

# Emerging Disease Threats to Pacific Salmon

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# What Do We Know About Fish Diseases and Pathogens?

- Most pathogens of fish were discovered in captive animals
- Include viruses, bacteria, protozoans and fungi
- Limited understanding of disease in populations of wild fish
- Stress can greatly increase mortality or disease
- Temperature is the most important environmental factor affecting the severity of disease in fish
- There is a global increase in emerging diseases of fish

# Why are Some Aquatic Animal Diseases and Pathogens Emerging?

- Better diagnostic assays
- Surveys of new species or geographic areas
- Intensive aquaculture in an endemic area
- Translocation of pathogens by aquaculture, fish trade, ballast water, anglers, etc.
- Natural movements of vectors, reservoirs and carriers
- Application of biotic stressors to ecosystems
  - Loss of habitat, changes in forage base
  - Presence of non-native species
- Changes in the physical environment
  - Inputs of contaminants or toxics
  - Temperature, water flow, pH, dissolved oxygen

# Disease in Fish Occurs in the Context of Many Anthropogenic Impacts

- Warming temperatures due to climate change
- Expansion of public and private aquaculture
- Inputs of pollutants, contaminants and toxins
- Habitat loss
- Commercial fisheries
- Non-native species

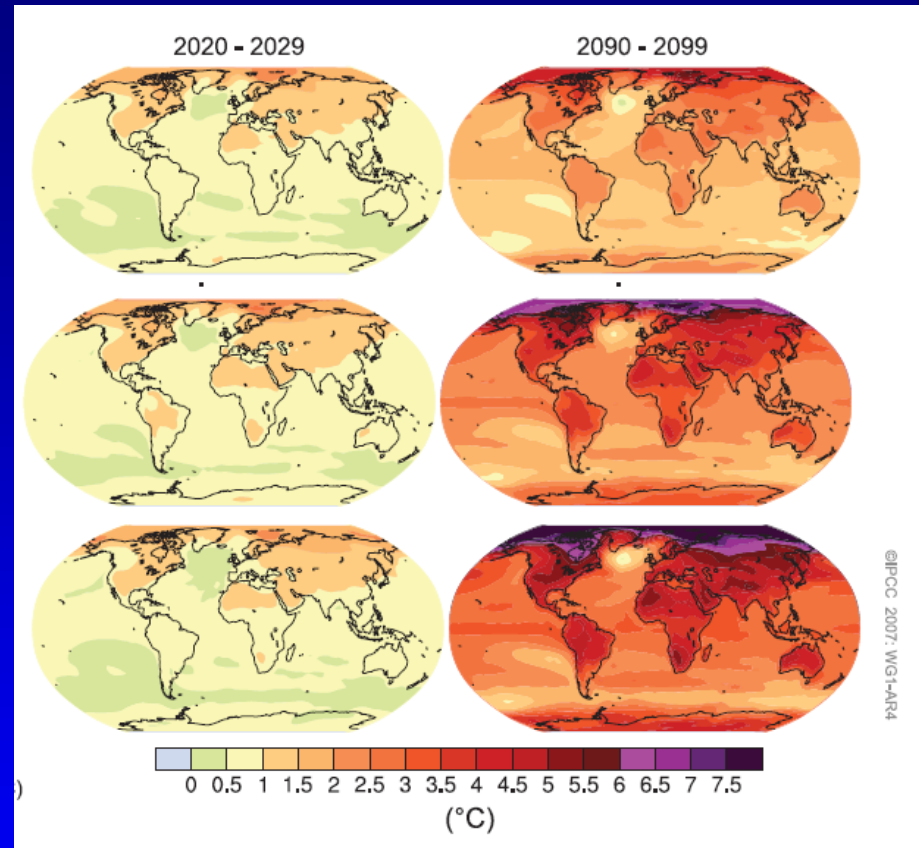


# Climate Change

*Intergovernmental Panel  
on Climate Change*

“Warming of the climate  
system is unequivocal”

- Melting ice and snow
- Violent weather
- Droughts and floods
- Ecosystem disruption
- Sea level rise
- Increased disease



Columnaris in Klamath and Columbia Rivers and Ichthyophonus  
in Yukon River are examples

# Effect of Water Temperature on Coho Salmon Infected with *Flavobacterium columnare*

Temperature (°C)	4	7	9	12	15	18	21	24
Control (% Dead)	1	0	0	1	3	4	1	1
Infected (% Dead)	0	0	0	4	51	99	100	100

Holt et al. 1975

# Time-to-Death (days) of Ichthyophonus-infected Trout at Three Temperatures

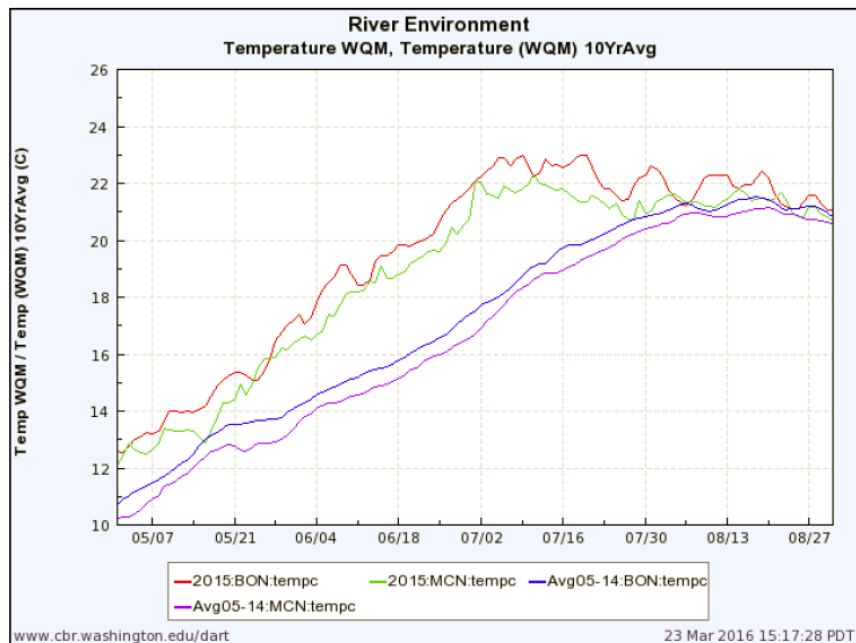
	<u>Infected</u>	<u>Control</u>
10°C	21.6	n.d.
15°C	13.4	n.d.
20°C	10.7	n.d.

Kocan et al. 2009

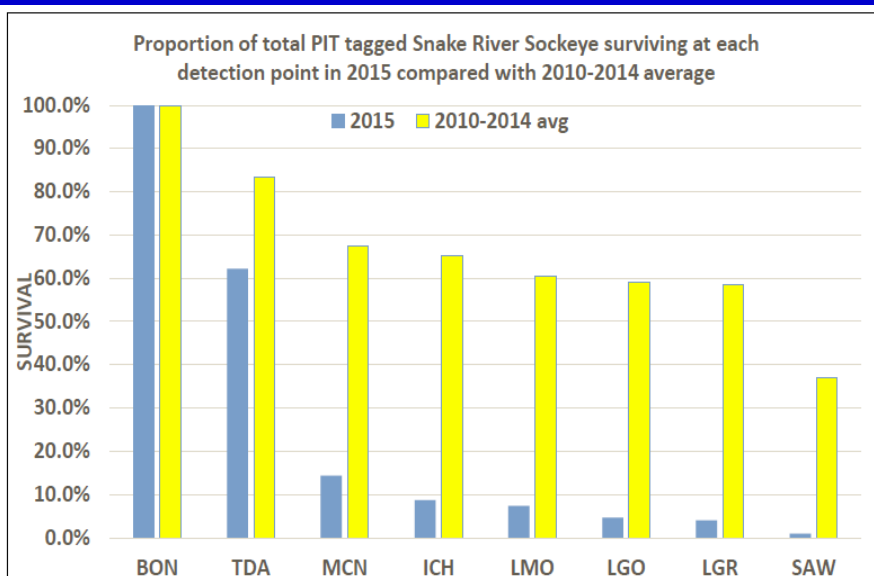
# Columbia River Fish Kills

- Catastrophic loss of returning adult sockeye in 2015
- Large run of fish decimated by disease during migration
- Very low flows and very high temperatures early in run
- Fish held in pools between mid-Columbia dams due to temperature blocks
- Death from columnaris and fungus
- Large sturgeon also affected
- Loss of more than 90% of some Snake River stocks





**Figure 2.** Columbia River temperature at Bonneville Dam and McNary Dam (forebays) in 2015 relative to the prior 10-year average.

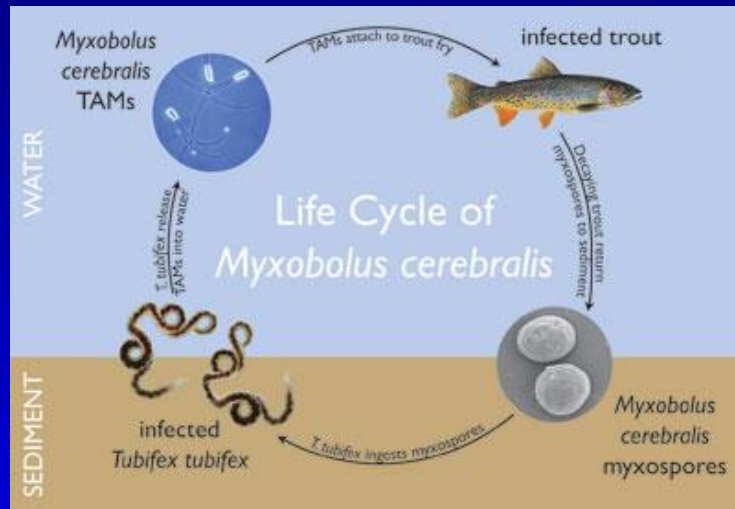


**Figure 12.** Proportion of total PIT-tagged Snake River sockeye salmon detected at Bonneville Dam that survived to each subsequent detection point (The Dalles, McNary, Ice Harbor, Lower Monumental, Little Goose, and Lower Granite dams and the Sawtooth Hatchery weir) in 2015 compared to average for 2010-2014. Source: PTAGIS data

# Introduction of Exotic Pathogens

- Often associated with public and private aquaculture or the trade in ornamental fish
  - International movements of infected fish or eggs
  - Use of raw fish or fish products as food for cultured species
- Recreational fishing can spread pathogens
  - Baitfish
  - Angler's equipment
- Other pathways also important
  - Ballast water
  - Migratory fish
- Whirling disease, herpesvirus in Australian pilchards, viral hemorrhagic septicemia, infectious salmon anemia, spring viremia of carp and koi herpesvirus are examples

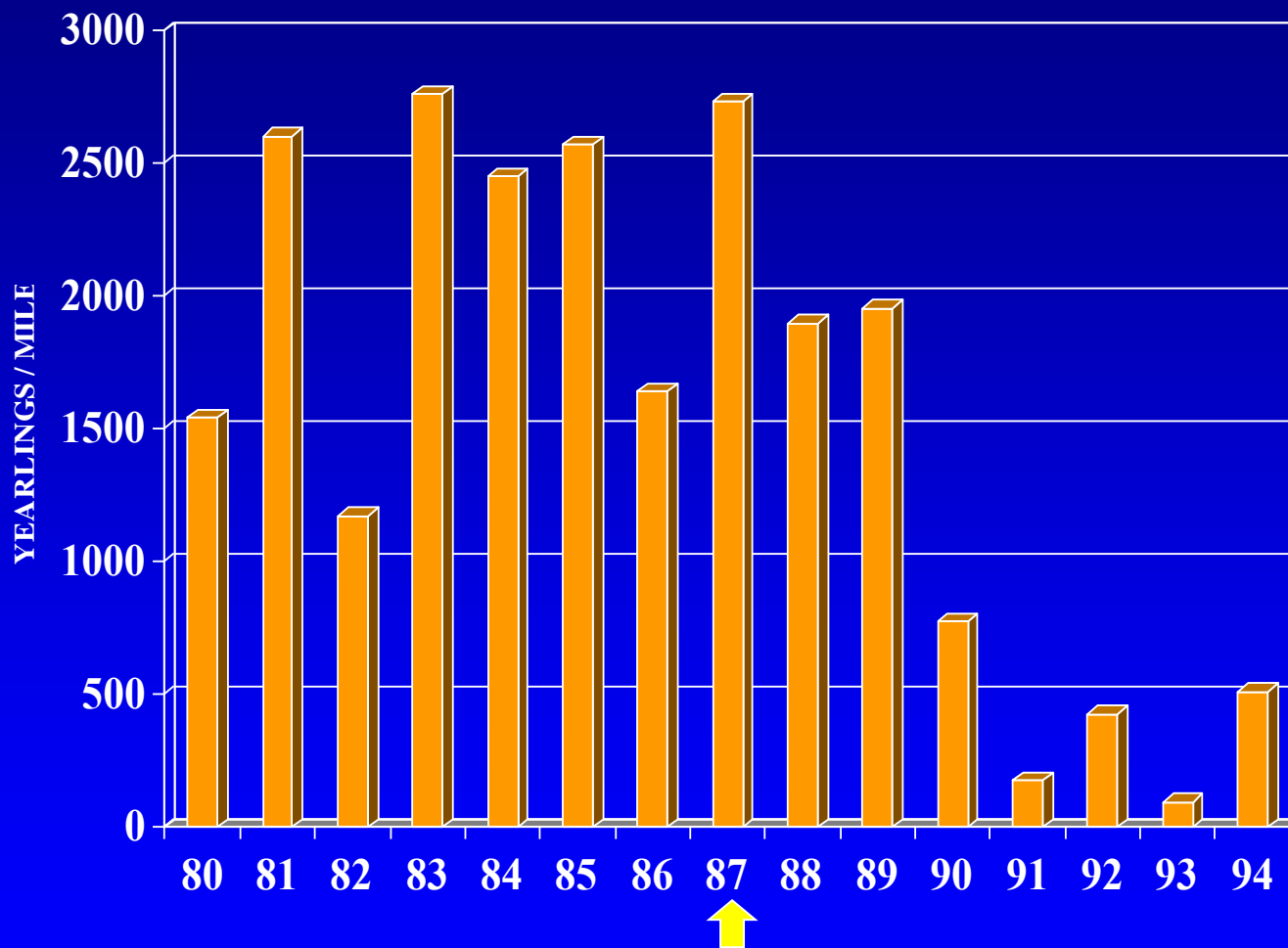
# Whirling Disease in the Madison River, Montana



- Caused by myxosporean parasite, *Myxobolus cerebralis*
- Introduced from Europe to US in 1950s
- By 2000 - spread widely to nearly half the states via movement of infected fish
- Variable losses in wild or native trout (esp. rainbow)
- Declines of 90% or greater in some systems of the inter-mountain west
- Increased resistance in some stocks of rainbow trout
- Limited recovery in some populations



# Yearling Class Strength in Madison River (1980-1994)



**Whirling disease introduced in 1987**

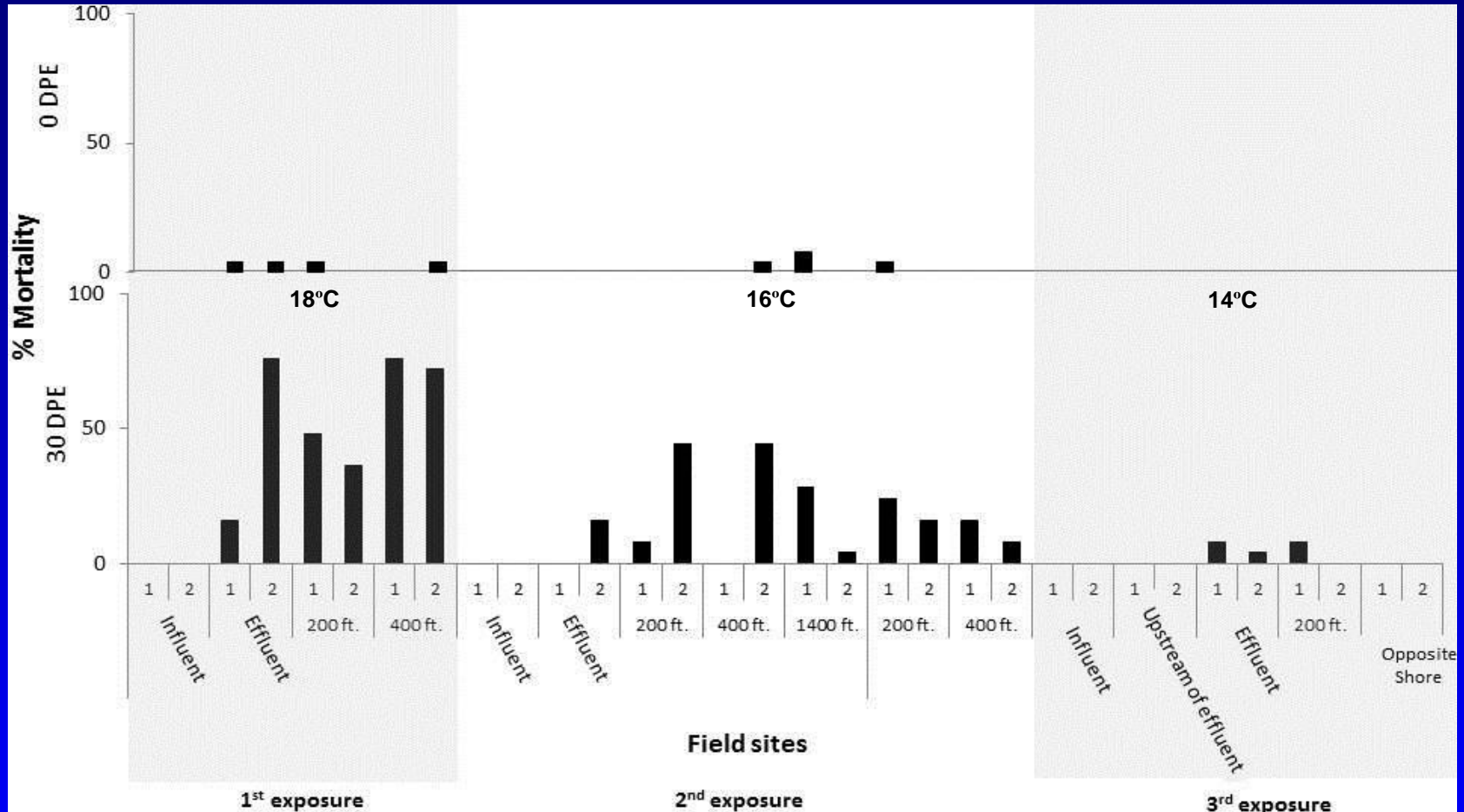
D. Vincent, Pers. Comm.

# Amplification of Endemic Pathogens

- Involves pathogens already maintained among wild fish
- Diseased fish in intensive aquaculture can release very high levels of pathogens into the environment that may increase “infection pressure” on native populations
- Aquaculture facilities may also release pathogens for extended times that affect different life stages than typical of the wild
- Sea lice, bacterial kidney disease, columnaris, betanodaviruses, and infectious pancreatic necrosis are examples



# Salmon Hatcheries as Pathogen Sources



Mortality from *Flavobacterium columnare* infections in replicate groups of *Oncorhynchus tshawytscha* sentinel fish exposed at Dexter Ponds Oregon on Sept. 13-20; Sept. 27-Oct. 2; Oct. 17-24, 2013.

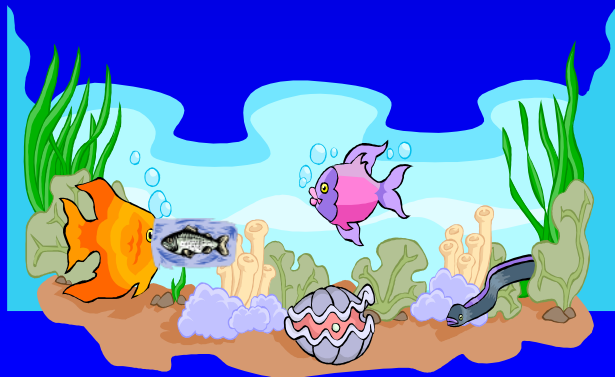
# Evolution of Endemic Pathogens

- Prolonged exposure of fish in hatcheries allows pathogens to evolve to become more virulent, to tolerate different conditions (e.g. temperature) or to infect a new species ('host jump')
- Such hatchery-adapted pathogens may then 'spill-back' to increase the risk to wild fish
- Nature of the pathogen, hatchery practices and exposure history of wild stocks are important factors
- Infectious hematopoietic necrosis, viral hemorrhagic septicemia, piscine orthoreovirus, columnaris and infectious salmon anemia are examples

# Drivers of Pathogen Evolution Leading to Host Jumps and Increased Virulence

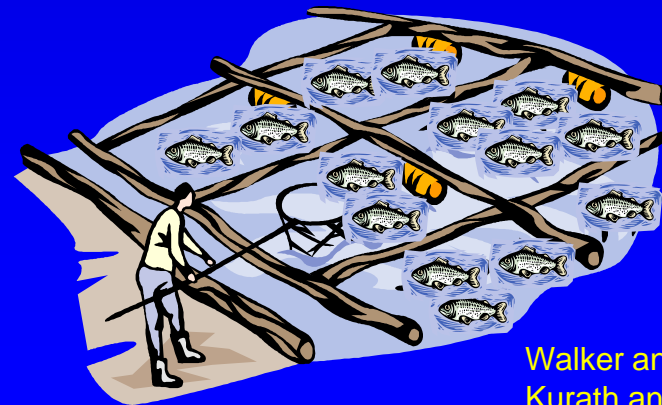
## Wild populations

- Relatively low density
- Different species
- Multiple age classes
- Variation in innate resistance
- Variable levels of immunity
- Intermittent exposure sources
- Pathogen at stable fitness peak



## Hatchery populations

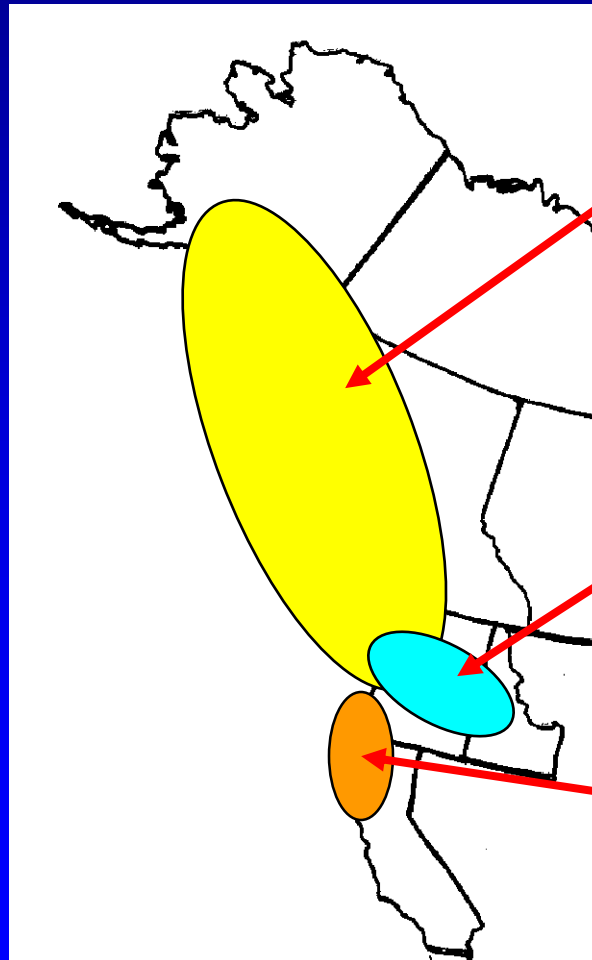
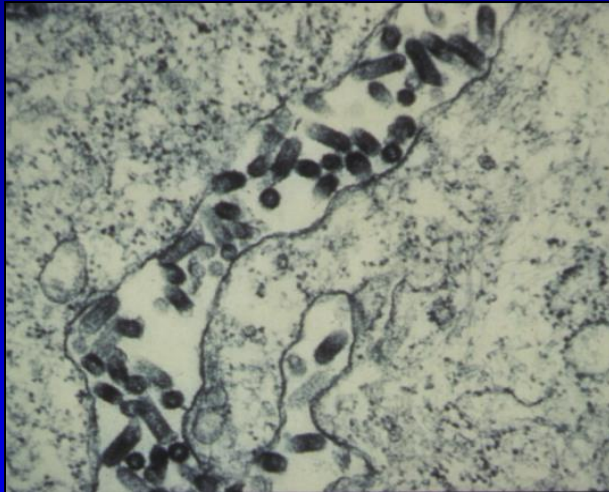
- High density rearing
- Single species and age class
- Similar genetic background
- Frequent input of naïve animals
- Continuous chain of infection
- No constraint to increased virulence
- Allows adaptation to new host





# Evolution of Pathogens in Aquaculture

## Infectious Hematopoietic Necrosis Virus



**U**

Upper region - Alaska, British Columbia, Washington and Oregon. Mostly sockeye

**M**

Middle region - Hagerman Valley, Idaho extending into lower Columbia River Basin. Mostly rainbow and steelhead

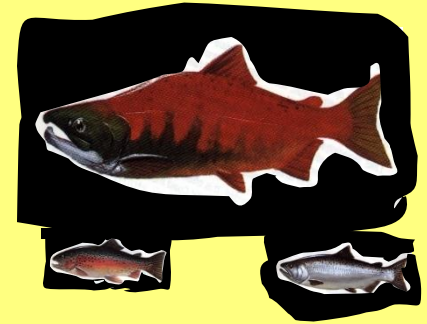
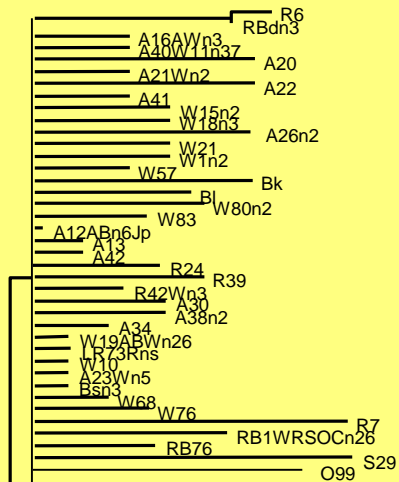
**L**

Lower region - Sacramento River Basin, coastal rivers of Northern California and Southern Oregon. Mostly Chinook

# IHN Virus Phylogeny

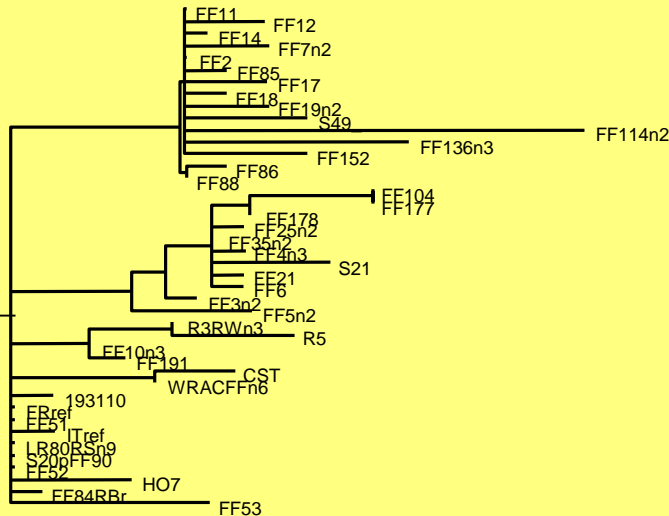
Kurath et al. 2003

U genogroup  
Maximum diversity 3.0%



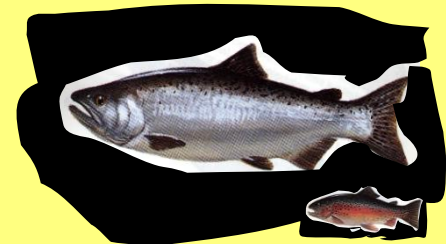
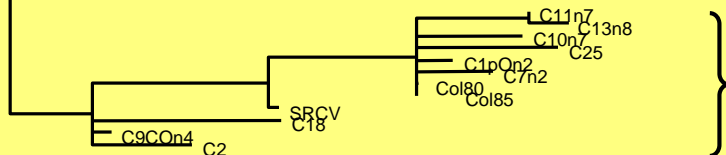
Sockeye,  
chinook, steelhead

M genogroup  
Maximum diversity 7.6%



Rainbow trout  
steelhead, Chinook

L genogroup  
Maximum diversity 3.3%



Chinook, steelhead

# IHNV in the Columbia River Basin

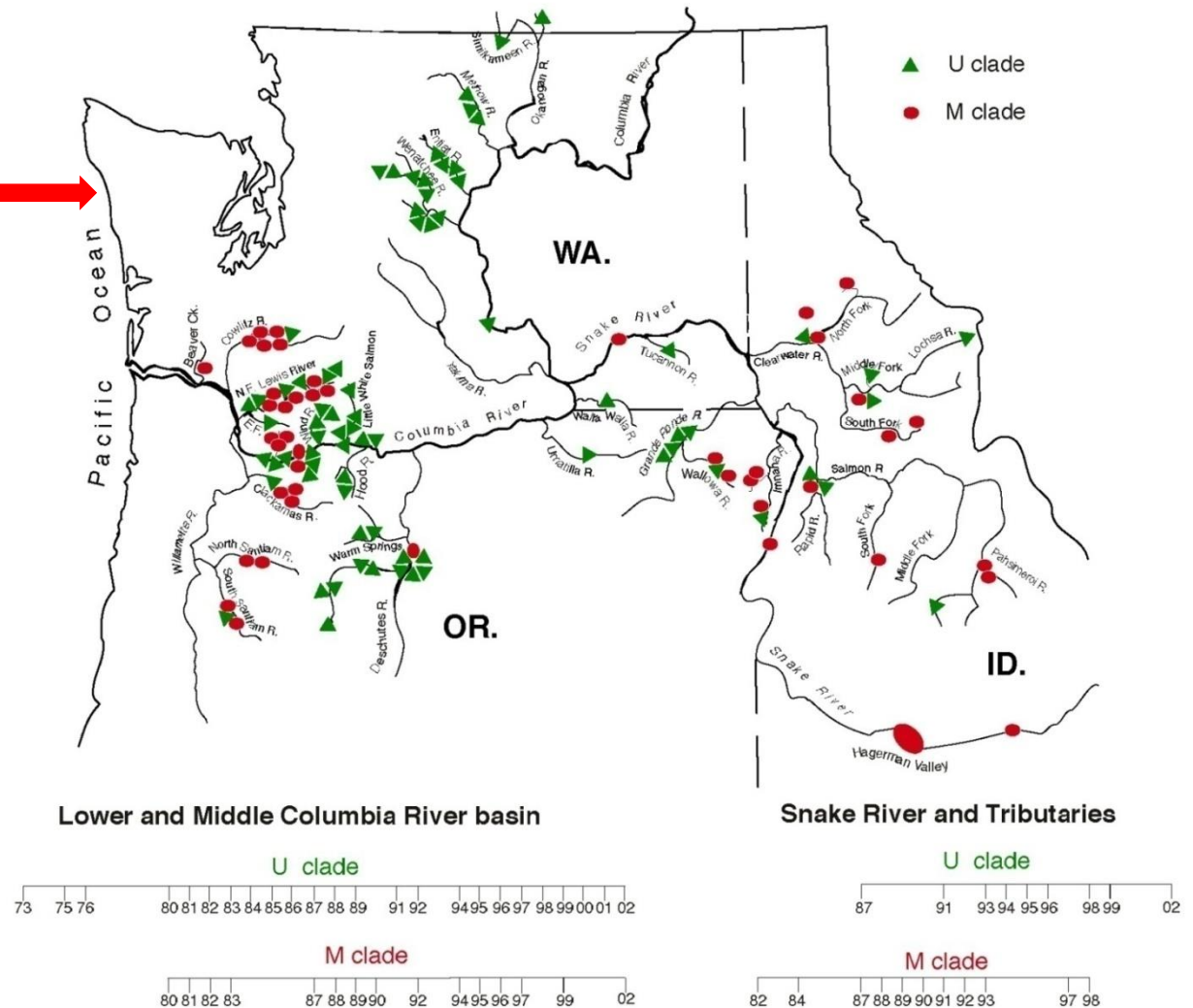
2007-2011 - M genogroup of IHNV emerges in hatchery and wild steelhead on the Washington coast

Breyta et al. 2013



● M group virus

▲ U group virus



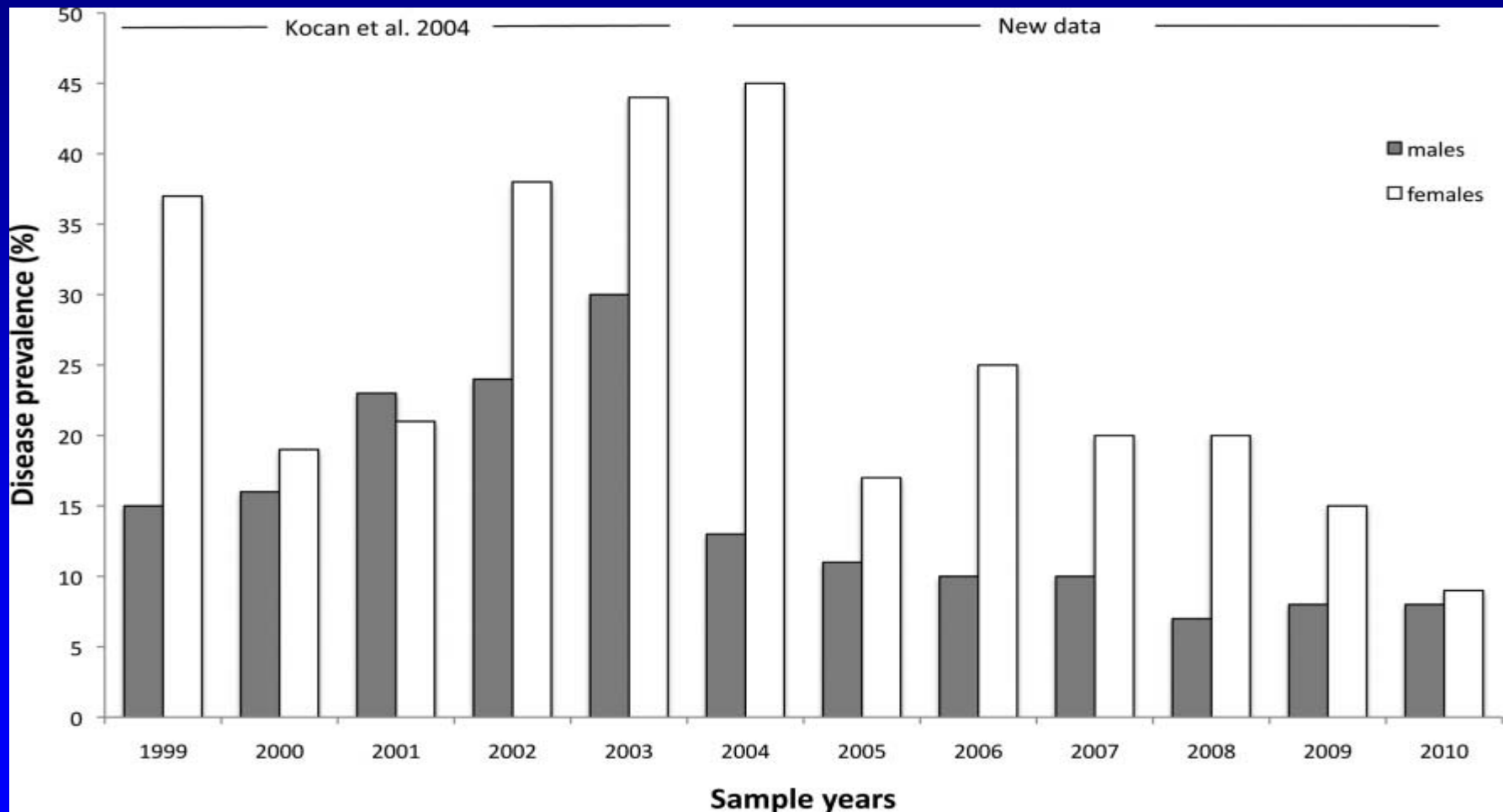
# Alterations in Food Webs

- Industrial fisheries, disease, non-native species, habitat alterations and climate change can deplete normal prey species or change food webs
- Prey-switching can alter pathways of exposure to pathogen
- Prey-switching can alter aspects of disease resistance tied to nutritional factors
- Ichthyophonus in Chinook salmon, thiamine deficiencies in the Baltic Sea and Great Lakes are examples



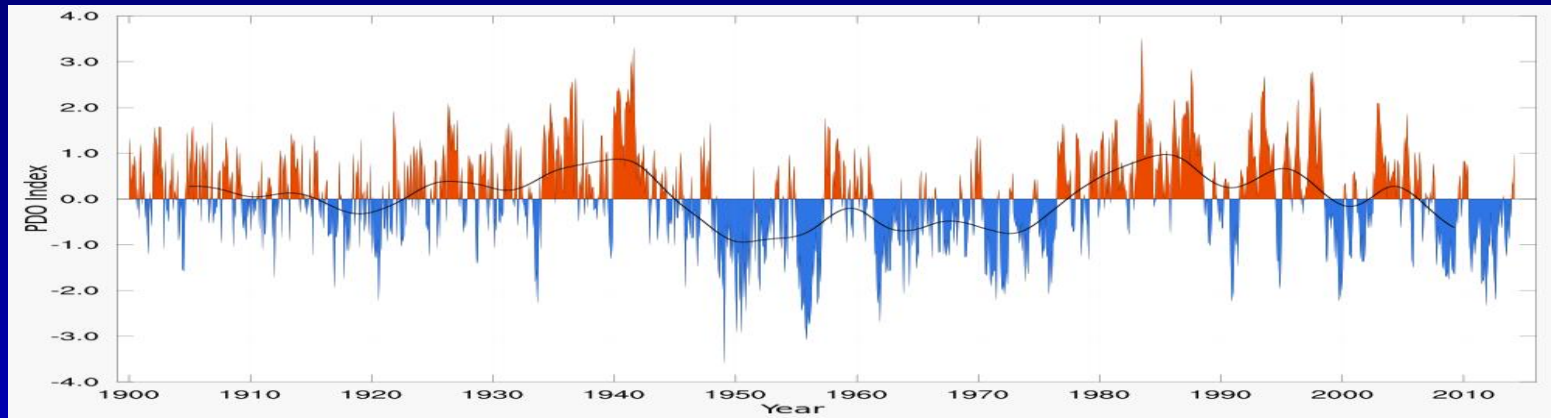


# Prevalence of Ichthyophonus in the middle portion of the Yukon River 1999-2010



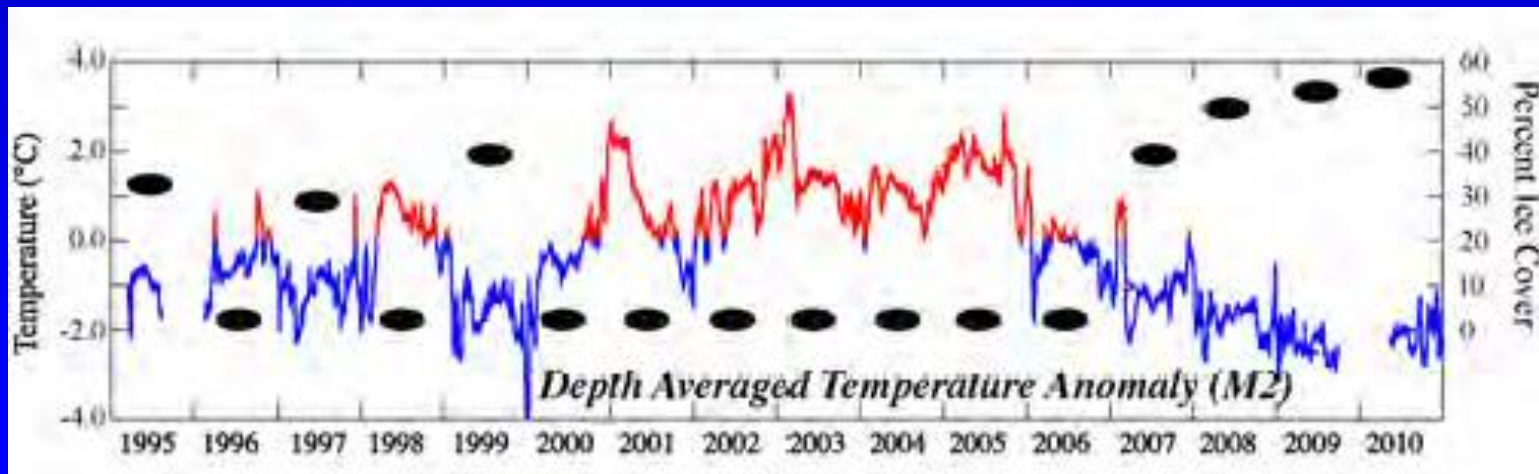


# Pacific Decadal Oscillation 1900-2014



<http://jisao.washington.edu/pdo/>

## Temperatures in the Bering Sea 1995-2010

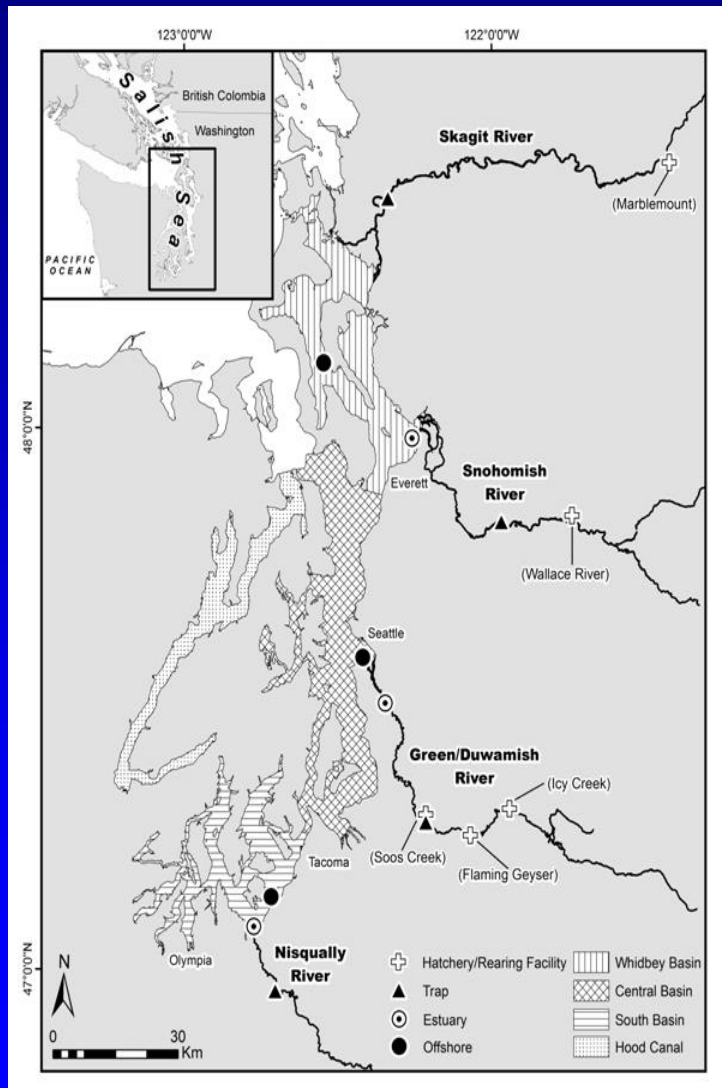


# Introduction of Pollutants to Ecosystems

- Effluents from cities, agriculture or industry may have adverse effects on the health of wild fish or increase stress
  - Inputs of chemicals (toxins, drugs, antibiotics, hydrocarbons)
  - High loads of nutrients (algae growth, low D.O.)
  - Altered temperature (thermal effluents)
- Some compounds are estrogenic or immunosuppressive and affect the health or immune function of aquatic animals
  - Estrogenic compounds – altered reproduction, immune function
  - Metals, herbicides, pesticides – direct toxicity, immune suppression
- Most likely in systems with high inputs or in small watersheds
- Chesapeake Bay, Great Lakes, Puget Sound are examples



# Contaminant Exposures in Puget Sound, Washington



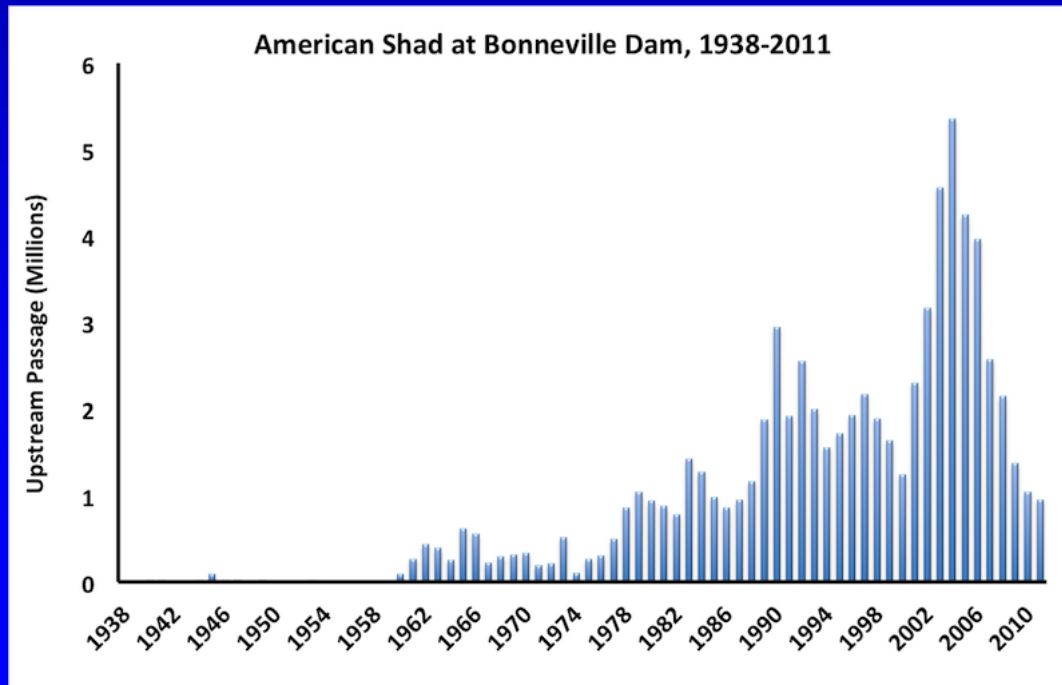
- Puget Sound receives a complex mixture of effluents from cities, agriculture and industry
- Fish from certain areas show higher contaminant burdens and greater clinical disease
- Many compounds present have been shown to affect fish immune function and disease susceptibility in salmon

Arkush et al. 2015  
Chen et al. 2018

# Introduction or Spread of Non-native Species

- Non-native species may be a source of introduction for exotic pathogens
- Non-native species may amplify endemic pathogens
- Non-native species may serve as reservoirs of infection
- American shad, Grass carp and Round gobi are examples

# Prevalence of American Shad in the Columbia River 1938 - 2011



- American shad were imported into California in 1871 and spread northward
- In the Columbia River, shad rapidly increased in number until they exceeded that of salmon
- Shad serve as a reservoir of *Ichthyophonus* and are a potential disease risk for Pacific salmonids

Hershberger et al 2009

# Summary

- Diseases in wild fish occur in the context of other factors
  - Warming temperatures due to climate change
  - Expansion of public and private aquaculture
  - Inputs of pollutants, contaminants and toxins
  - Habitat loss
  - Commercial fisheries
  - Non-native species
- Many of these factors can act synergistically to drive the emergence of new diseases in aquatic animals
- More research is needed on the effects of these factors on natural mortality levels in wild stocks

# Thank You!

