Apr 6th, 2:15 PM - 2:30 PM

Effects of large infrastructure on the underwater visual environment and heightened predation on salmon in the Salish Sea

David A. Beauchamp
U.S. Geological Survey, United States, davebea@uw.edu

Infrastructure Impacts on the Underwater Visual Environment & Salmonid Predation

Dave Beauchamp
USGS-Western Fisheries Research Center

Tom Roorda, Photo credit

Hood Canal Bridge

Photo credit: Hans Daubenberger

USGS science for a changing world

SALISH SEA MARINE SURVIVAL PROJECT
www.marinesurvivalproject.com

Human Impacts on Visual Environment

- **Change in land & water use**
- **Nutrient input/diversion (Ag & Urban)**
  - **Productivity & Organic turbidity**
- **Turbidity Change:**
  - **Increased by erosion (Land Development, Ag)**
  - **Decreased by dams (sediment traps, altered spring run-off patterns)**
- **Urbanization-Artificial Lighting**

Artificial Light At Night (ALAN)

Mexico City at night

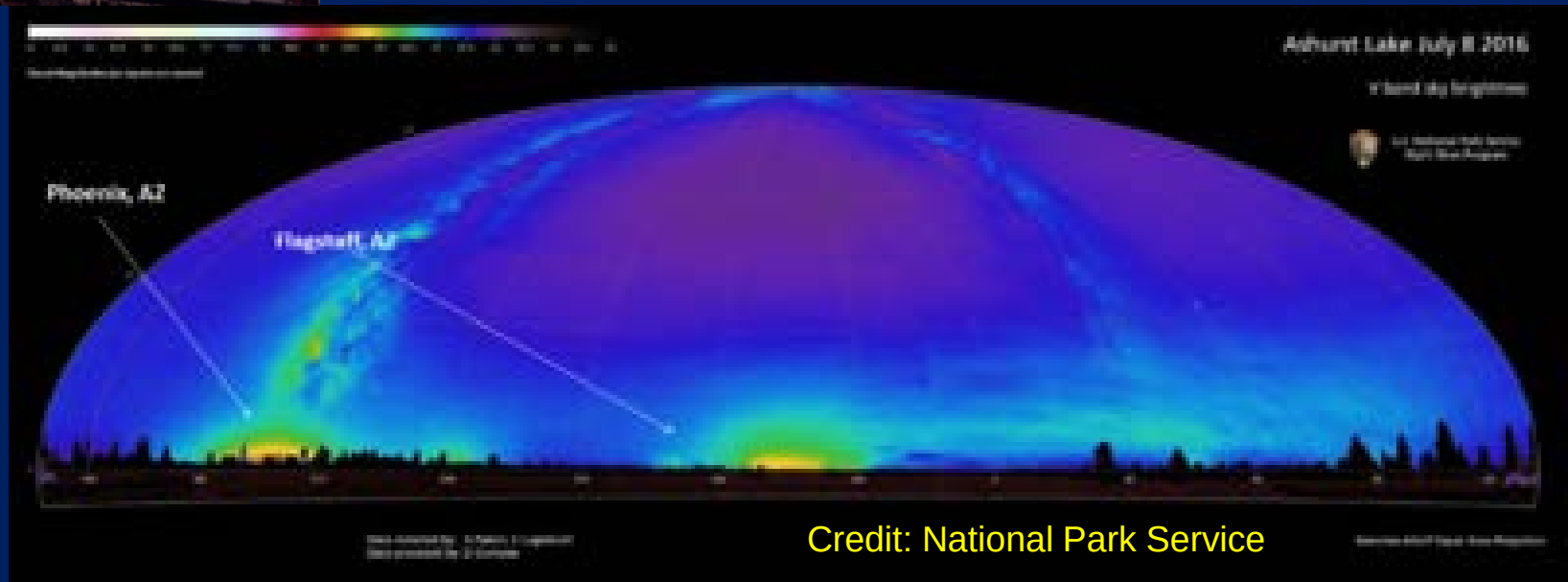
By Fernando Tomás from Zaragoza, Spain - Flickr, CC BY 2.0, https://commons.wikimedia.org/w/index.php?curid=348732

1- Direct spillover of light into aquatic habitats
-Localized effects (1-100 m)

2- Skyglow is light reflected from the atmosphere or clouds back to earth at high levels around cities
-Far-reaching effects (10-80 km from source)

Skyglow can increase light by Ecologically significant levels 10s of km from source, creating Light halos around cities

-increases light in pelagic waters far from the source



Credit: National Park Service

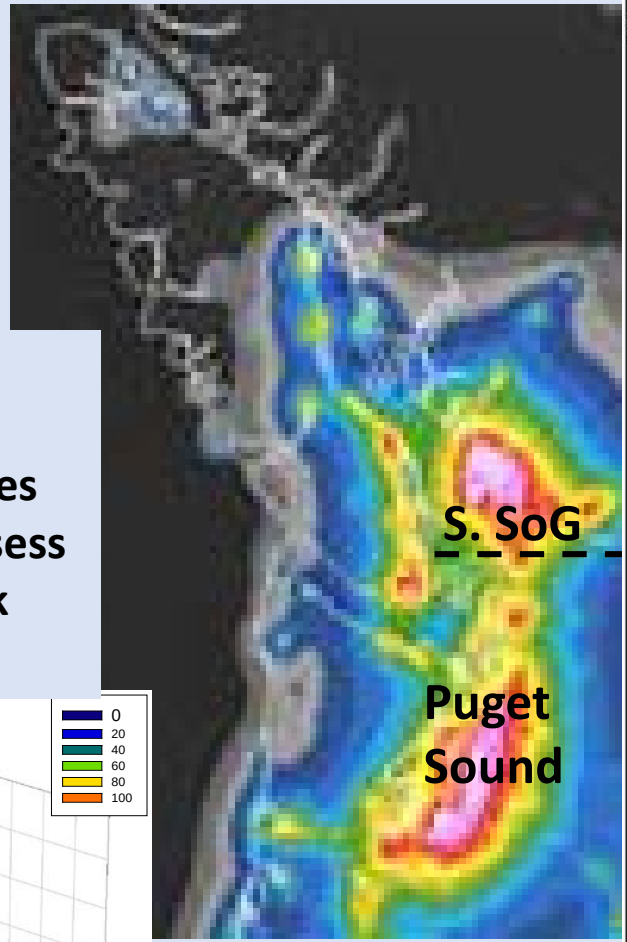
Why Focus on Visual Environment?

- Vision is the primary sensory mechanism used by predators in Pelagic (openwater) habitats
- Vision essential for Foraging & Predator Avoidance:
  - **Planktivores** (eat zooplankton)
  - **Piscivores** (eat fish)

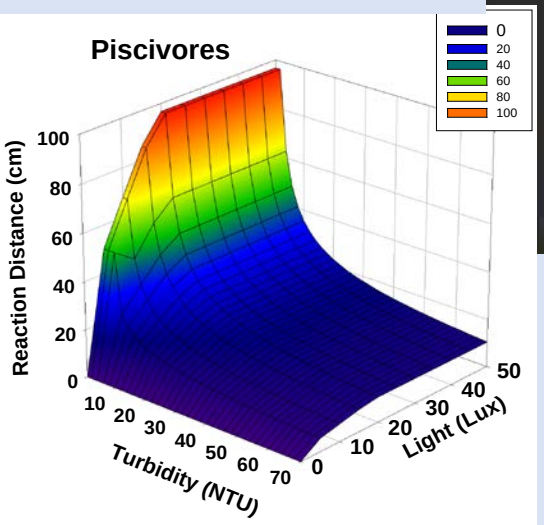
- Visual conditions are dynamic through time & space, and vary widely among waters
- Food webs function differently as visual conditions change
- Land-Water Use & Infrastructure have changed the underwater visual environment (artificial lighting, dams, ag/urban run-off)

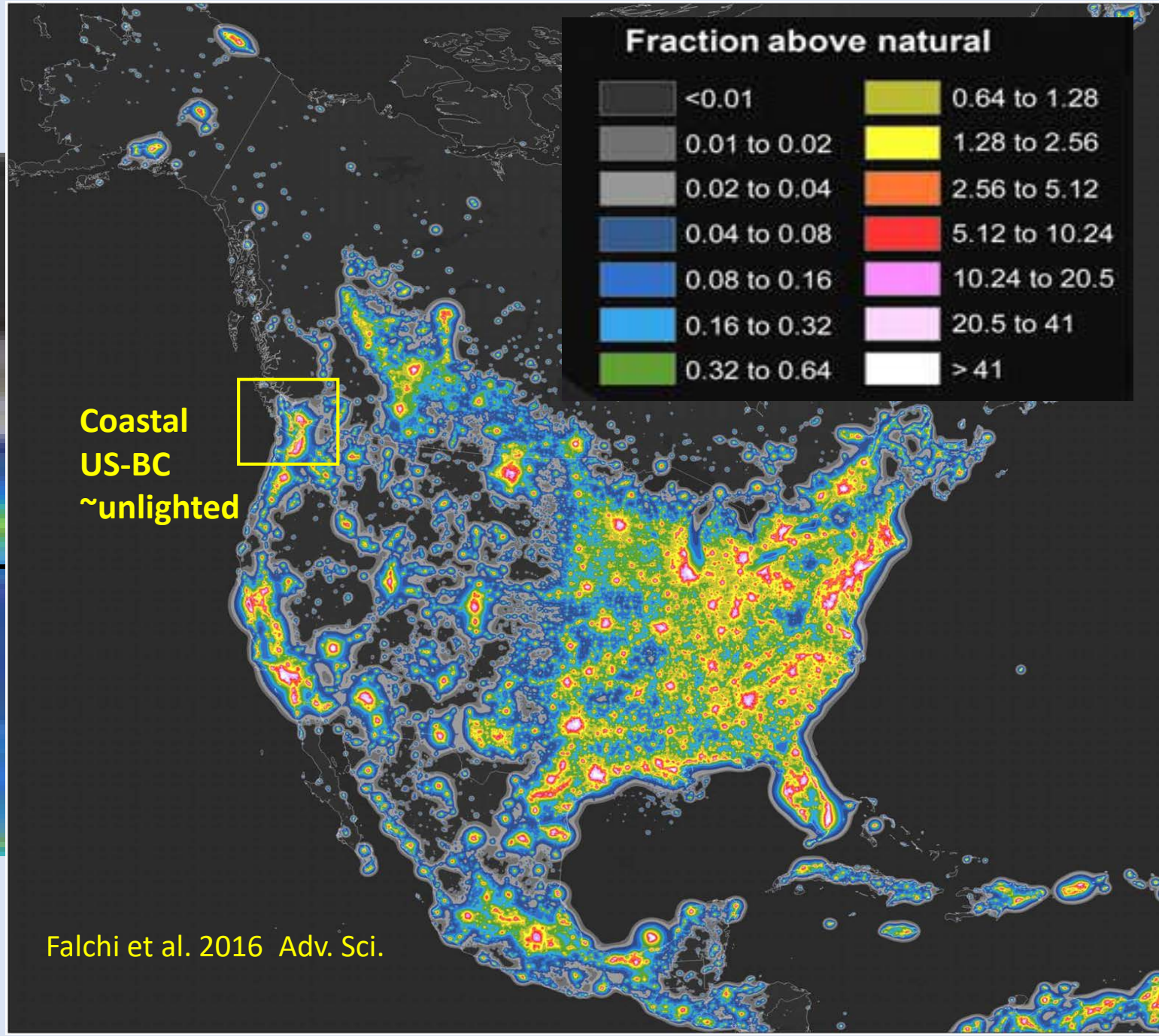
Night Satellite Imagery

Salish Sea & Coastal Wa-BC



Link change in light environment to visual capabilities of predators to assess how predation risk has changed

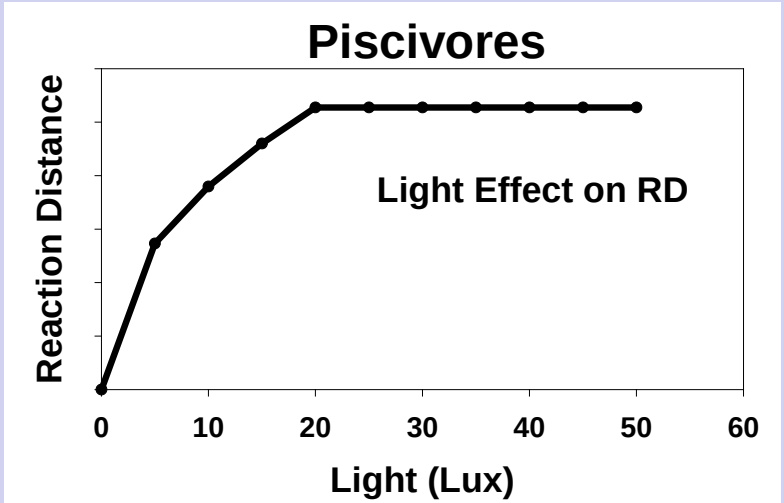




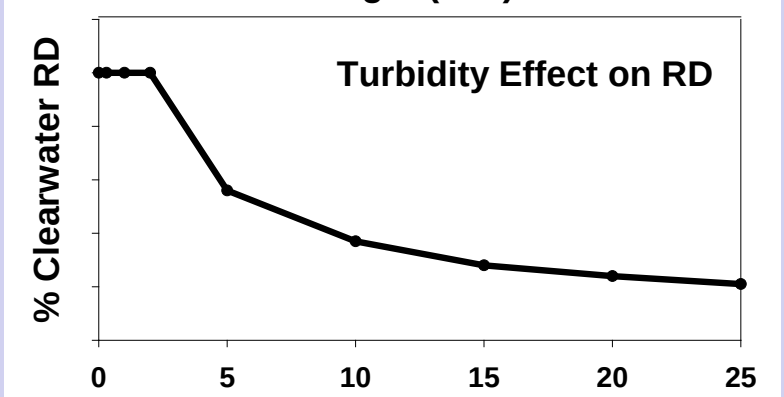
Falchi et al. 2016 Adv. Sci.

Threshold Effects on Visual Prey Detection

Characteristic response to Light



Characteristic response to Turbidity

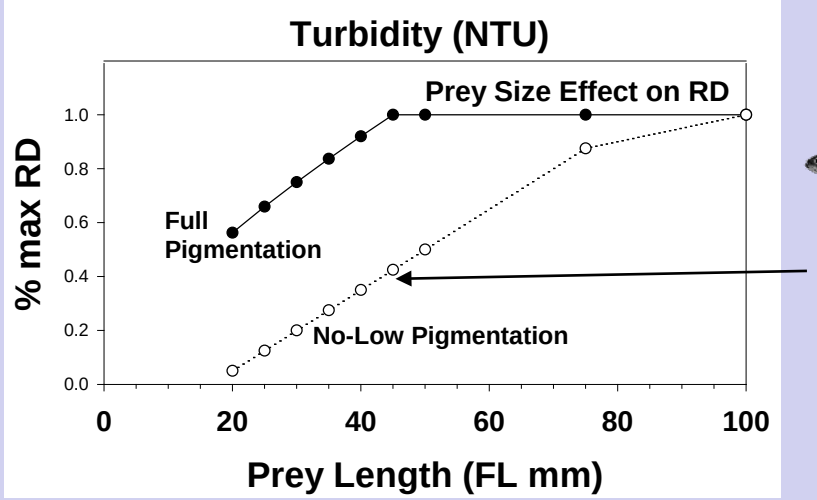


Prey Size:

RD reduced for Prey < 45-50 mm
-Pigmentation important

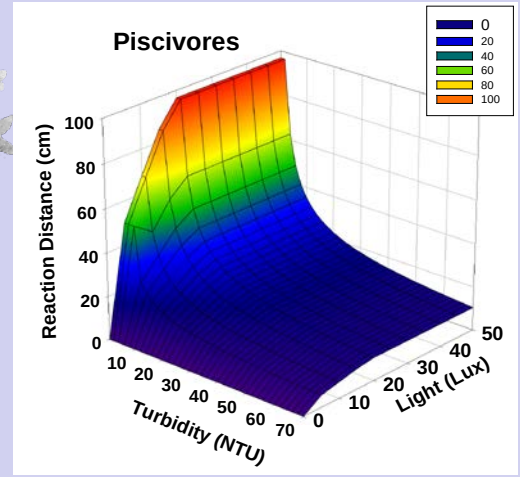
RD constant for Prey > 50 mm

-**Schools** no easier to detect than Single prey fish > 50 mm!



Functions for piscivorous:
Chinook Salmon
Coastal Cutthroat trout
Inland Cutthroat trout
Rainbow trout
Lake Trout

Apply functions to Ambient Visual conditions to predict Foraging capability at:
-any depth
-any time of day or night
-any time of year

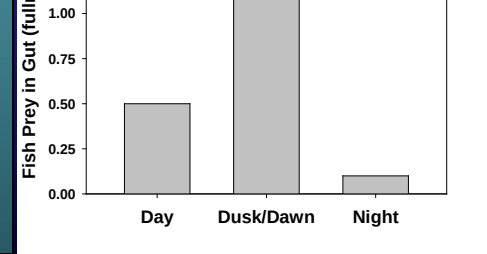


Diel Visual Foraging

Day

Dusk

Night

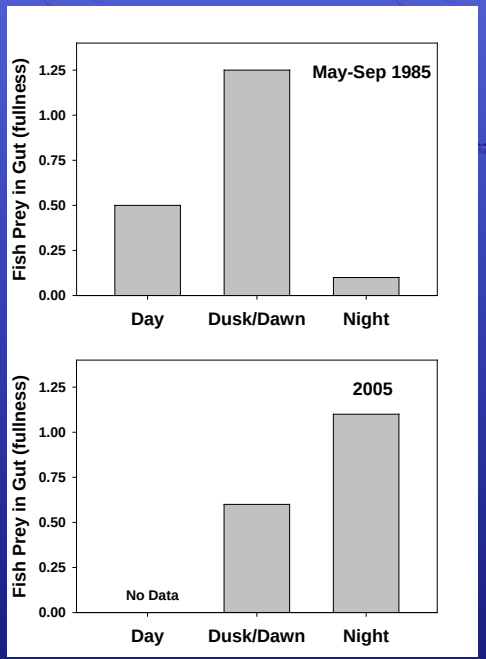


Oligotrophic Waters

Day

Dusk

Night



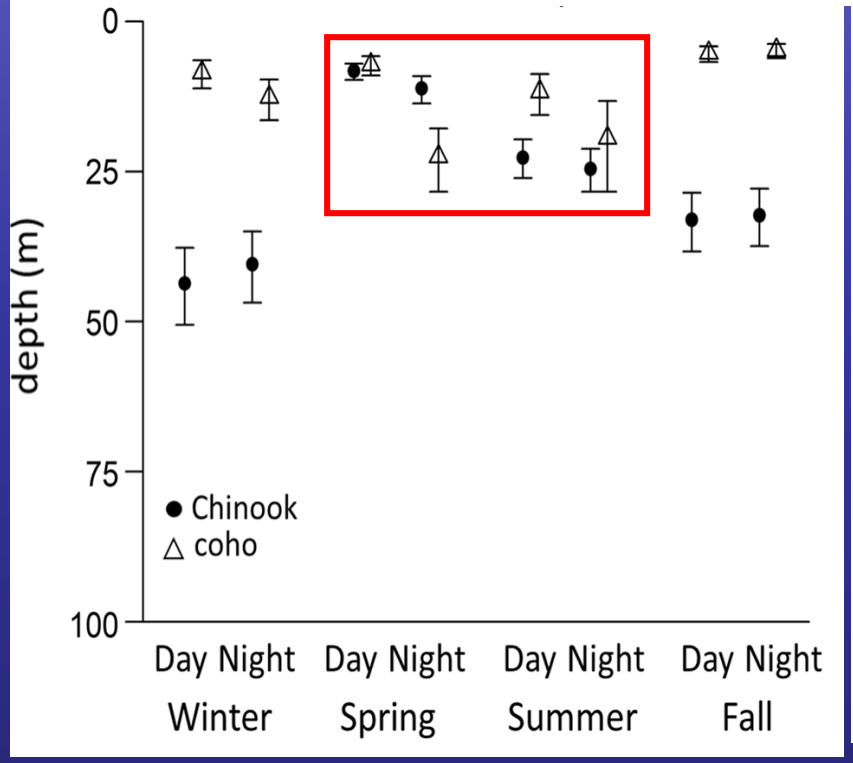
Artificial Light Pollution is shifting Night toward twilight conditions that increase predators' efficiency

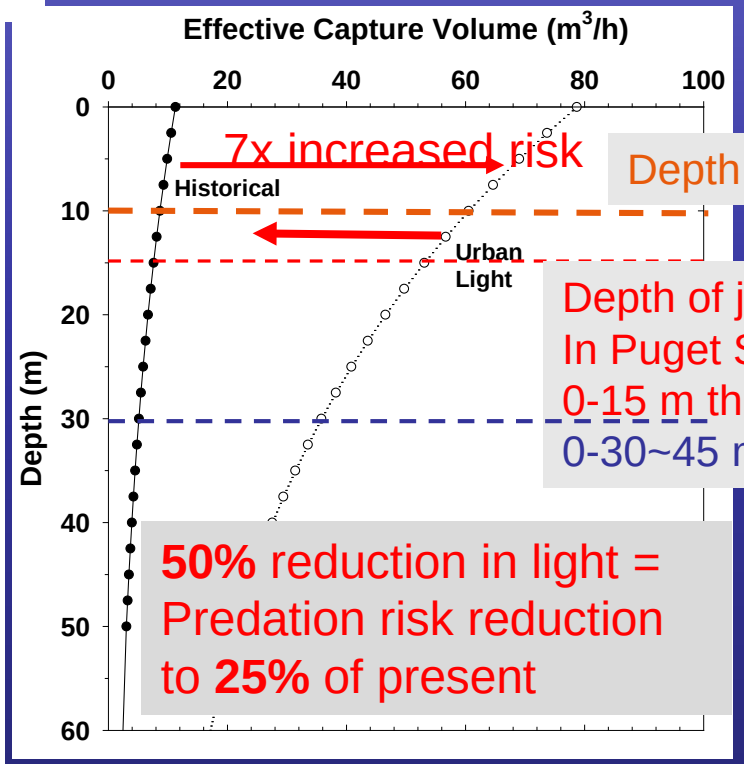
Effect of Urban Light Pollution on Predation Risk:

-Nocturnal Migratory Corridors & Feeding Habitat

-Dark Nocturnal Refuge in Early Marine Life

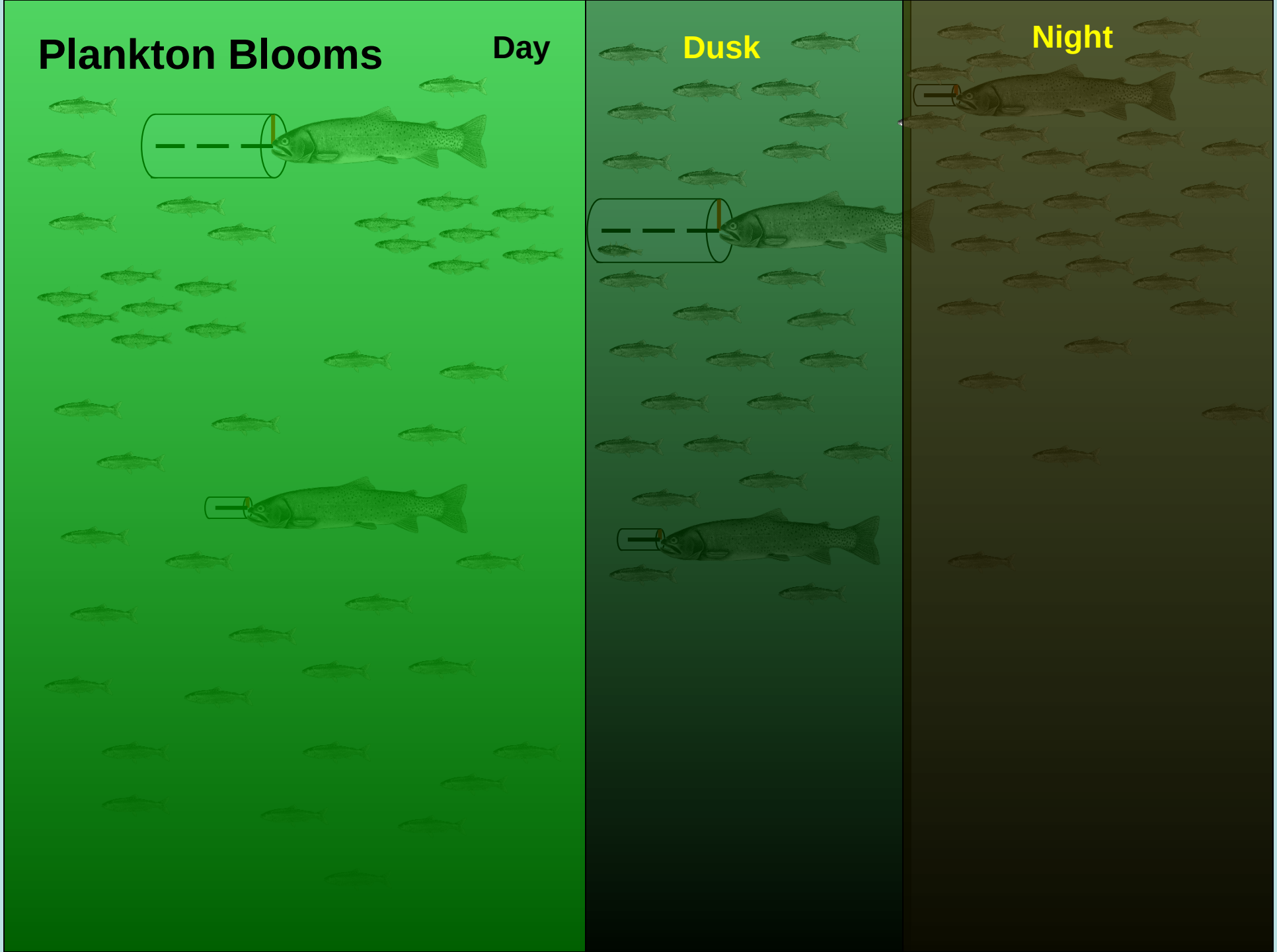
Depth Distribution of Resident Chinook & Coho (Smith et al. 2015 MEPS)





Resident Chinook & Coho overlap with depths of juvenile salmon

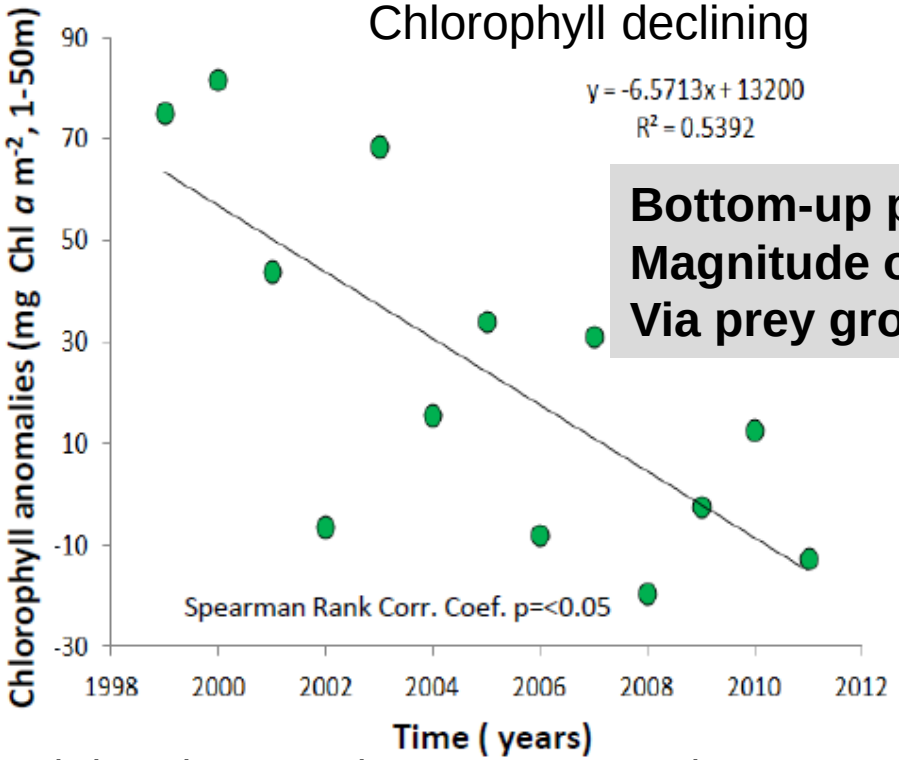
Sufficient light penetration at night to support effective nocturnal predation


Plankton Blooms
Day
Dusk
Night

Depth integrated chlorophyll, a proxy for sub-surface phytoplankton biomass has been declining.

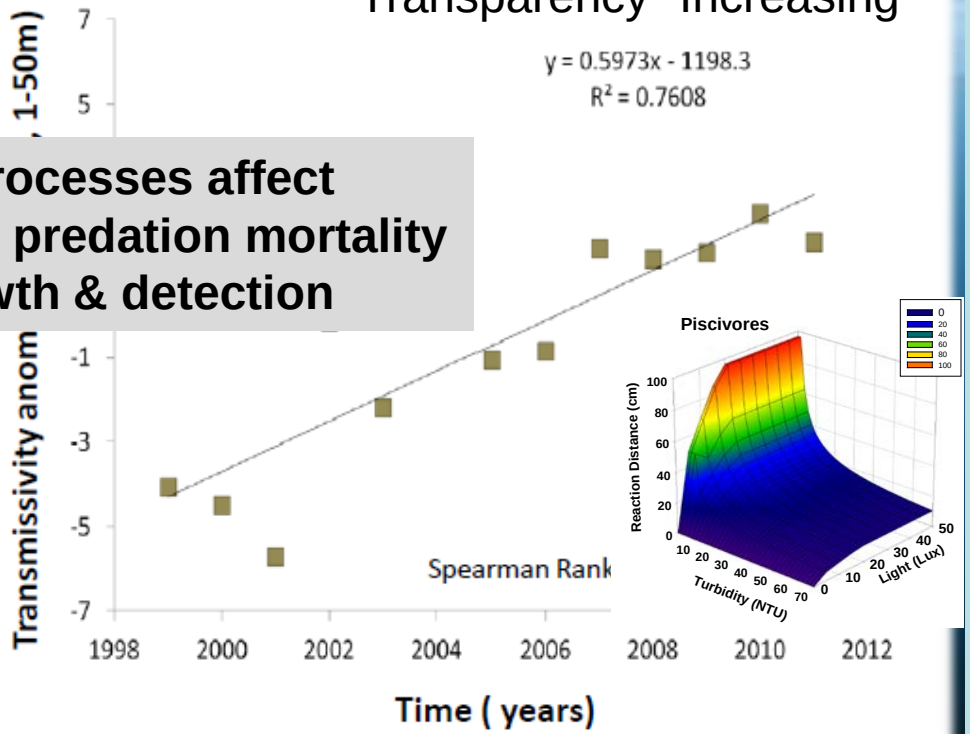
Puget Sound Water Quality Trends

Chlorophyll declining

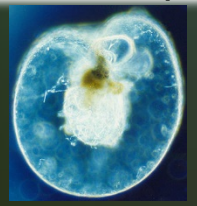


Bottom-up processes affect
Magnitude of predation mortality
Via prey growth & detection

"Transparency" Increasing

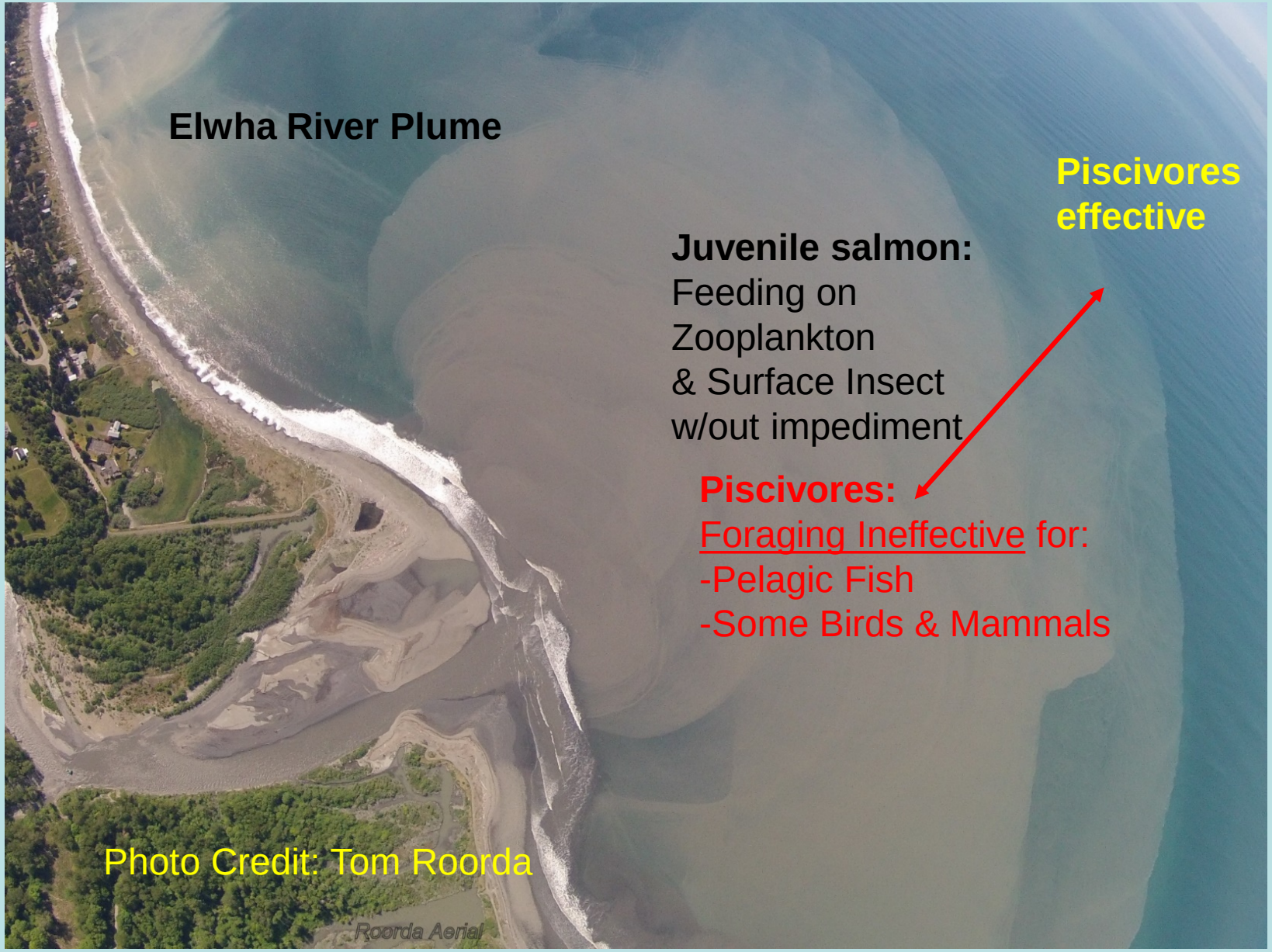


Christopher Krembs, WA Dept. Ecology



Increasing *Noctoluca:*
Gelatinous dinoflagellate
Feeds on Diatoms

Decline in edible phytoplankton (Diatoms)
Increased transparency & Predation risk


Elwha River Plume
Piscivores effective
Juvenile salmon:
Feeding on
Zooplankton
& Surface Insect
w/out impediment
Piscivores:
Foraging Ineffective for:
-Pelagic Fish
-Some Birds & Mammals
Photo Credit: Tom Roorda
Roorda Aerial

Mechanistic Integration Needed

Important to recognize mechanistic interplay among water quality-quantity with bottom-up and top-down processes as they affect salmon productivity & ecosystem health

Mechanistic Guide for Restoration

-Identify & target critical life stages & habitats

-Prioritize restoration of habitat **function** to enhance Growth & Survival

-Calibrate expectations to goals and actions targeting short- versus long-term restoration

Summary: Top-Down Processes

- Piscivorous Fish exhibit size-selective predation
  - Size-selectivity likely more variable for mammals & birds
  - Harbor seals implicated in marine mortality of steelhead, but their effects on Chinook and Coho less understood
- Visual foraging conditions have shifted in favor of predators
  - All major salmon predators primarily use vision to feed
  - Artificial lighting & skyglow have significantly increased nocturnal threat environment throughout Puget Sound
  - Increasing subsurface transparency increases efficiency of visual predators (shifting plankton dynamics, timing and duration of turbidity plumes: dams, erosion)

ALAN: Artificial Light At Night

Known & Potential Impacts

-Increase predation on juvenile salmon & forage fish during rearing & migration

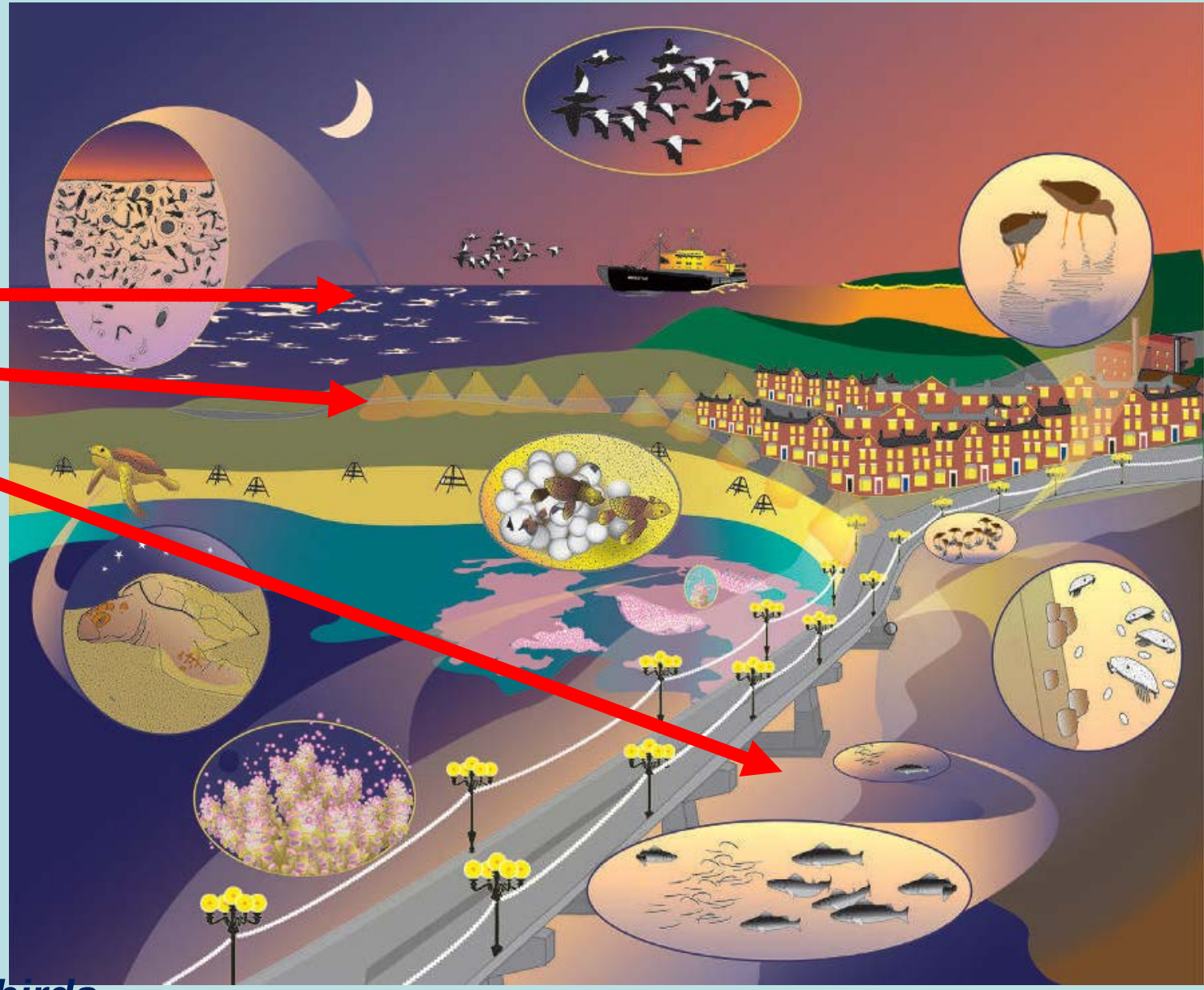
-Aggregation of fish under lighted piers or bridges intensifies predation.

-Suppress zooplankton diel vertical migration by artificial skyglow.

-Disrupt larval invert. settlement site selection in Sessile spp.

-De-synchronize broadcast spawning- Lunar cycle cues

-Extend nocturnal foraging by wading birds



Davies et al. 2014 Frontiers in Ecol & Env 12(6):347-355

-Increased skyglow increases chronic nocturnal predation on smaller fish

Acknowledgments

Collaborators

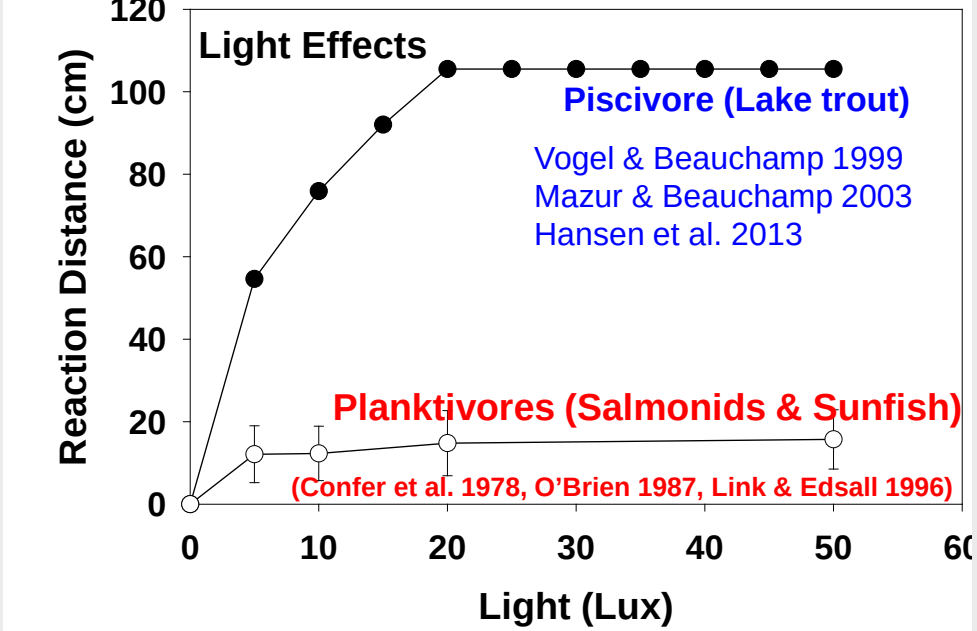
- Lummi Nation Natural Resources
- City of Bellingham
- Washington Conservation Corps
- Skagit River System Cooperative
- Tulalip Tribe
- Snohomish County
- Nisqually Tribe
- Washington Dept. Fish & Wildlife
- Crew of the F/V Franciscan No. 1
- Russell Barsh (Kwiaht Consulting)
- Mike O'Connell (LLTK)
- DFO Canada

Funding Sources

- Pacific Salmon Commission
- Washington Sea Grant
- San Juan County Salmon Recovery Board
- Washington RCO
- Puget Sound Partnership
- Long Live the Kings
- Pacific Salmon Foundation

Field and Lab Help

- Kristin Connelly, Jenny Gardner, Joe Donohoe, Casey Clark, Maggie O'Neil, Haila Schultz, Mark Sorel, Adam Hansen, Keister & Beauchamp Labs at UW



Env. Effects on Search Vol.

Light Effects:

-RD increases rapidly until reaching saturation intensity threshold (SIT)

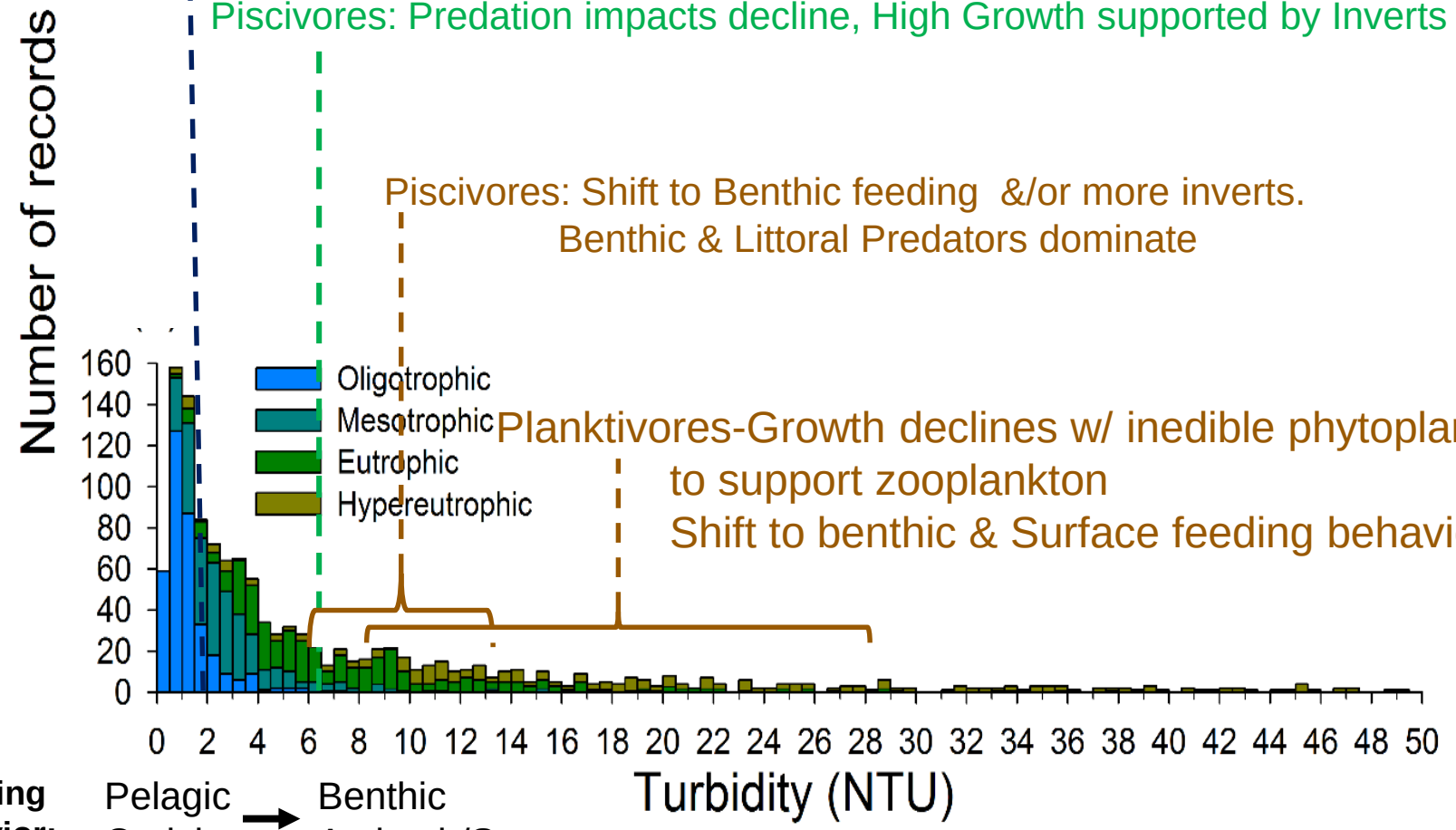
-Max RD for Piscivores ~5x higher than for Planktivores

Predicted Pelagic Piscivore-Planktivore Dynamics as Productivity Increases

Planktivores: go from Lo Growth & Hi Risk to Hi Growth & Hi Risk
Piscivores impose Heavy Predation: go from Lo Growth to High Growth

Planktivores: Risk declines rapidly & Growth Improves; Less DVM & Schools
Piscivores: Predation impacts decline, High Growth supported by Inverts

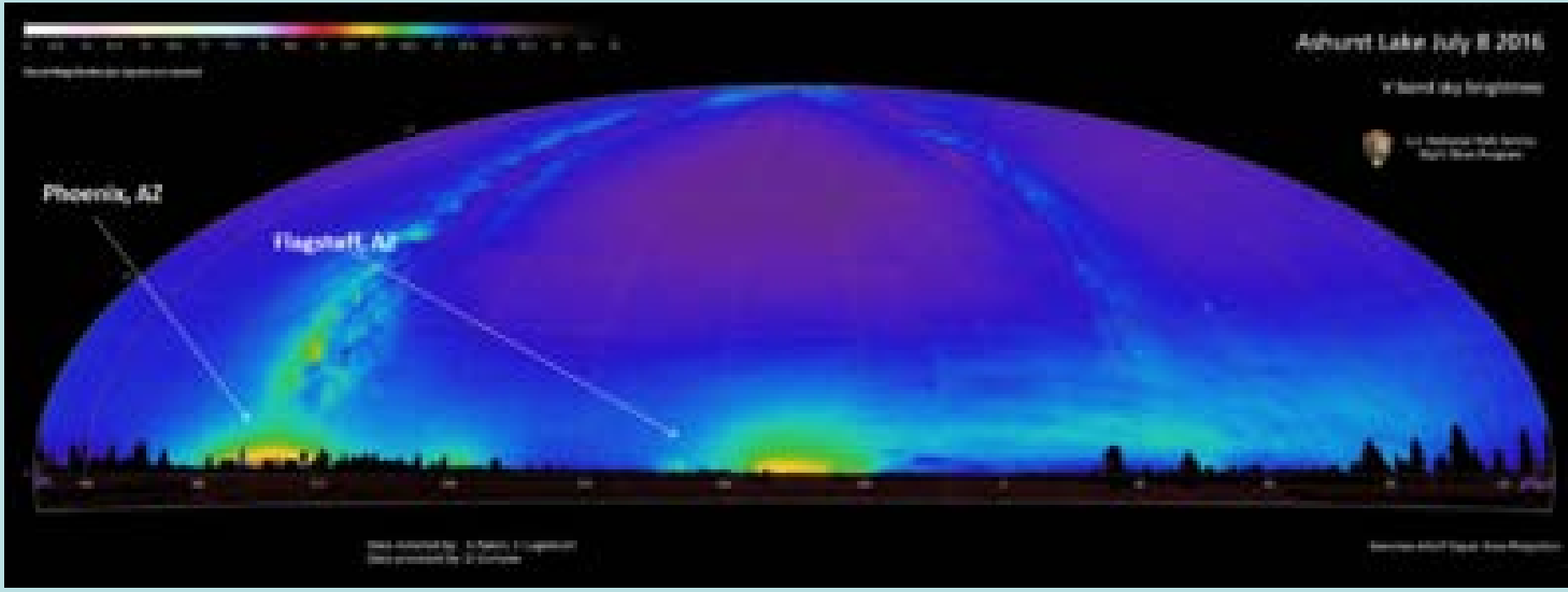
Piscivores: Shift to Benthic feeding &/or more inverts.
Benthic & Littoral Predators dominate



Planktivores-Growth declines w/ inedible phytoplankton to support zooplankton
Shift to benthic & Surface feeding behavior/spp.

Foraging Behavior: Pelagic Cruising → Benthic Ambush/Sweep

Sensory Mechanism: Visual → Tactile-Chemo-Electro reception


Phoenix, AZ
Flagstaff, AZ