coho (OCC)





Climate Links to Salmon



Complexities

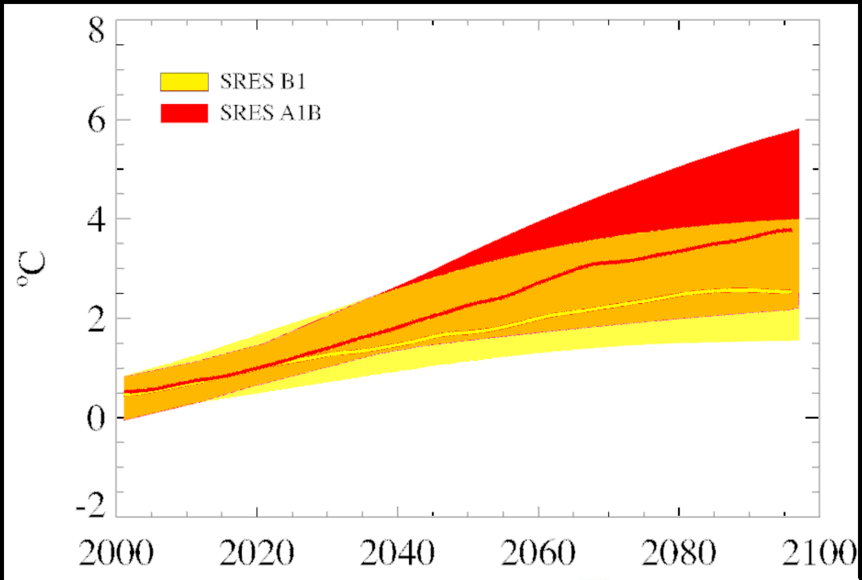
- Salmon integrate conditions across systems
  - Terrestrial, Freshwater, Estuarine, Marine
- Multiple pathways connect physical climate to salmon population dynamics
- Connections vary in importance depending on system state
  - Typical of complex adaptive systems
- It is perhaps impossible to get quanitative predictions of climate effects on salmon
- But, we should be able to characterize the risks and uncertainties

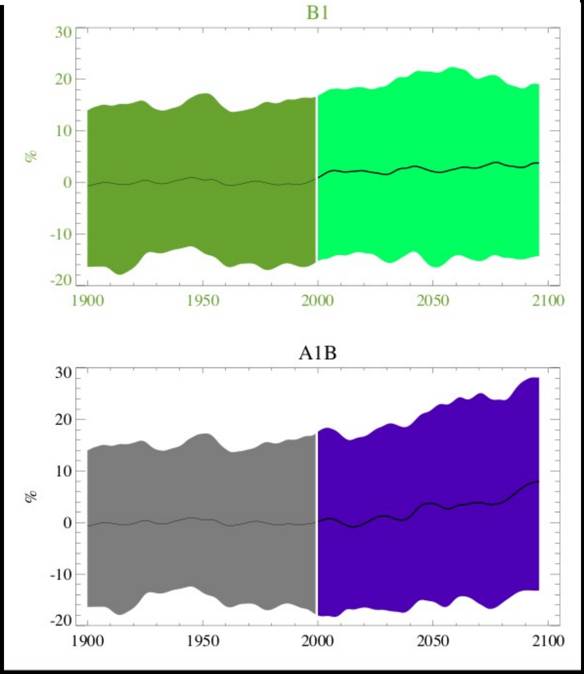
Approach

- Qualitative approach
  - No reliable means of quantifying effects
  - 'Outlook', not a 'forecast'
- Strictly from published literature
  - Summaries & interpretations of regional downscaling analyses & salmon ecology
- Three-step procedure
  - Summarize predicted physical changes
  - Identify processes affecting salmon by habitat
    - Terrestrial, Freshwater, Estuarine, Marine
  - Provide qualitative score on likely effect
    - 5-point scale: strong positive (++) to strong negative (--)
    - Also rate degree of certainty

Physical/Chemical Results

- Terrestrial & Freshwater
  - Air temperature
    - Average up 0.8C this century, additional 1.7 to 5.6C by 2100
  - Precipitation
    - Likely Increase in winter, de-crease in summer
  - Snowpack
    - Snowpack down > 50% since 1950, likely 40%-70% more loss by 2050.
  - Streamflow
    - Reduced summer flows, esp. for snowfed streams (Umpqua)
    - Increased flood risk
  - Stream temperature
    - Expect summer increases due to air temperature and flow

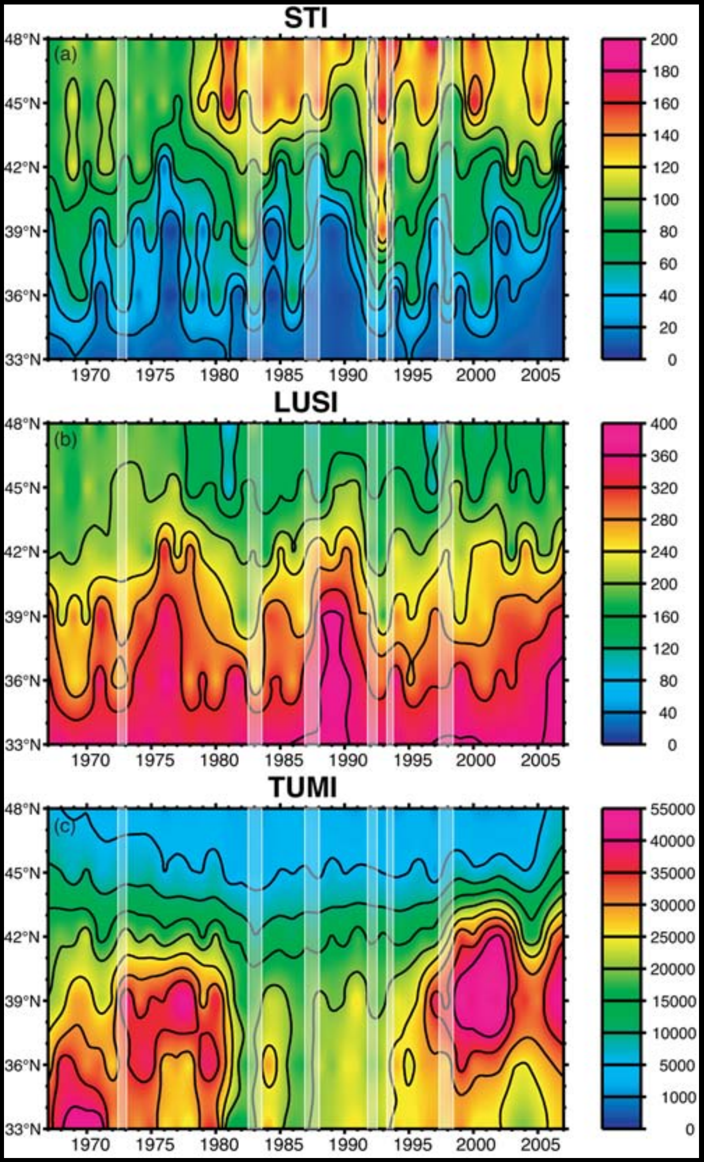




Mote et al., 2008

Physical/Chemical Results

- Estuarine & Marine
  - Sea level
    - Projected increase for Wash-ington coast range 15 cm to 1.25 m by 2100, Oregon probably similar
    - Confounded by local tectonics
  - Sea temperature
    - Global average is warming
    - California Current projections mixed
    - Surface and deep water trends may be opposite
  - Upwelling
    - Much disagreement on future,
    - Recent trend toward later on-set, shorter season
  - Ocean acidification



Bograd et al. 2009

Summary – Physics

Pattern	Certainty	Sources
Terrestrial & Freshwater		
Increased air temperature	High	Mote et al., 2003; Mote, 2003; Leung et al., 2004; Mote et al., 2008b; Karl et al., 2009
Increased winter precipitation	Low	Mote et al., 2003; Mote, 2003; Leung et al., 2004; Mote et al., 2008b; Karl et al., 2009
Decreased summer precipitation	Low	Mote et al., 2003; Leung et al., 2004; Mote et al., 2008b; Karl et al., 2009
Reduced winter/spring snowpack	High	Barnett et al., 2004; Barnett et al., 2008; Stewart et al., 2004; Stewart et al., 2005; Mote et al., 2005; Mote, 2006; Hamlet et al., 2005; Karl et al., 2009
Reduced summer stream flow	High	Mote et al., 2003; Karl et al., 2009
Earlier spring peak flow	High	Mote et al., 2003; Leung et al., 2004; Karl et al., 2009
Increased flood frequency & intensity	Moderate	Mote et al., 2003; Leung et al., 2004; Hamlet & Lettenmaier, 2007
Higher summer stream temperature	Moderate	Morrison et al., 2002; Ferrari et al., 2007; Lettenmaier et al., 2008
Estuarine & Marine		
Higher sea level	High	Bindoff et al., 2007; Mote et al., 2008a; Karl et al., 2009
Higher ocean temperature	High	Auad et al., 2006; Bindoff et al., 2007; Mote et al., 2008b
Intensified upwelling	Moderate	Bakun, 1990; Mote & Mantua, 2002; Snyder et al., 2003; Diffenbaugh, 2005; Bograd et al., 2009
Delayed spring transition	Moderate	Snyder et al., 2003; Bograd et al., 2009
Increased ocean acidity	High	Bindoff et al., 2007; Feely et al., 2004; Fabry et al., 2008; Feely et al., 2008

Effects on Coho Salmon

- Effects on OC Coho Habitats & Biology
  - Terrestrial Habitats
  - Freshwater Habitats
  - Estuarine Habitats
  - Ocean Habitats

Terrestrial & Freshwater

	Physical Change	Processes	Effect	Certainty	Main Sources
Terrestrial	Warmer, drier summers	Increased fires, increased tree stress & disease affect LWD, sediment supplies, riparian zone structure	- - to 0	Low	Cederholm & Reid, 1987; Mote et al., 2003; ISAB, 2007; Peterson et al., 2008
	Reduced snowpack, warmer winters	Increased growth of higher elevation forests affect LWD, sediment, riparian zone structure	0 to +	Low	Cederholm & Reid, 1987; Mote et al., 2003; ISAB, 2007; Peterson et al., 2008
Freshwater	Reduced summer flow	Less accessible summer rearing habitat	-	Moderate	Crozier & Zabel, 2006; Crozier et al., 2008; ISAB, 2007; Mantua et al., 2009
	Earlier peak flow	Potential migration timing mismatch	- to 0 (-- to 0 in Umpqua)	Moderate	Crozier et al., 2008
	Increased floods	Redd disruption, juvenile displacement, upstream migration	- to 0 (- - to - in Umpqua)	Moderate	ISAB, 2007; Mantua et al., 2009
	Higher stream temperature	Thermal stress, restricted habitat availability, increased susceptibility to disease and parasites	- - to -	Moderate	Marine & Cech, 2004; ISAB, 2007; Crozier et al., 2008; Farrell et al., 2008; Marcogliese, 2008; Mantua et al., 2009;

Estuarine & Marine

	Physical Change	Processes	Effect	Certainty	Main Sources
Estuarine	Higher Sea Level	Reduced availability of wet-land habitats	-- to -	High	Kennedy, 1990; Scavia et al., 2002; Roessig et al., 2004; Mote et al., 2008a
	Higher water tempera-ture	Thermal stress, increased susceptibility to disease and parasites	-- to -	Moderate	Marine & Cech, 2004; Marcogliese, 2008
	Combined effects	Changing estuarine ecosys-tem composition and struc-ture	-- to +	Low	Kennedy, 1990; Scavia et al., 2002; Roessig et al., 2004
Marine	Higher ocean tempera-ture	Thermal stress, shifts in mi-gration, susceptibility to dis-ease & parasites	-- to -	Moderate	Welch et al., 1995; Cole, 2000; Marine & Cech, 2004; Marcogliese, 2008
	Intensified upwelling	Increased nutrients (food supply), coastal cooling, ecosystem shifts; increased offshore transport	0 to ++	Moderate	Nickelson, 1986; Fisher & Pearcy, 1988
	Delayed spring transi-tion	Food timing mismatch with outmigrants, ecosystem shifts	- to 0	Moderate	Schwing et al., 2006; Brodeur et al., 2005; Emmett et al., 2006
	Increased acidity	Disruption of food supply, ecosystem shifts	-- to -	Moderate	Fabry et al., 2008
	Combined effects	Changing composition and structure of ecosystem; changing food supply and predation	-- to +	Low	Fabry et al., 2008; Peterson & Schwing, 2003; Brodeur et al., 2005; Emmett et al., 2006; Bograd et al., 2009

Terrestrial Habitats

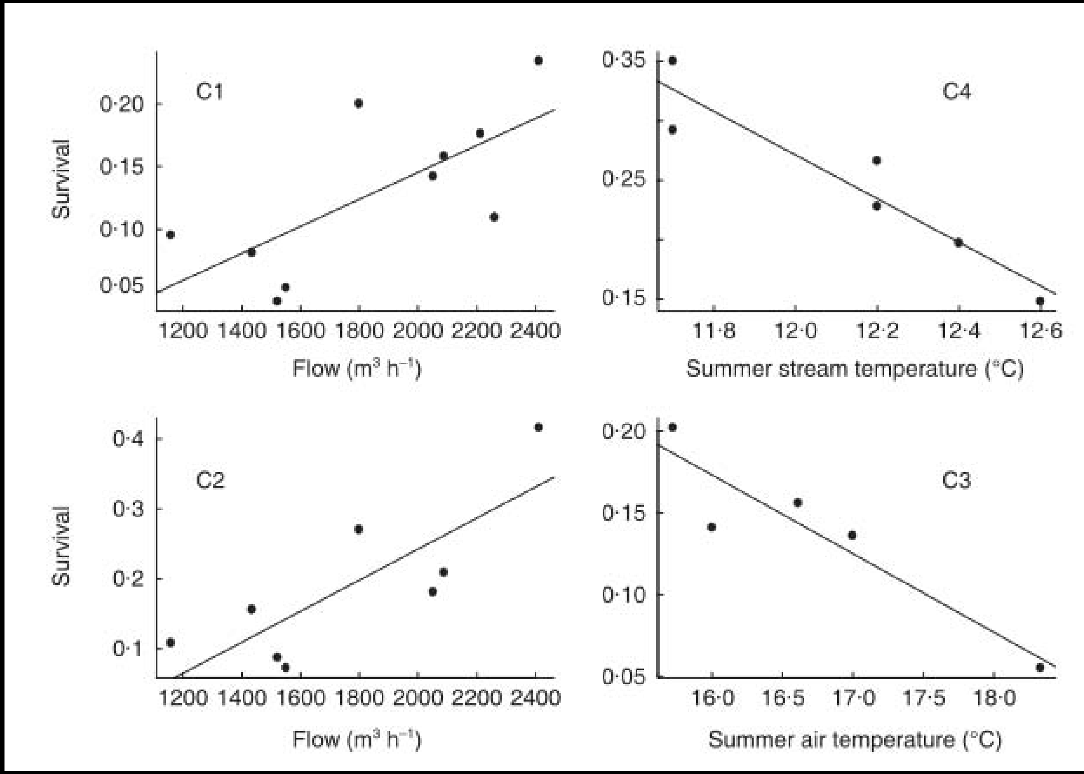
- Effects on stream habitats
  - Changed dynamics of large wood
  - Interactions with beaver dynamics

water.washington.edu

nwfsc.noaa.gov

Freshwater Habitats

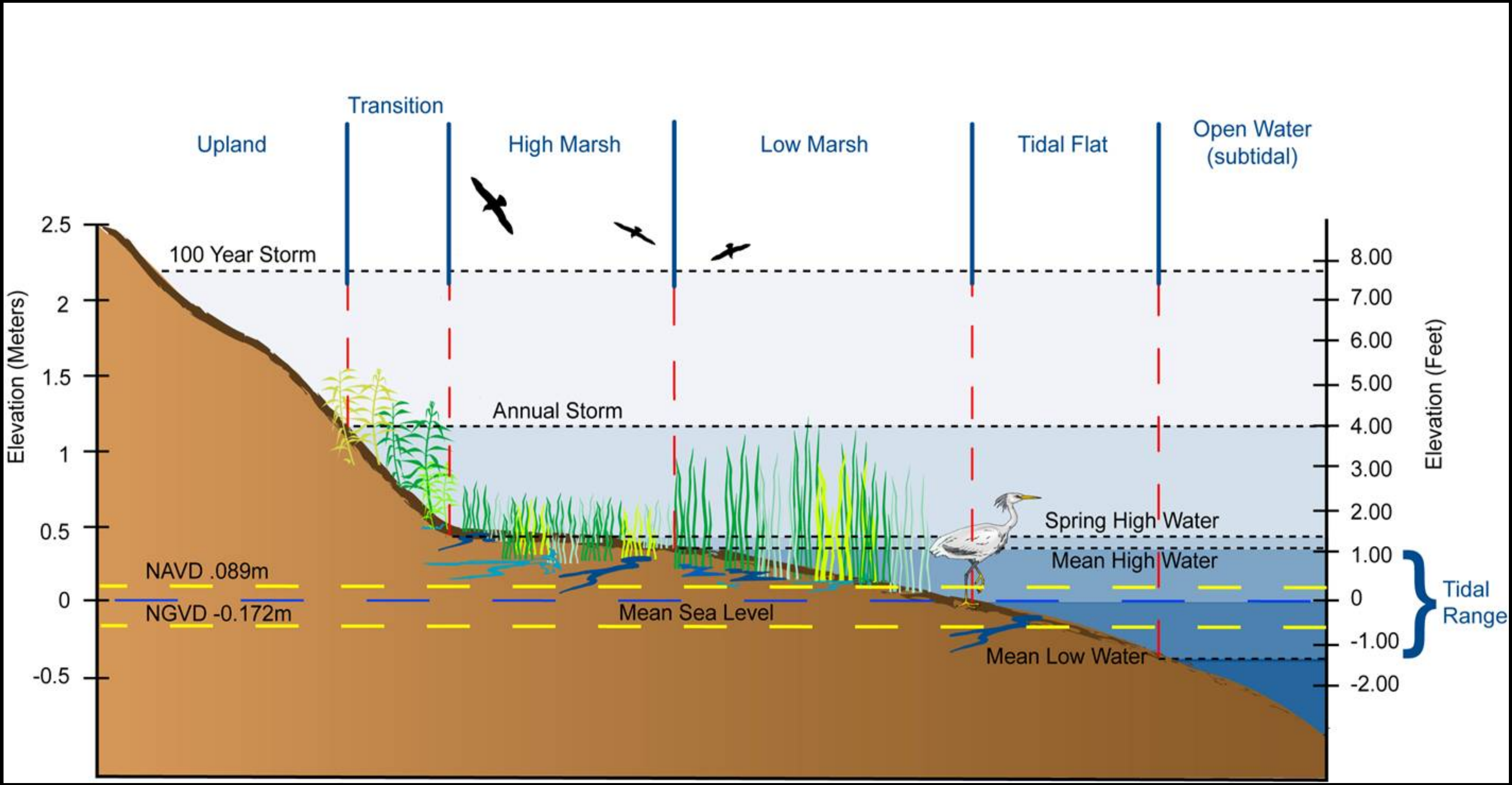
- Reduced summer flows
- Earlier peak flows (Umpqua)
- Increased flood frequency & intensity
- Higher stream temperatures



Crozier & Zabel 2006

Estuarine Habitats

- Higher sea level
  - Loss of tidal wetlands



maps.risingsea.net

Ocean Habitats

- Increased acidity
  - Physiological stress
  - Reduced abundance of some prey

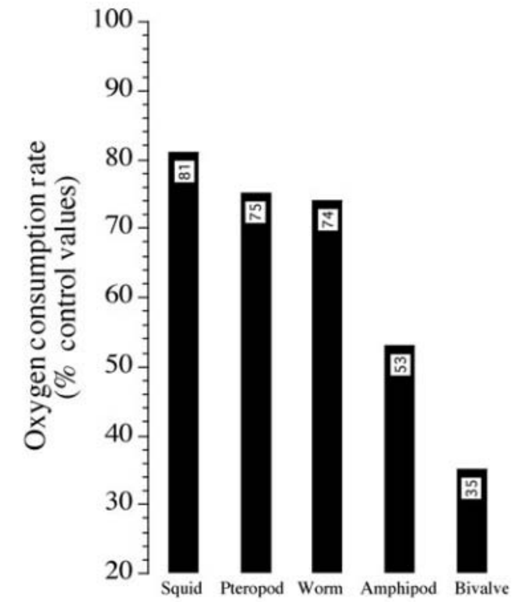
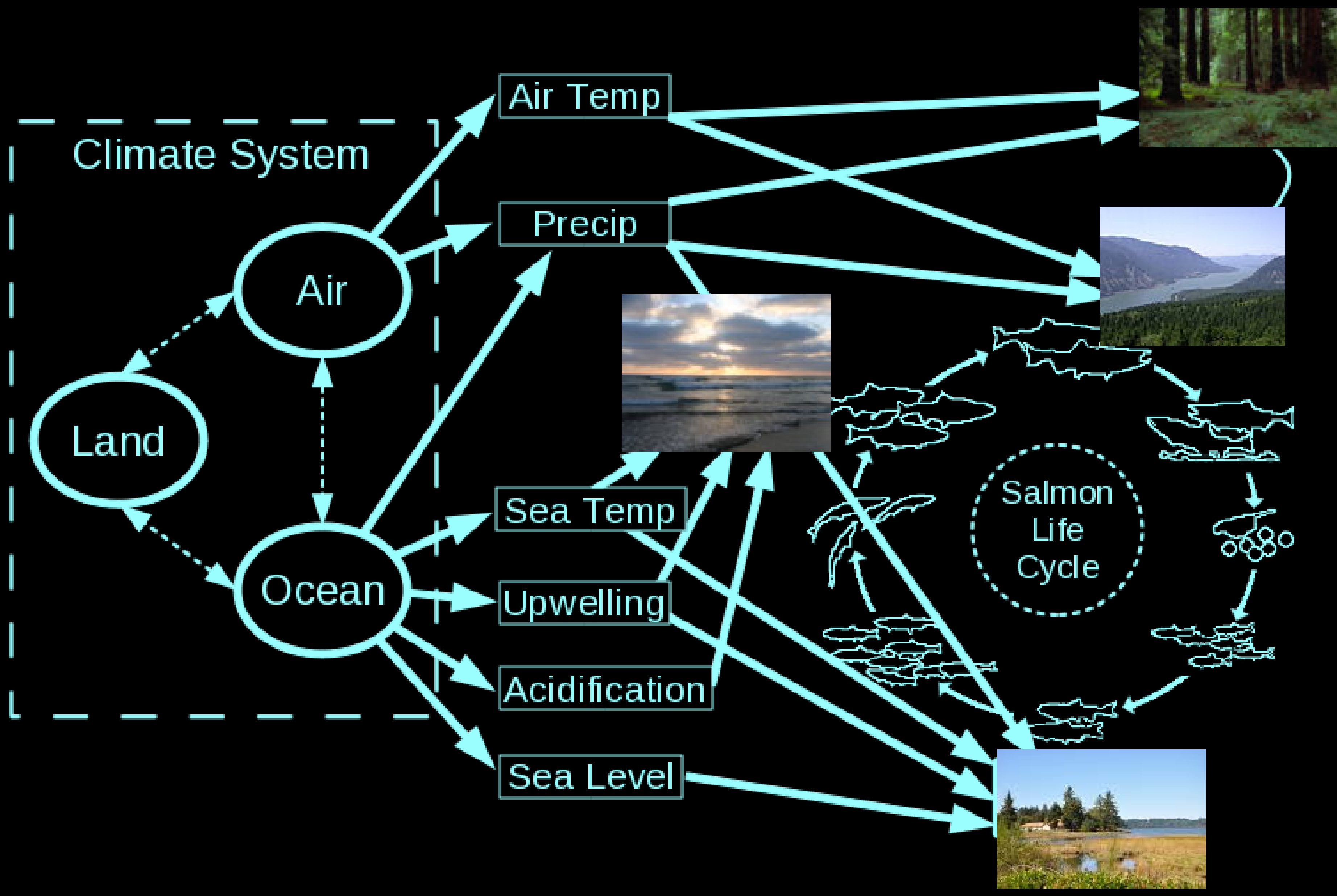


Figure 8. Oxygen consumption rates under elevated CO_2 for marine animals as a percentage of control rates (air saturation). Decreases in routine metabolism, an adaptive strategy to short-term hypercapnia, of the squid *Dosidicus gigas* ~1000 ppmv (0.1% at 20°C), the pteropod mollusc *Limacina helicina antarctica* under 789 ppmv (−1.86°C), the worm *Sipunculus nudus* and an amphipod *Phronima sedentaris* under 10 000 ppm (1.0%), and the bivalve *Mytilus edulis* under ~5000 ppmv (0.5%, pH 7.3, 18°C) carbon dioxide. (R. Rosa, and B. Seibel, unpublished data; Pörtner and Reipschläger (1996); Michaelidis *et al.* (2005)).

Fabry et al. , 2008


Climate System
Air
Land
Ocean
Air Temp
Precip
Sea Temp
Upwelling
Acidification
Sea Level
Salmon Life Cycle

Conclusions

- Individual life stage effects
  - Predominantly negative, a few positive
  - Many weak or uncertain
- Cumulative effects
  - Across life cycle and across generations
    - Life stage effects are multiplicative, amplifying individual effects
    - Uncertainties also accumulate across life stages
- Likely strong negative effect of climate change on Oregon Coast coho salmon
- However, there remain great uncertainties in the biological response

Desires

- What we would like
  - Quantitative estimates of climate change impacts on salmon
    - Is this a pipe dream for such a complex system?
    - Can we at least quantify uncertainty?

- Improved climate models
  - Better local resolution
    - Coast Range orographic effects
    - Coastal ocean dynamics (over shelf)
  - Seasonality/phenology
  - Unbiased long-term temperature forecasts (freshwater & marine)

Acknowledgements

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  - The global climate modeling community;
  - The IPCC; and
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