Ocean Outbreaks: Salmon, Starfish, and Beyond

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Salmon in the Pacific NW

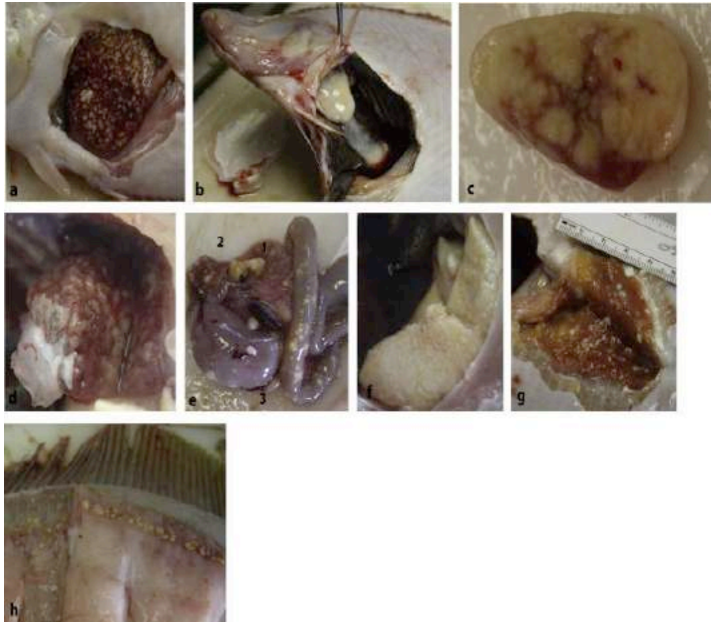
- Anadromous
  - ocean → freshwater to spawn
- Predatory
- What are some threats salmon face discussed in the text?
  - Warming temperatures
    - Heat stress, increase disease susceptibility
  - Spillover from aquaculture
    - outcompeting, interbreeding
      - Ex: San Juan island escape
  - Overfishing
  - Pollution

Infectious Salmon Anemia Virus (ISAV)

- RNA virus - replicates even faster
- Easy transmission
  - Live up to 8 days in water
  - Vectored fish to fish and by sea lice
  - Via shipments of live fish
- First appeared in farmed salmon in Norway in 1984
  - Spread globally (Scotland 98, Chile 2007, Canada 96, Maine 2001)
  - 90% mortality
- Since then have controlled it through hygiene, stringent culling and isolation procedures, and vaccinations
- Canda, BC, Oregon and Washington most bountiful salmon pops
  - Wondering if ISAV in pacific NW
    - No detection found yet since potential one in BC which was dismissed for unapproved molecular primers

Diseases affecting PNW Salmon

- Protistan *Ichthyophonus boferi* in Chinook in Yukon River
  - Tissue tropism, necrosis, inflammation
  - Fish-killing pathogen with broad host range
    - Present in salish waters, responsible for disease in over 100 species, lethal
  - Kills directly or passed on by predation
    - Carl Hunstberger: outbreaks recently in herring from NW Atlantic
      - Elevated temperatures ↑ outbreak & impacts in lab



Prevalence and description of *Ichthyophonus* sp. in yellowtail flounder (*Limanda ferruginea*) from a seasonal survey on Georges Bank.

Diseases affecting PNW Salmon

- Infectious haematopoietic necrosis virus in PNW
  - Anemic, hemorrhaging, inflammation
  - Spreads in freshwater river phase
  - 2001-3 outbreak in BC , 81% of farms

Journal of Aquatic Animal Health 14:25–34, 2002
American Fisheries Society 2002

Genetic Characterization of Infectious Hematopoietic Necrosis Virus of Coastal Salmonid Stocks in Washington State

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Abstract.—Infectious hematopoietic necrosis virus (IHNV) is a pathogen that infects many Pacific salmonid stocks from the watersheds of North America. Previous studies have thoroughly characterized the genetic diversity of IHNV isolates from Alaska and the Hagerman Valley in Idaho. To enhance understanding of the evolution and viral transmission patterns of IHNV within the Pacific Northwest geographic range, we analyzed the G gene of IHNV isolates from the coastal watersheds of Washington State by ribonuclease protection assay (RPA) and nucleotide sequencing. The RPA analysis of 23 isolates indicated that the Skagit basin IHNV isolates were relatively homogeneous as a result of the dominance of one G gene haplotype (S). Sequence analysis of 303 bases in the middle of the G gene (midG region) of 61 isolates confirmed the high frequency of a Skagit River basin sequence and identified another sequence commonly found in isolates from the Lake Washington basin. Overall, both the RPA and sequence analysis showed that the Washington coastal IHNV isolates are genetically homogeneous and have little genetic diversity. This is similar to the genetic diversity pattern of IHNV from Alaska and contrasts sharply with the high genetic diversity demonstrated for IHNV isolates from fish farms along the Snake River in Idaho. The high degree of sequence and haplotype similarity between the Washington coastal IHNV isolates and those from Alaska and British Columbia suggests that they have a common viral ancestor. Phylogenetic analyses of the isolates we studied and those from different regions throughout the virus's geographic range confirms a conserved pattern of evolution of the virus in salmonid stocks north of the Columbia River, which forms Washington's southern border.

Emmenegger, E. J., & Kurath, G. (2002). Genetic Characterization of Infectious Hematopoietic Necrosis Virus of Coastal Salmonid Stocks in Washington State. *Journal of Aquatic Animal Health*, *14*(1), 25–34. doi: 10.1577/1548-8667(2002)014<0025:gcoihn>2.0.co;2

- IHNV evolving and transmitting from BC and Alaska down to Washington

Fisheries

- Aquaculture is increasing as part of solution to feeding growing population
  - PNW most bountiful salmon population in U.S.
- Decline in fishery populations → negative effects:
  - Wild salmon fisheries essential to economy
    - Marine disease responsible for billions of dollars of loss
    - 67 diseases, 49% fish, 28% mollusc, 21% crustacean, 1% echino
  - Food source for orcas (and us!)
- Innovations:
  - Development of vaccines
  - Breeding resistant fish
- Challenges:
  - Difficult to track disease in wild populations
  - Transmission different between wild vs. farmed

What comes next?

Given this information, what changes should be made to prevent future disease outbreaks in fisheries?

- Need:
  - Develop more stringent protocols
  - Better hygienic practices
  - Careful surveillance to safeguard from disease
  - Better policy management in regard to wild fisheries and aquaculture

A Keystone Species

What is a keystone species?

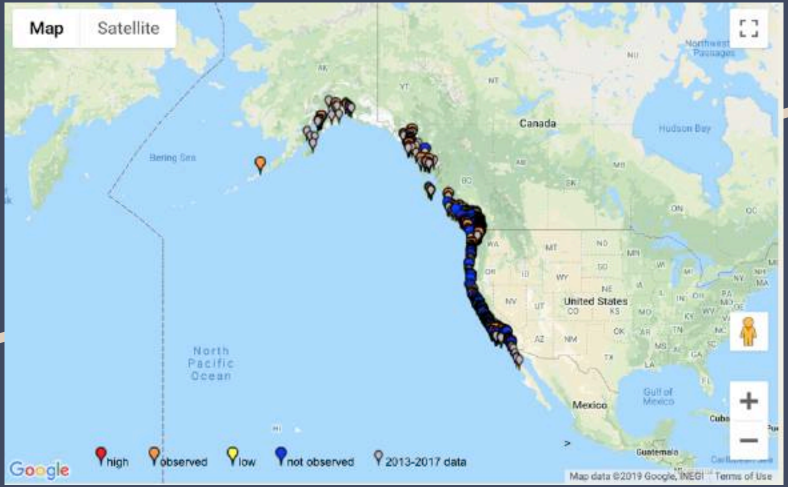
Keystone species: a species that has a disproportionately large effect on its environment relative to its abundance.

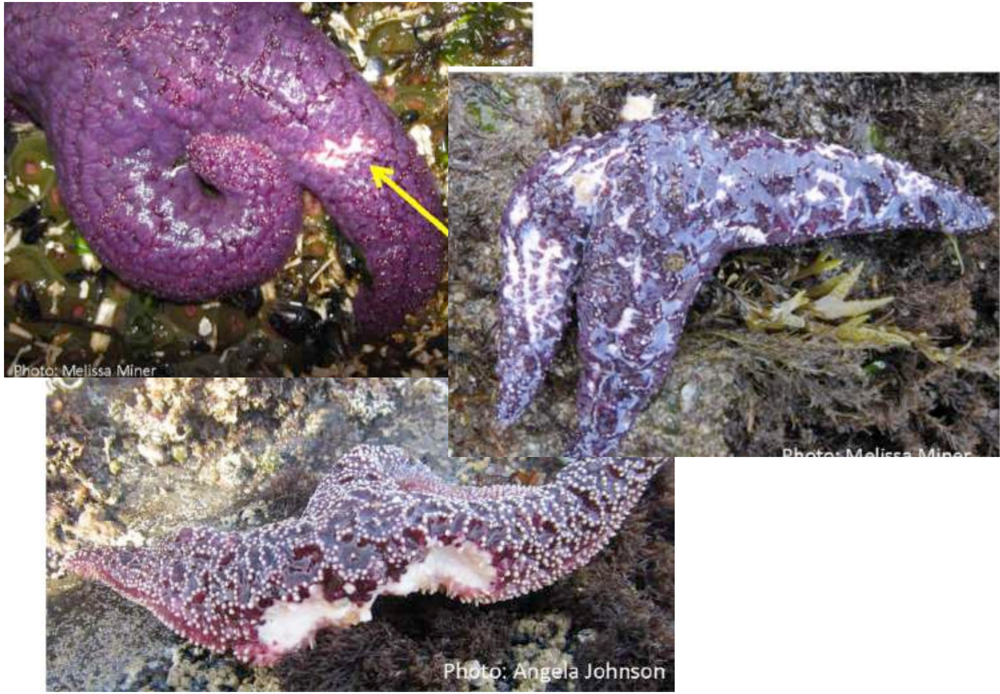
Sea Stars - Asteroids

- Important Marine predators
- Help maintain biodiversity of intertidal ecosystems
- Eat marine herbivores like mussels and sea urchins
- Can travel over large distances

Sea Star Wasting Disease (SSWD)

- Mass mortality event of sea stars
  - Impacted 20 species of asteroids
- Ranged from Southern Alaska to Baja California

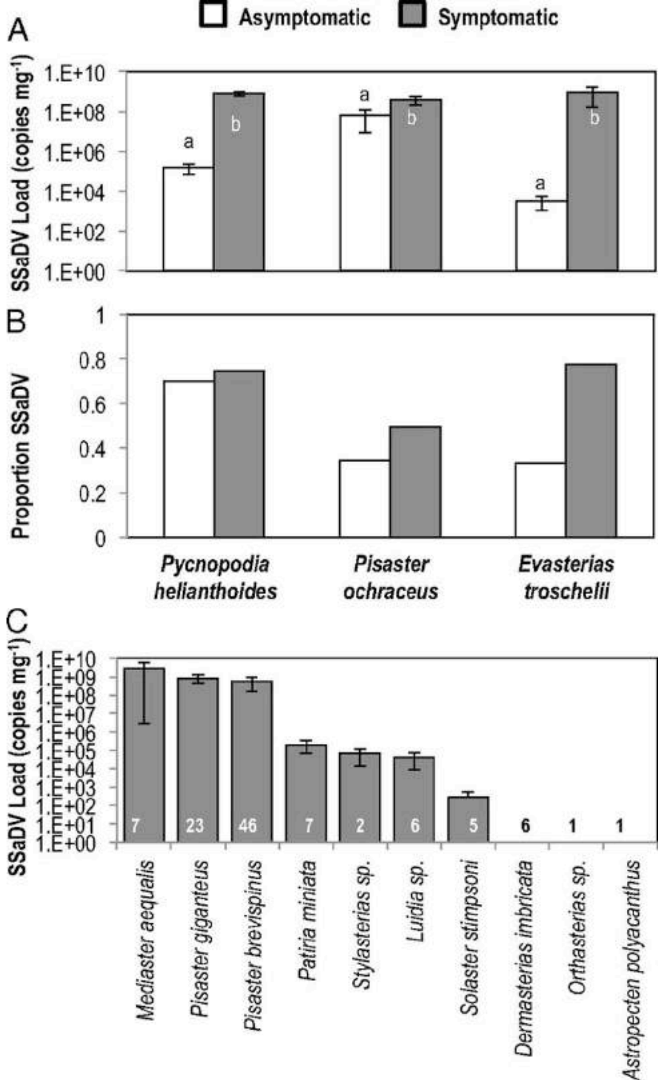




Symptoms:
- Twisting of arms
- Development of lesions on the arms and body
- Tissue degradation
- Loss of one or multiple arms
- Internal organs emerging from lesions
- Death by rapid degradation “melting”

Sea Star Wasting Disease (SSWD)

- Originally thought to be caused by sea-star associated densovirus
- Warming events possibly activating the disease
  - Stresses the animal
  - Creates a better environment for the virus
- More recent studies have found that only SSWD in sunflower stars can be attributed to the densovirus
- The overall SSWD is now thought to be caused by a collection of environmental and viral causes throughout the range



The Difficulties with Marine Pathogens

- The Ocean provides the ideal breeding ground for many pathogens
- Need to eliminate environmental causation factors
  - Temperature anomalies
  - Pollution
  - Changes in salinity
- Greater complexity of microbes

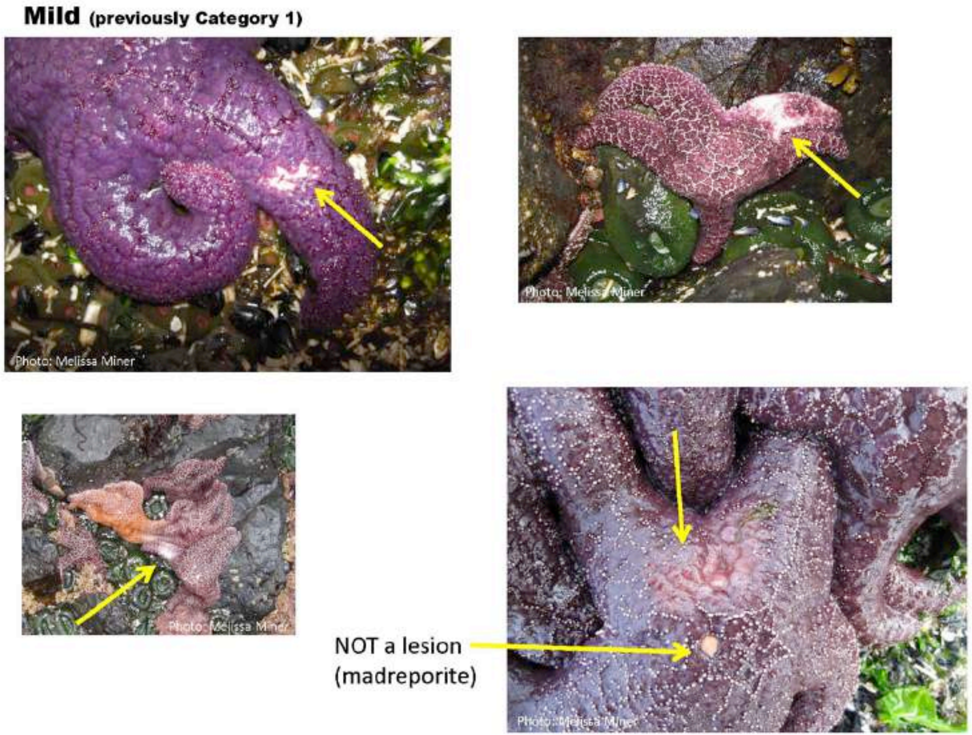
What were some of the early barriers faced when trying to address the causes of the mass mortality event?

- Lack of consensus among the scientific community
- Lack of proper funding
- Mortality event began before proper surveys could begin
- Difficulties in identifying causative marine pathogens
  - Need for large volume of samples
  - High number of marine viruses in samples
  - Need for proper quarantine facilities
- Unpredictability of new mortality events

The Importance of Citizen Science

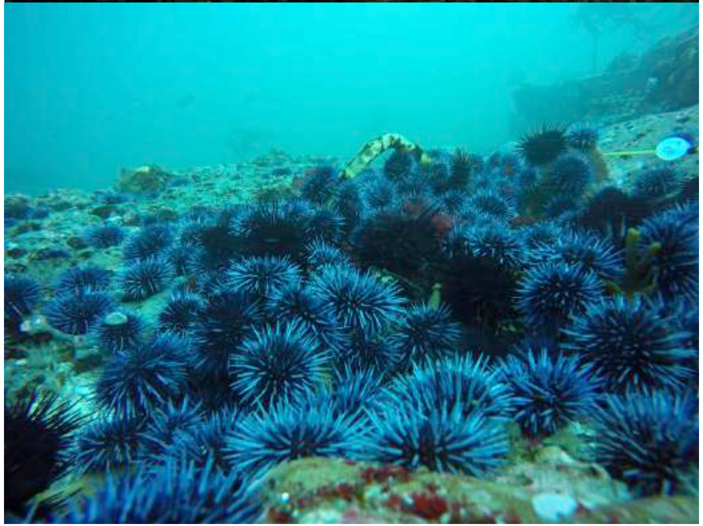
Multi Agency Rocky Tidal Intertidal Network (MARINe)
seastarwasting.org

- Without the observations of divers early on in the outbreak the disease may have gone unnoticed for a long time
- Citizen science data system
- Public contributions of instances of SSWD
- Contributes to long-term monitoring of SSWD



The Aftermath

- As of September 17, 2019 Sunflower stars have disappeared from the coasts of California and Oregon
    - Extreme declines in the populations in Washington and Alaska
    - Decimation of kelp beds with replacement by urchin barrens
    - Trophic cascade has significant effect on overall ecosystem
        - Loss of nursery sites and fish habitat
- Some good news!
    - Ochre stars have bounced back in certain locales
    - The newly recruited ochre stars exhibit a significant genetic change suggesting the next generation is resistant to SSWD



Nature’s Services to the Rescue

- Plastic pollution in coral triangle

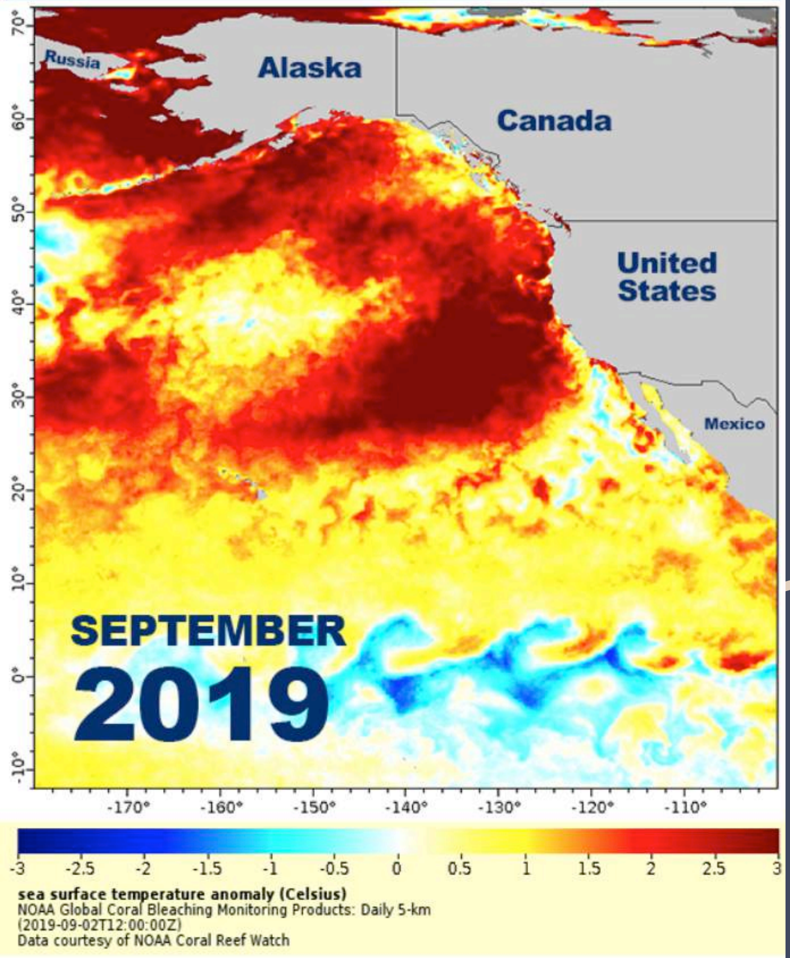
- Seagrass beds in the removal of bacteria

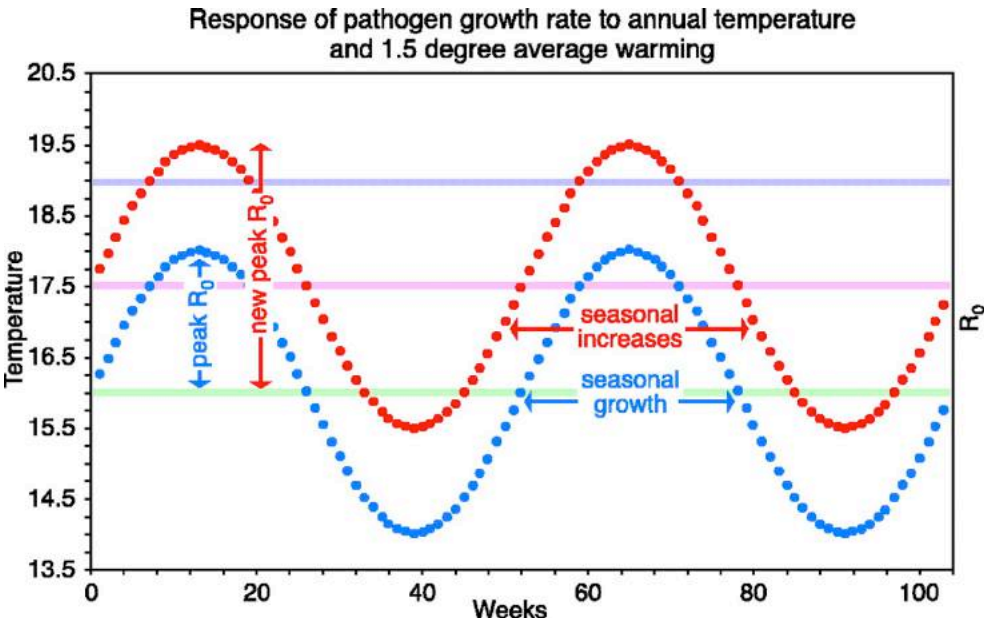
Marine Mammal Morbillivirus

- Morbillivirus virus is a close relative to canine distemper disease
- Has been recorded in seals and cetaceans
  - Phocine Distemper virus - Seals
  - Cetacean morbillivirus- Dolphins and Whales
- Transmittable to southern resident killer whales
- Has the potential to impact the recovery of the endangered species

Could there be a benefit to having a disease outbreak in a marine megafauna like orcas?

Current





- Shows influence of an avg 1.5° rise in temperature on reproductive rate of pathogen. When *R*0 > 1, a pathogen will increase. The lower
- blue line = average weekly temperature before climate change, the upper red line = avg weekly temperature after an average 1.5° temperature increase
- disease problems severe when temp. > pink line and epidemic > purple line
- increases in temperature increase peak growth rate and annual duration of the period during which the pathogen is a problem

Harvell, D. C., et al. (2002). Climate Warming and Disease Risks for Terrestrial and Marine Biota. *Science*, *296*(5576), 2158–2162. doi: 10.1126/science.1063699

Monitoring Disease in the Future

- We have the ability and resources for better monitoring on land; implicate in marine
  - Potential use of similar systems in human disease outbreak monitoring
- Cut off flow of human sewage/animal waste into oceans
- Protect seagrass beds
- Policy change
  - Plastic bans

Tuesday we were asked if we were researching a disease, would we prefer to study a slow or fast disease outbreak.

Given all four marine outbreaks would you prefer to have to study a rapidly progressing or slower progressing marine disease? Have you changed your opinion since last class? Is there new information that has solidified your original opinion?

Discussion

What role can policy makers play in helping to monitor and prevent disease outbreaks in marine ecosystems in the future?

Rank; policy, research, or public awareness in terms of their importance in addressing marine outbreaks. Should they all play an equal role? Which one do you think our current approaches emphasizes the most?

References

Emmenegger, E. J., & Kurath, G. (2002). Genetic Characterization of Infectious Hematopoietic Necrosis Virus of Coastal Salmonid Stocks in Washington State. *Journal of Aquatic Animal Health*, *14*(1), 25–34. doi: 10.1577/1548-8667(2002)014<0025:gcoihn>2.0.co;2

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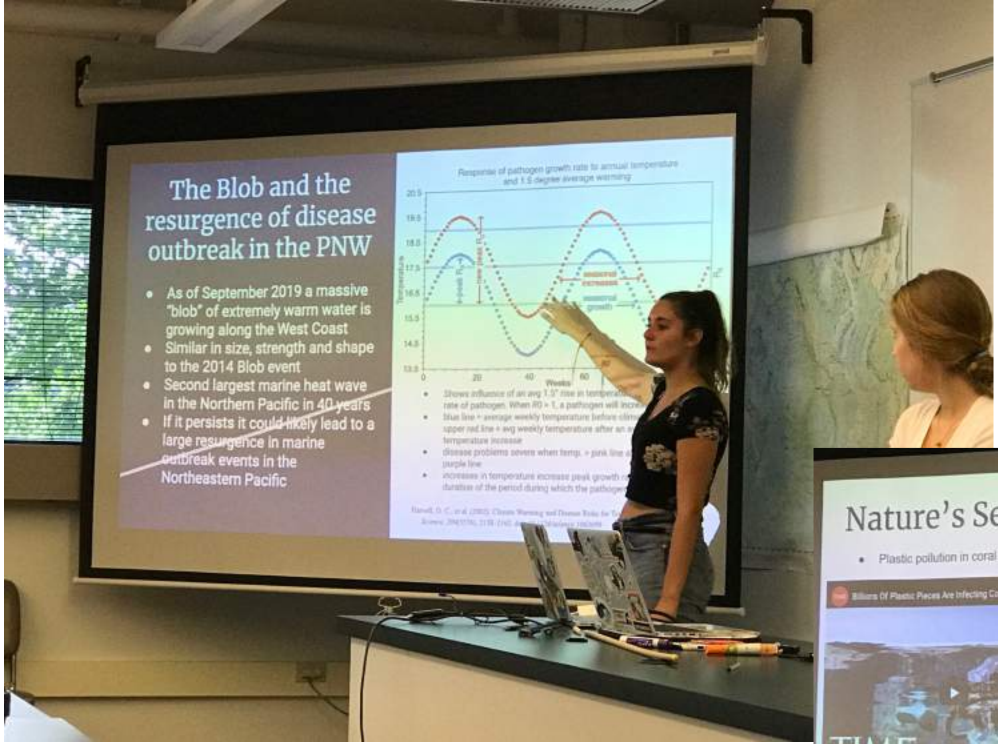
The Blob and the resurgence of disease outbreak in the PNW
As of September 2019 a massive "blob" of extremely warm water is growing along the West Coast
Similar in size, strength and shape to the 2014 Blob event
Second largest marine heat wave in the Northern Pacific in 40 years
If it persists it could likely lead to a large resurgence in marine outbreak events in the Northeastern Pacific


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TIME