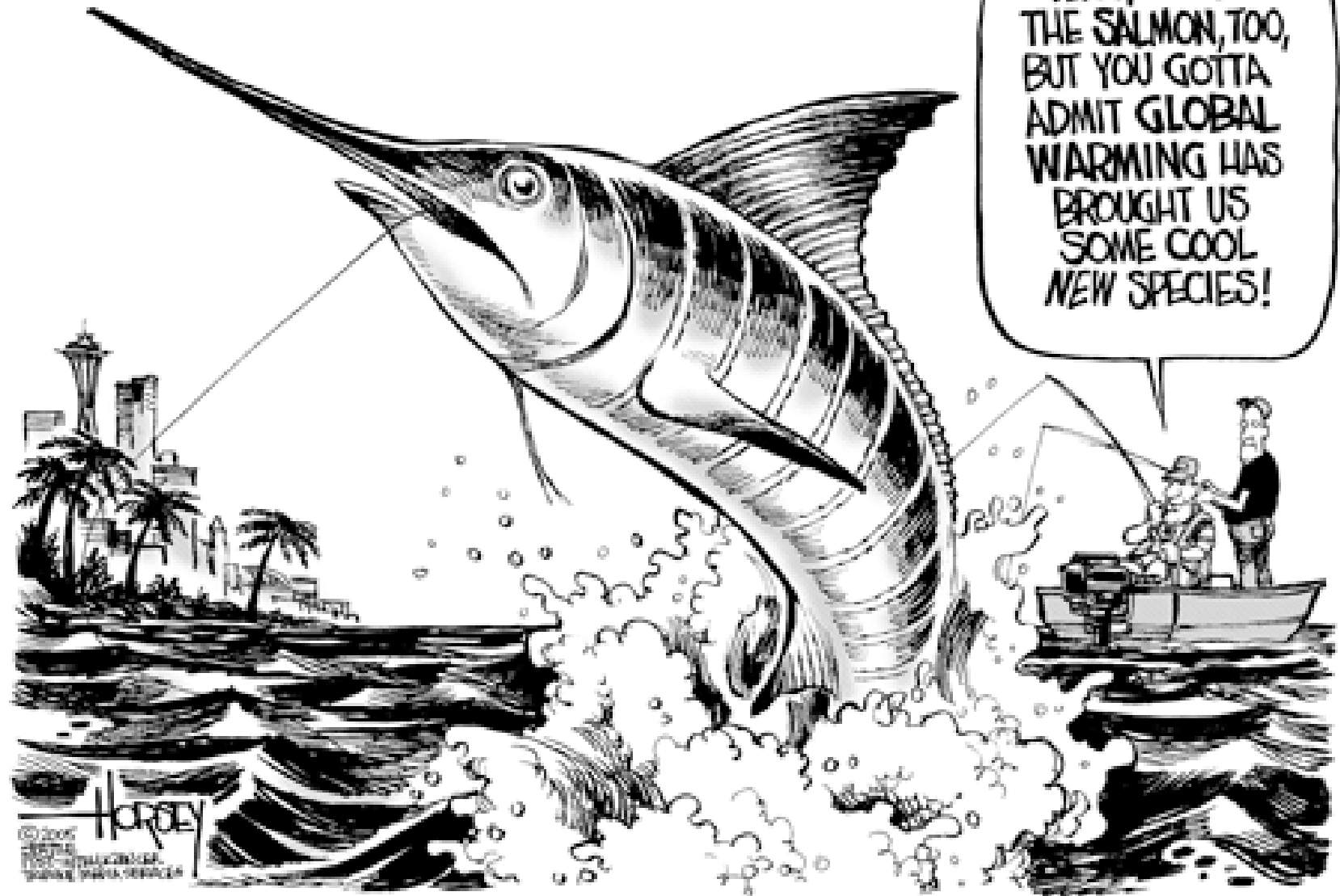


Puget Sound, 2045...



From the Seattle Post-Intelligencer, October 20, 2005



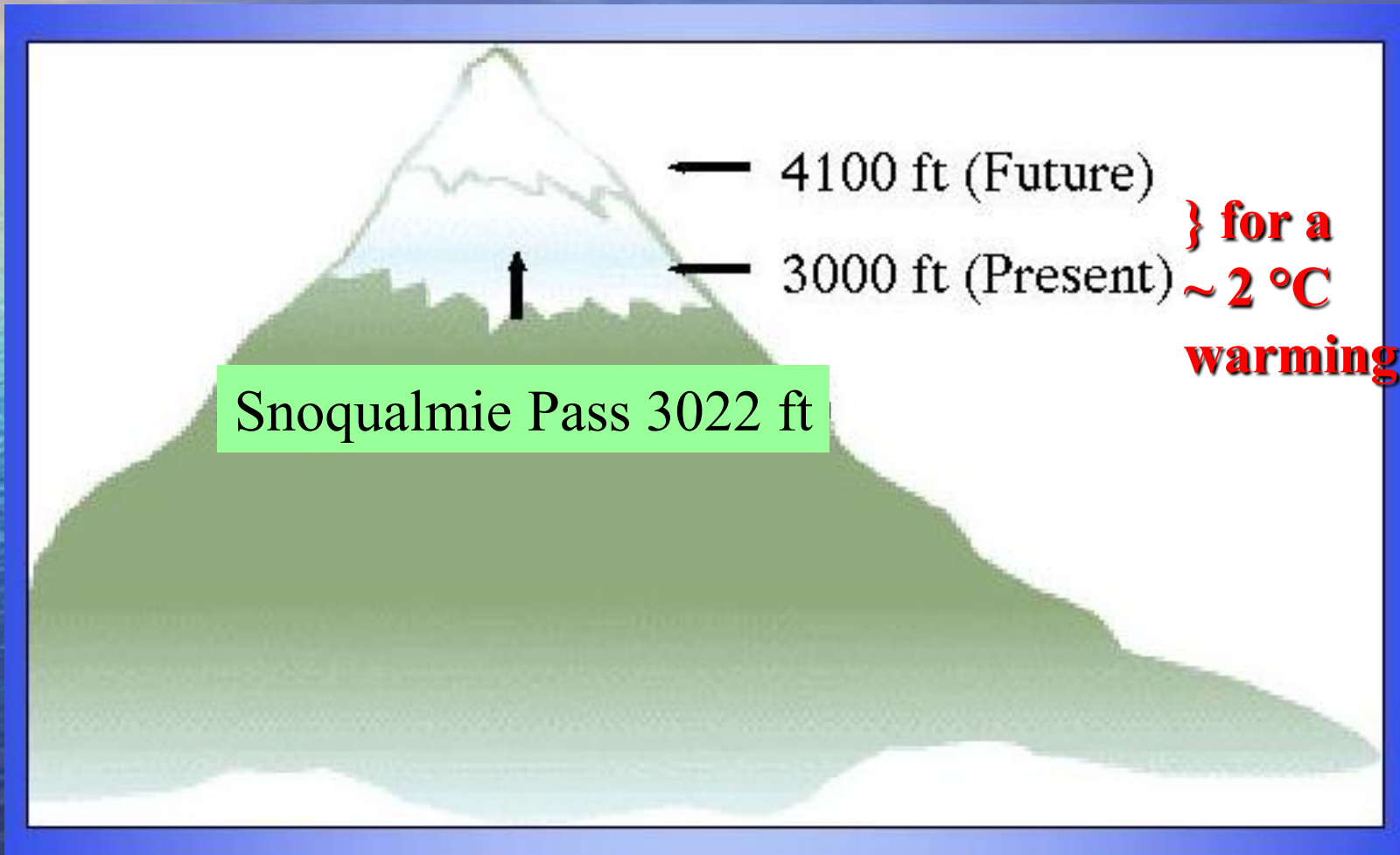
Climate Change Effects on Aquatic Habitats

Nate Mantua, Ingrid Tohver, Alan Hamlet,
Climate Impacts Group, University of
Washington

Mt Rainier National Park
Climate Change Workshop
March 2, 2011 -- Pack Forest

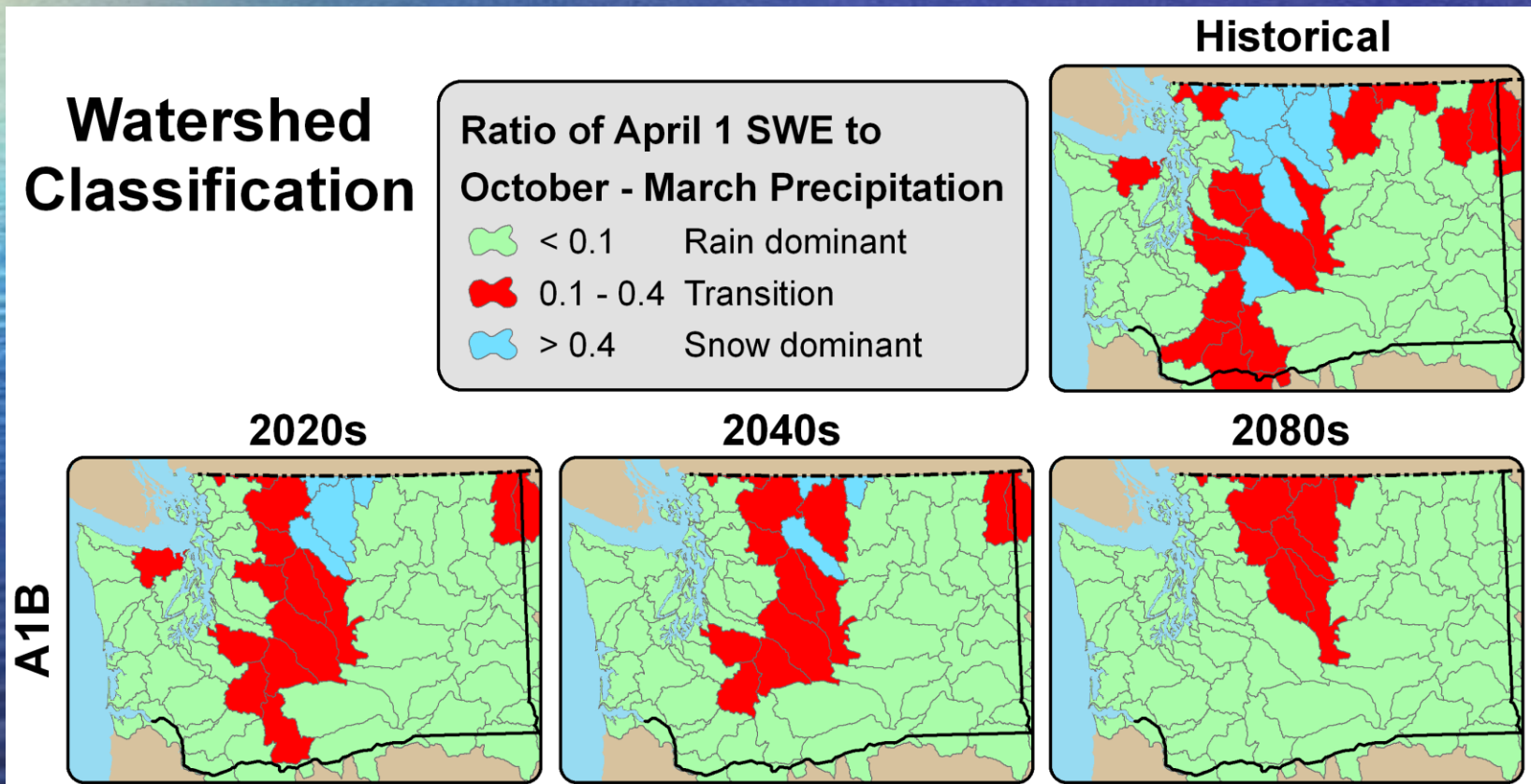


A robust impact of climate warming: **less snow**

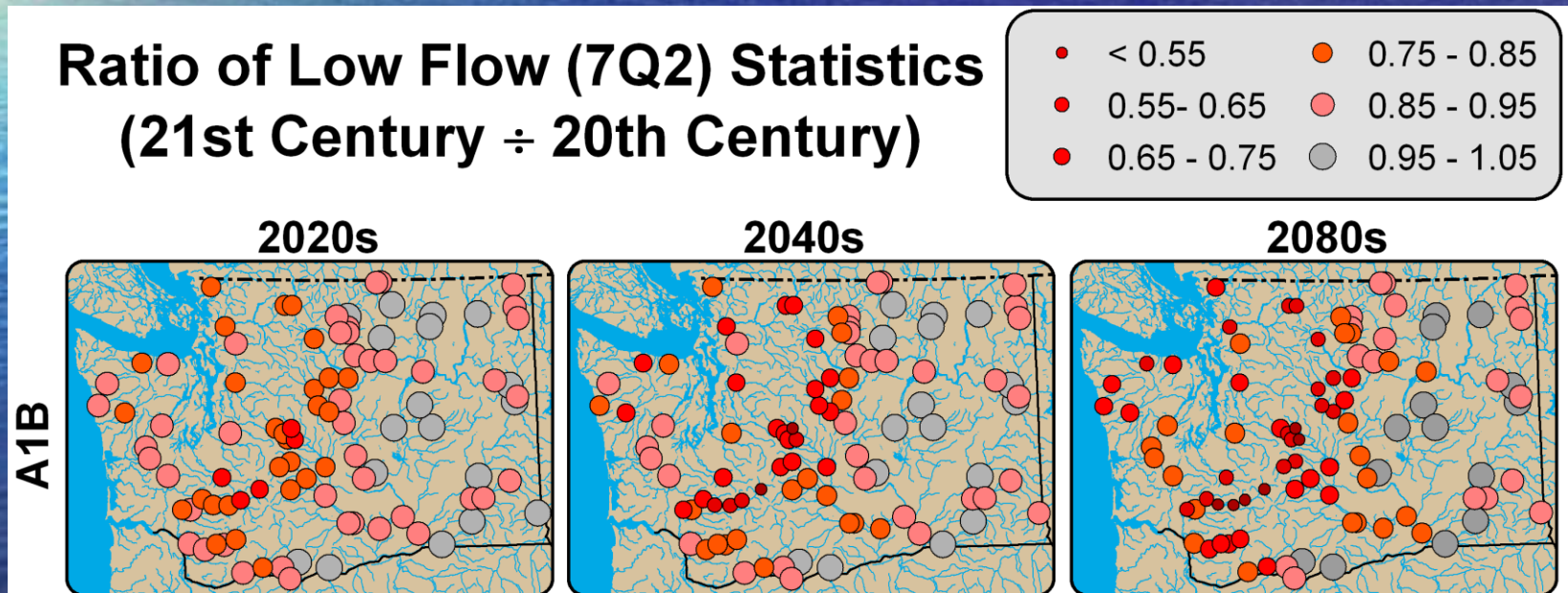


Dramatic changes in snowmelt systems

- Snowmelt rivers become transient basins
- Transient basins become rainfall dominant



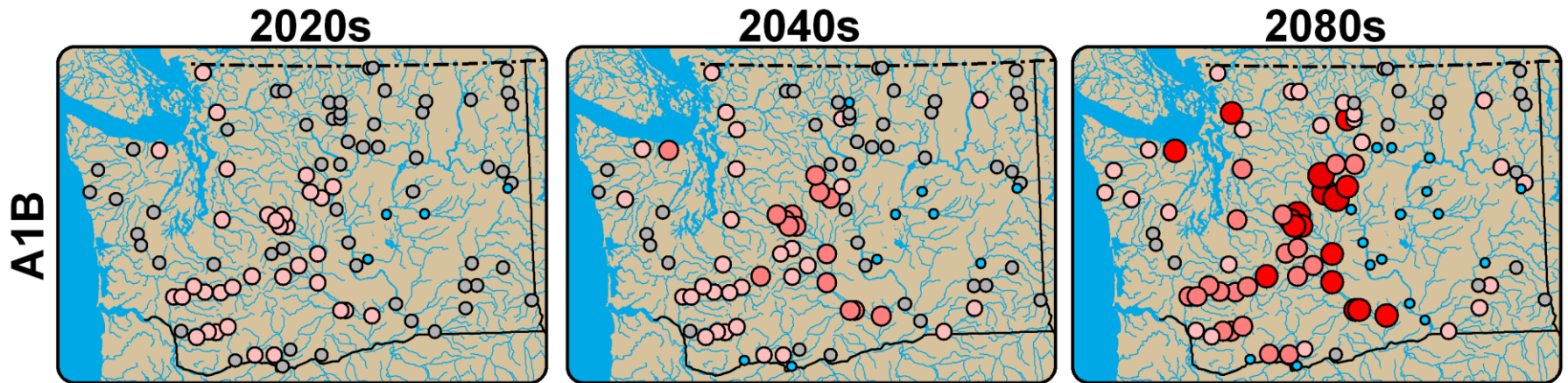
- **Summer base flows are projected to drop substantially (5 to 50%) for most streams in western WA and the Cascades**
 - **The duration of the summer low flow season is also projected to increase in snowmelt and transient runoff rivers, and this reduces rearing habitat**



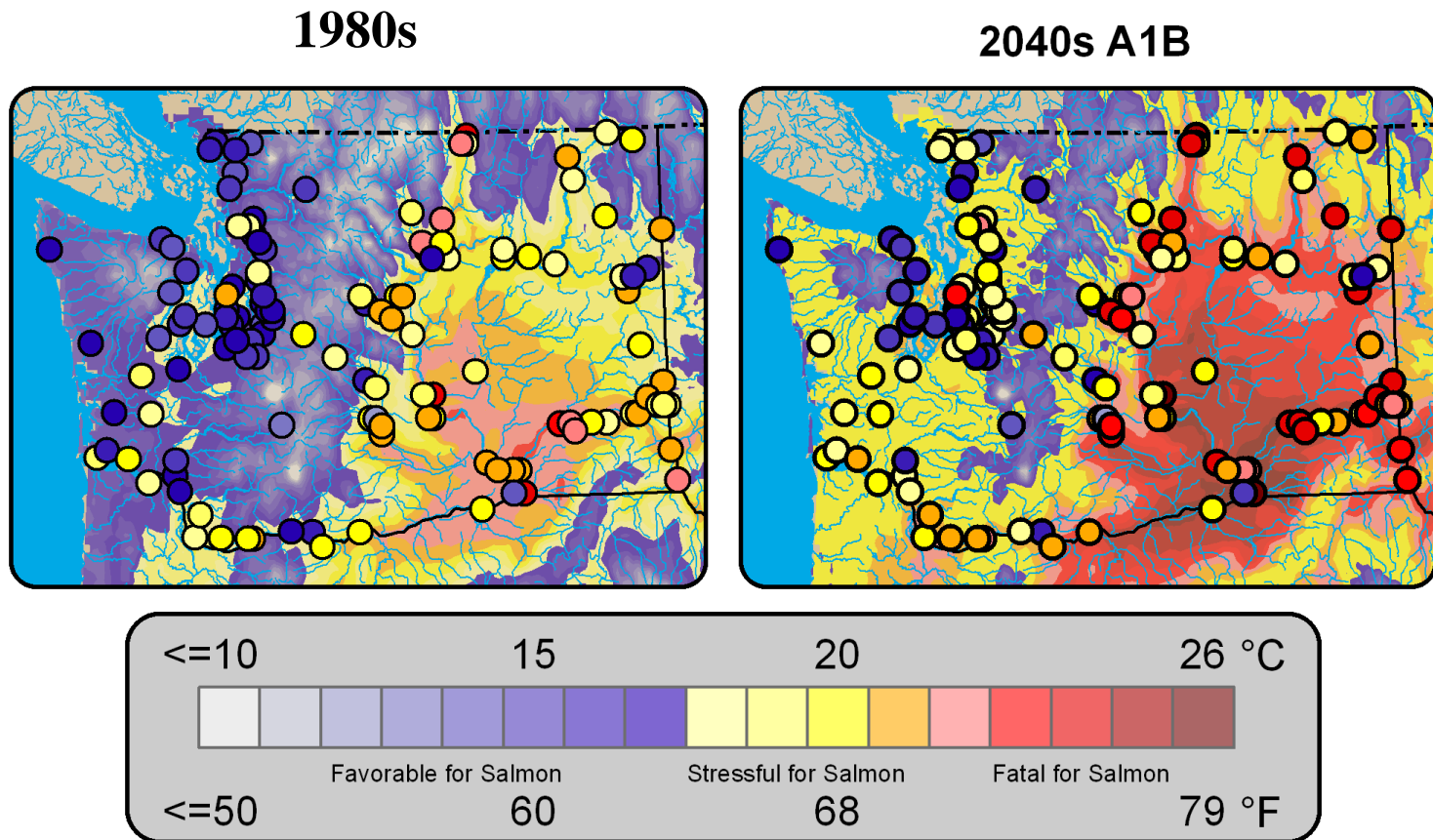
Mantua et al. 2010: **Climate change impacts on streamflow extremes and summertime stream temperature and their possible consequences for freshwater salmon habitat in Washington State (Climatic Change)**

- Models project **more winter flooding** in sensitive “transient runoff” river basins that are common in the Cascades
 - Likely reducing survival rates for incubating eggs and rearing parr

Ratio of 20-year Flood Statistics (21st Century ÷ 20th Century)



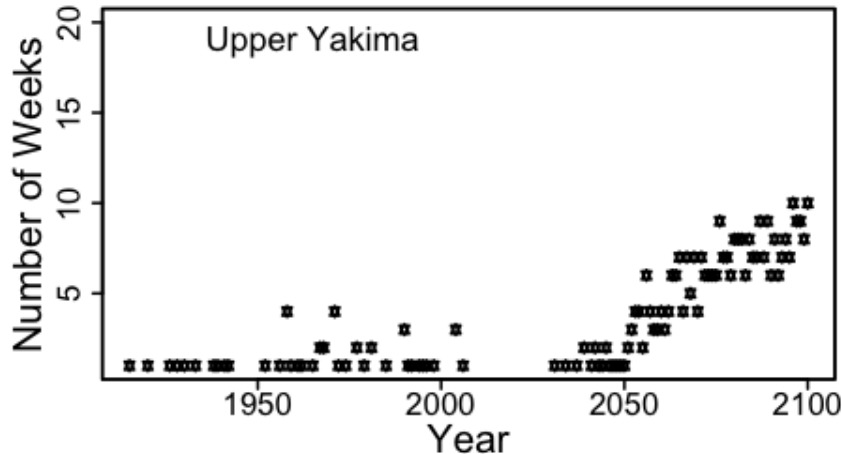
Western Washington's "maritime" summer climate becomes as warm as today's interior Columbia Basin, temperatures in the interior Columbia Basin become as warm as today's Central Valley in California



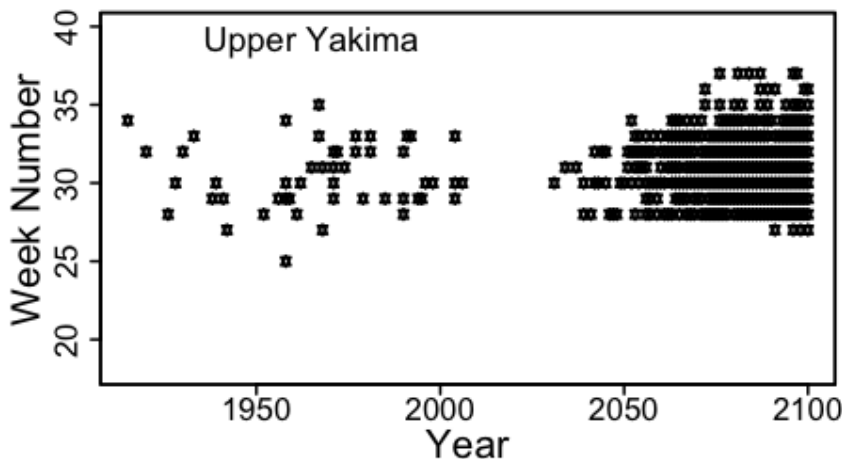
Thermal stress season

- Extended periods with weekly average water temperatures $> 21^{\circ}\text{C}$
 - Under this scenario, the season of thermal migration barriers for migrating salmon projected to last up to 11 weeks in the upper Yakima River

Number of Weeks Average Water Temperatures exceed 21°C

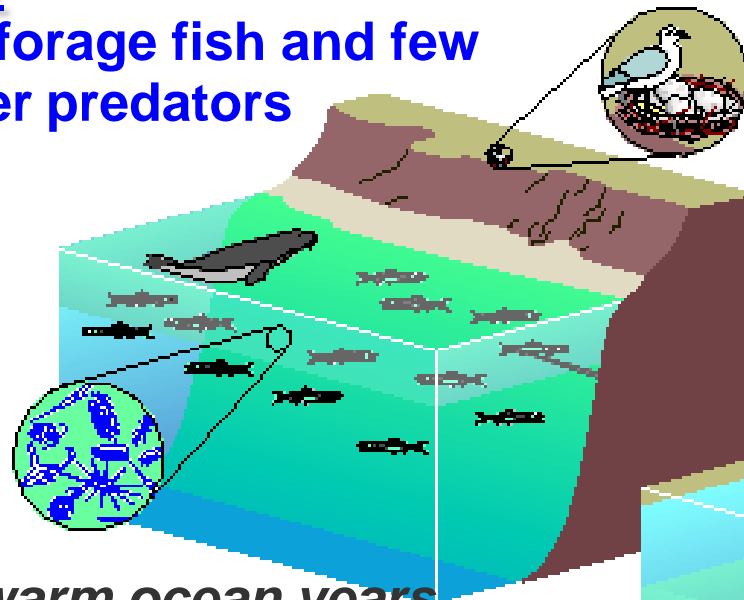


Week Number Exceeding 21°C

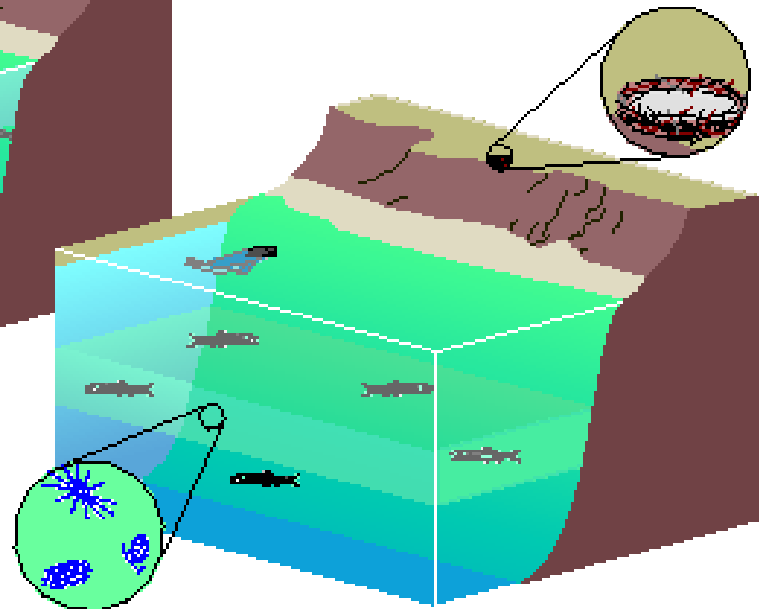


Upwelling food webs in our coastal ocean

Cool water, weak stratification
high nutrients, a productive
“subarctic” food-chain with
abundant forage fish and few
warm water predators

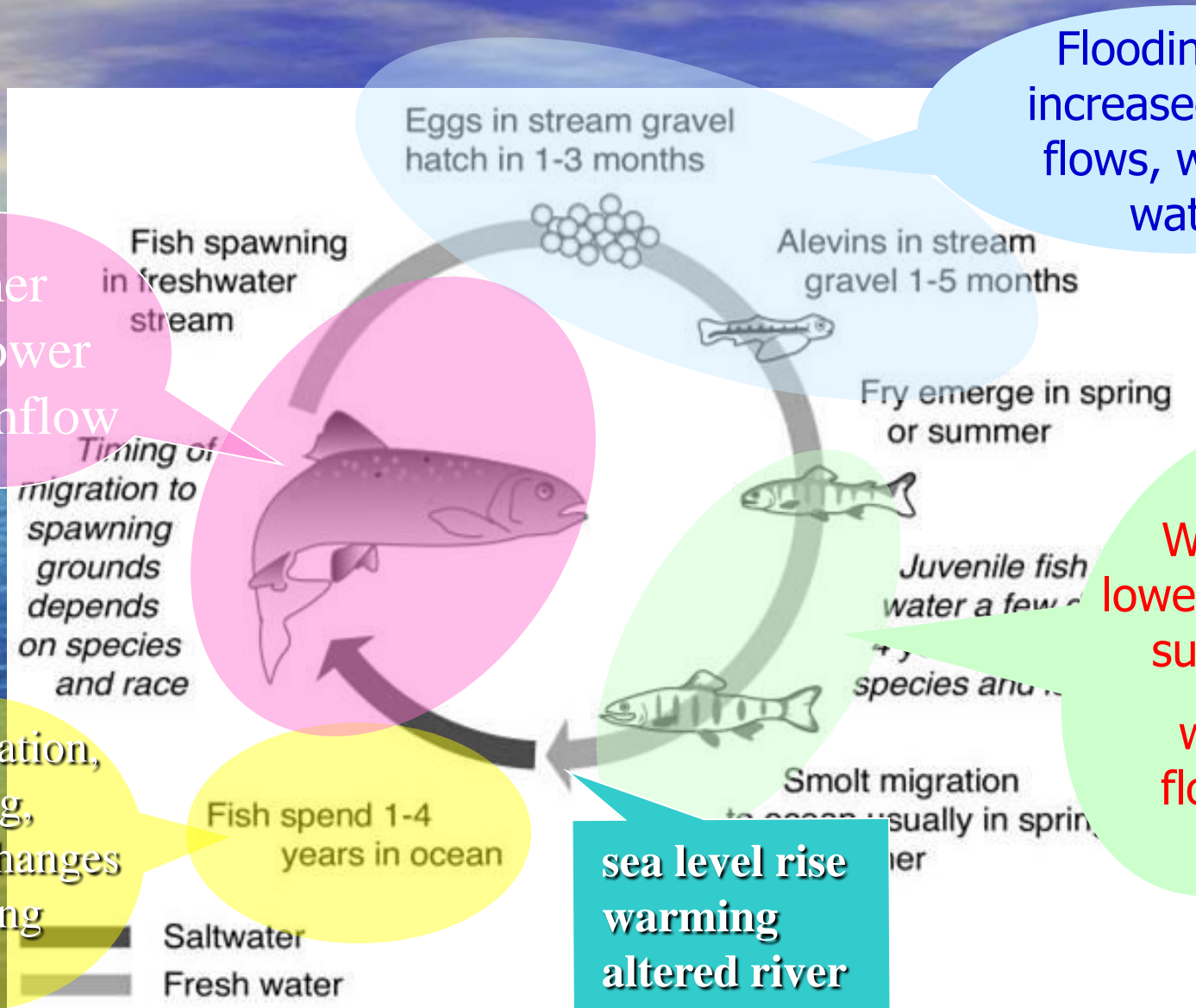


Warm stratified ocean, few
nutrients, low productivity
“subtropical” food web, a
lack of forage fish and
abundant predators



*Recently, warm ocean years
have generally been poor for
NW chinook, coho and sockeye,
but good for Puget Sound pink
and chum salmon.*

Impacts summary for PNW salmon



Warmer and lower streamflow

Flooding and increased mean flows, warmer water

Warmer lower flows in summer; winter flooding

acidification, warming, range changes upwelling winds?

sea level rise warming altered river discharge

Impacts will vary depending on life history and watershed types

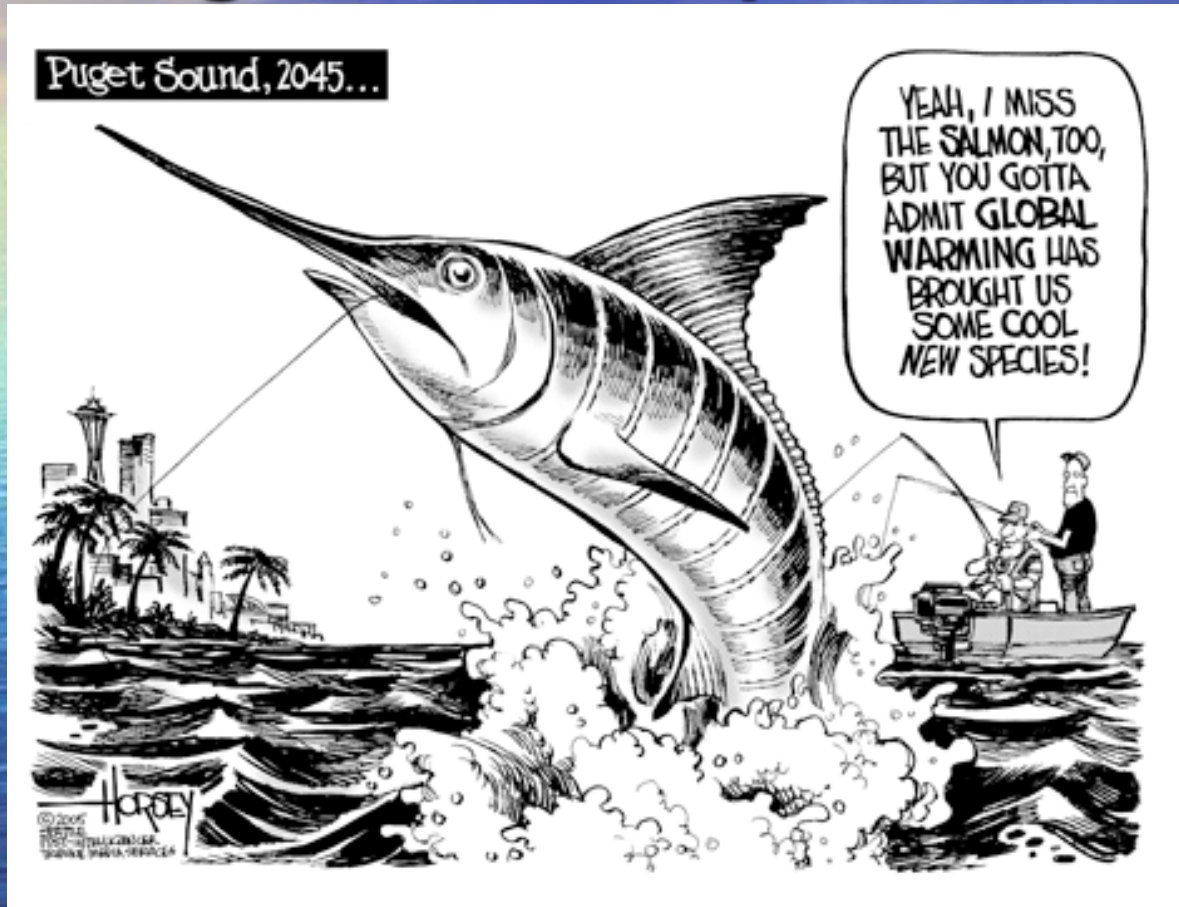
- **Low flows+warmer water = increased pre-spawn mortality for summer run and stream-type salmon and steelhead**
 - Clear indications for increased stress on Columbia Basin sockeye, summer steelhead, summer Chinook, and coho more generally



Harley Soltes/Seattle Times

- **Increased winter flooding in transient rain+snow watersheds**
 - a limiting factor for egg-fry survival for fall spawners + yearling parr overwinter survival in high-gradient reaches

In the ocean, species distributions change with temperature



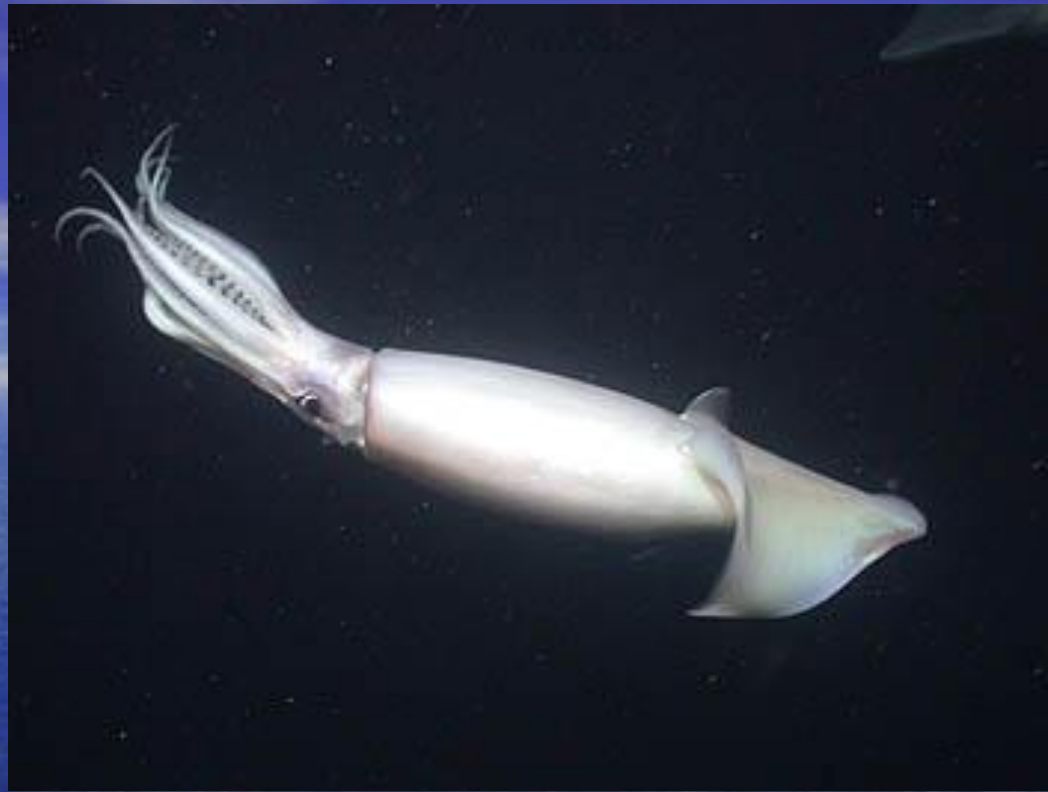
From the Seattle Post-Intelligencer, October 20, 2005



134 lb marlin caught 40 mi. west of Westport, WA, Sept 2, 2005

Photo obtained from the Seattle Times web-archives

A recent visitor that seems to like it here - prior to 1997 they'd never been observed in PNW waters, but were reported to be abundant in California waters in the 1930s.



Humboldt Squid, Jumbo flying squid, Diablos rojos (*Dosidicus Gigas*): a voracious predator that can reach up to 2m in length and weigh up to 45 kg

New predator-prey interactions



- A black bear with a salmon near Tofino, Vancouver Island



- A black bear with a Humboldt squid, also near Tofino, Vancouver Island