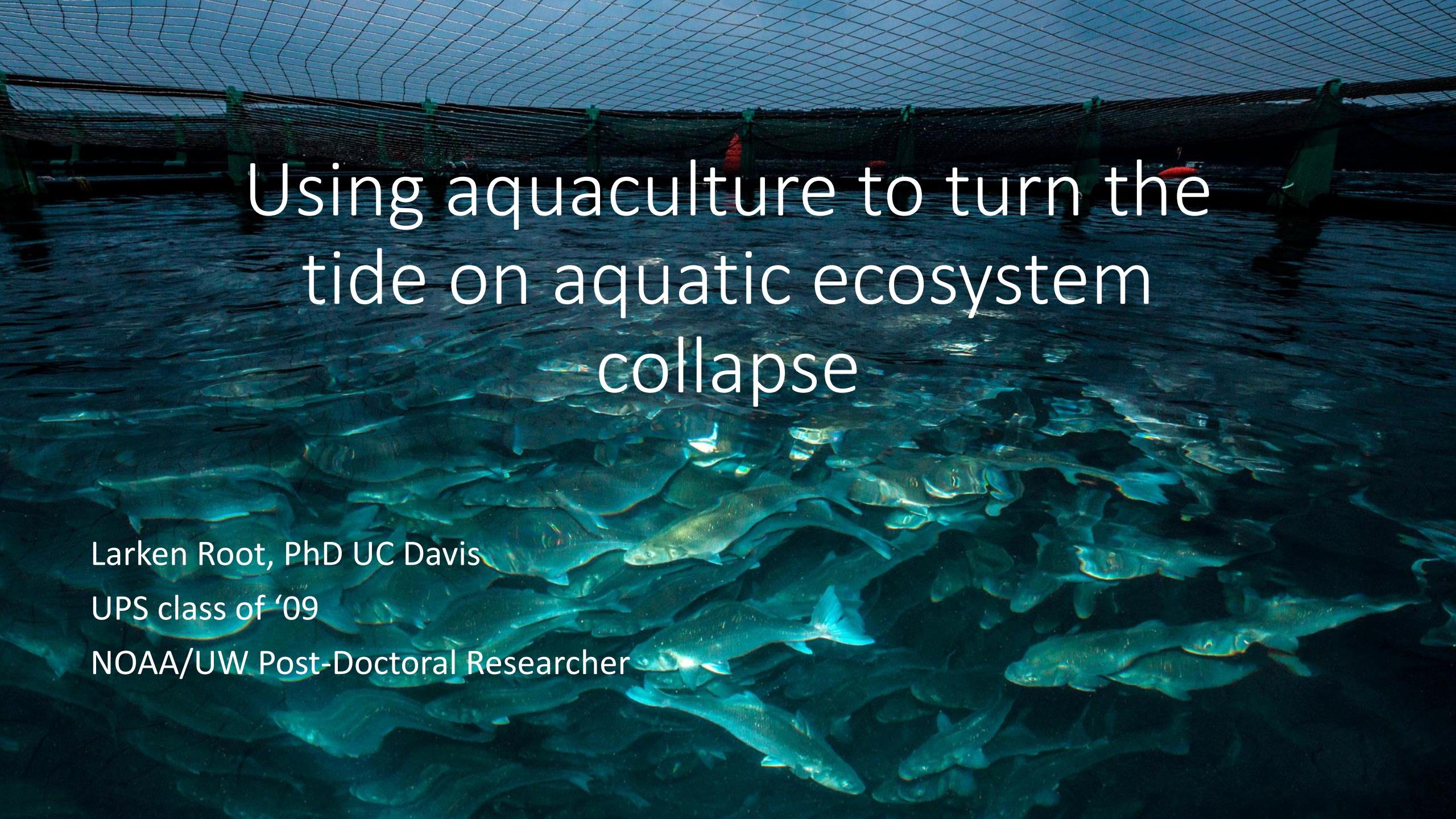


Using aquaculture to turn the tide on aquatic ecosystem collapse

Larken Root, PhD UC Davis

UPS class of ‘09

NOAA/UW Post-Doctoral Researcher

Overview

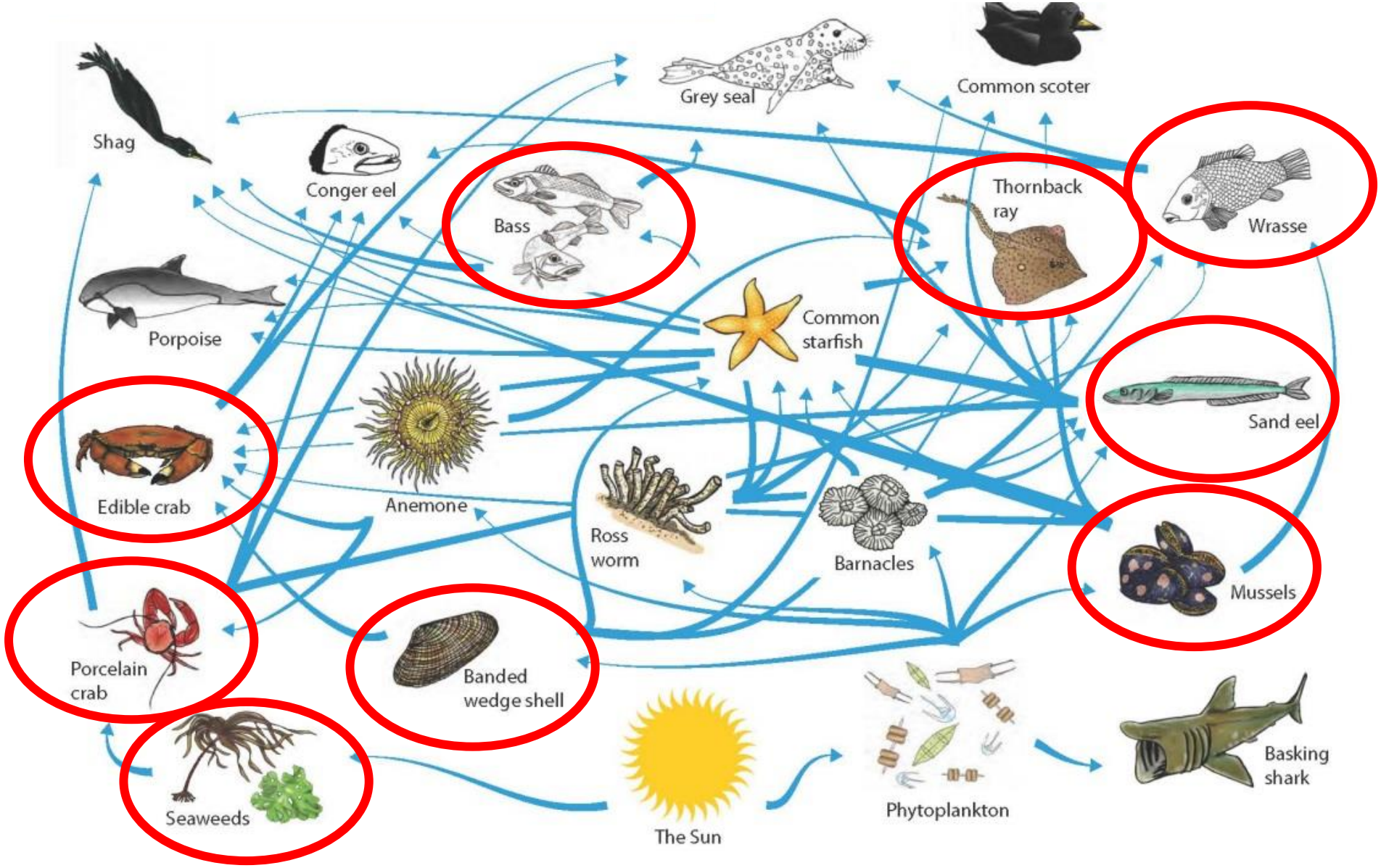
Aquatic ecosystems and seafood

Aquaculture as an alternative to fishing

Case Study: brackish water tilapia production

Restoration aquaculture

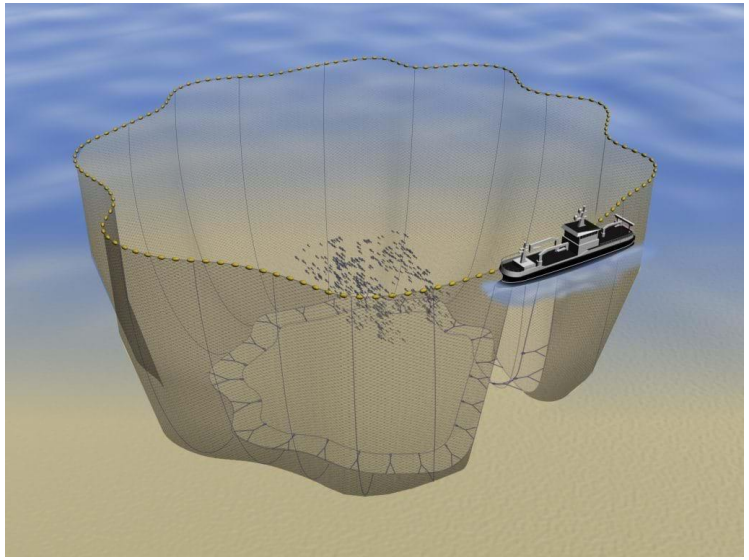
Case Study: local clams and ocean acidification


Shag
Grey seal
Common scoter
Conger eel
Bass
Thornback ray
Wrasse
Porpoise
Common starfish
Sand eel
Edible crab
Anemone
Ross worm
Barnacles
Mussels
Porcelain crab
Banded wedge shell
Seaweeds
The Sun
Phytoplankton
Basking shark

Where does seafood come from?

Wild Capture Fisheries

Most commercial capture fisheries use large nets hauled by fishing vessels



Purse Seine

Bottom Trawl

Aquaculture

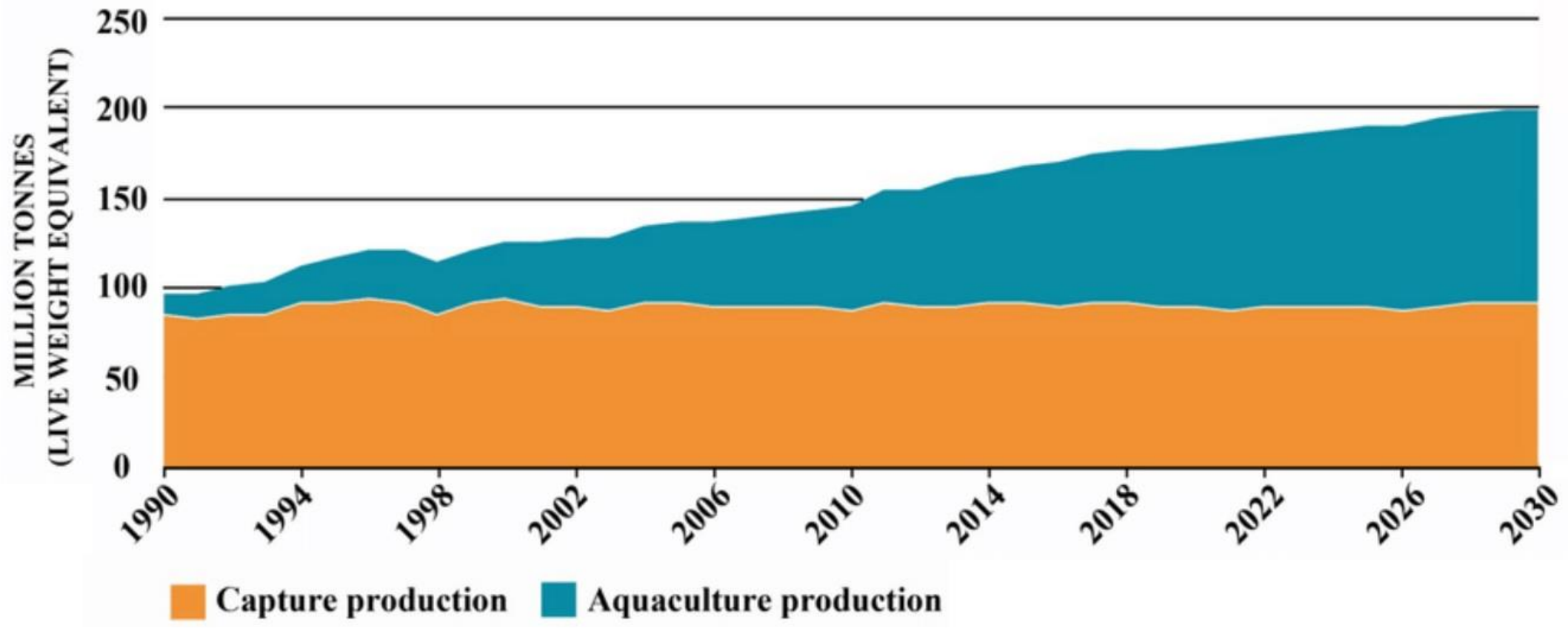
Unlike capture fisheries, aquaculture relies on human directed fish growth and reproduction by altering environmental conditions and/or feeding

Freshwater Ponds

Marine Net Pens

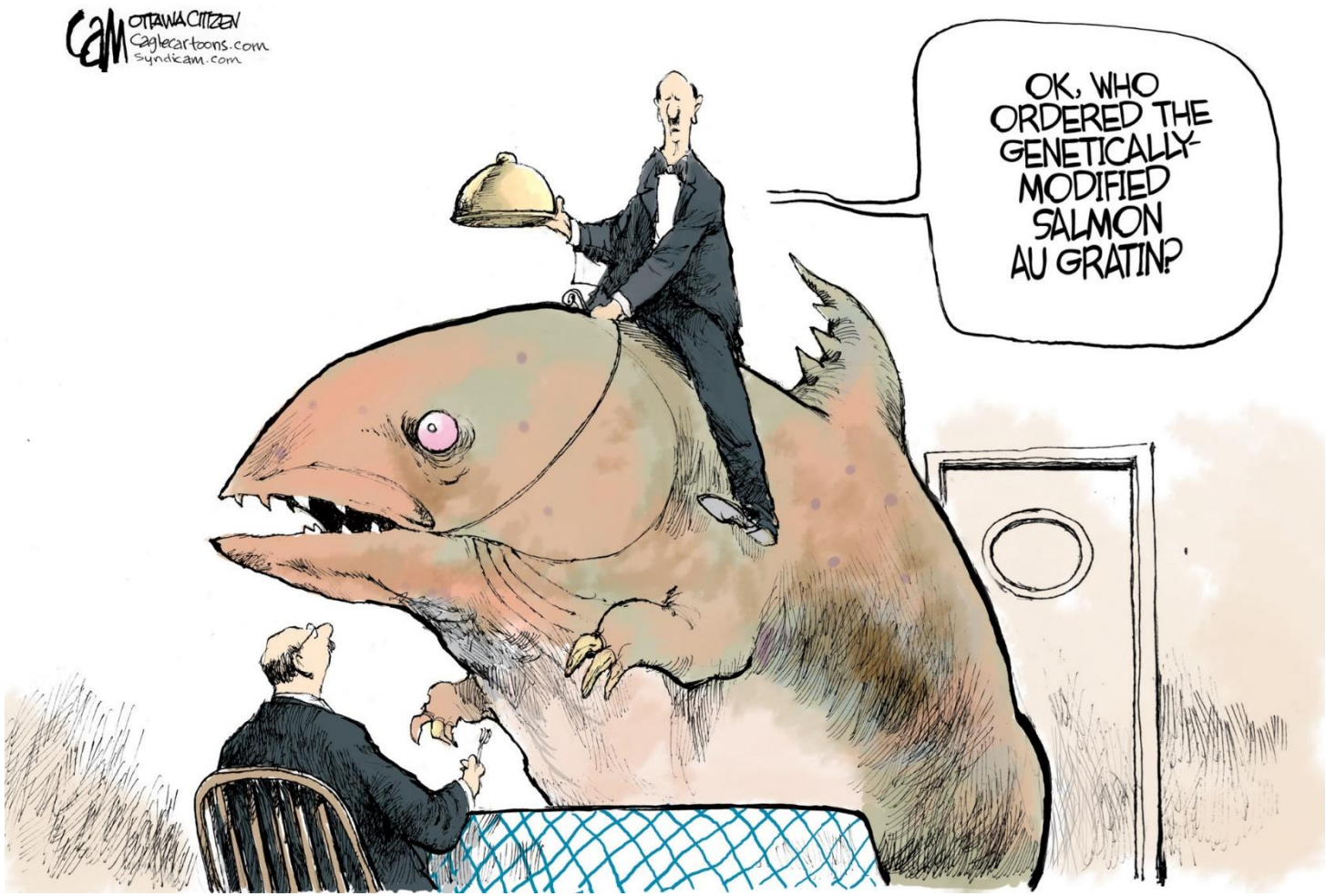
Recirculating Aquaculture System

Oyster Off Bottom



Aquaculture produces the majority of seafood

Disadvantages

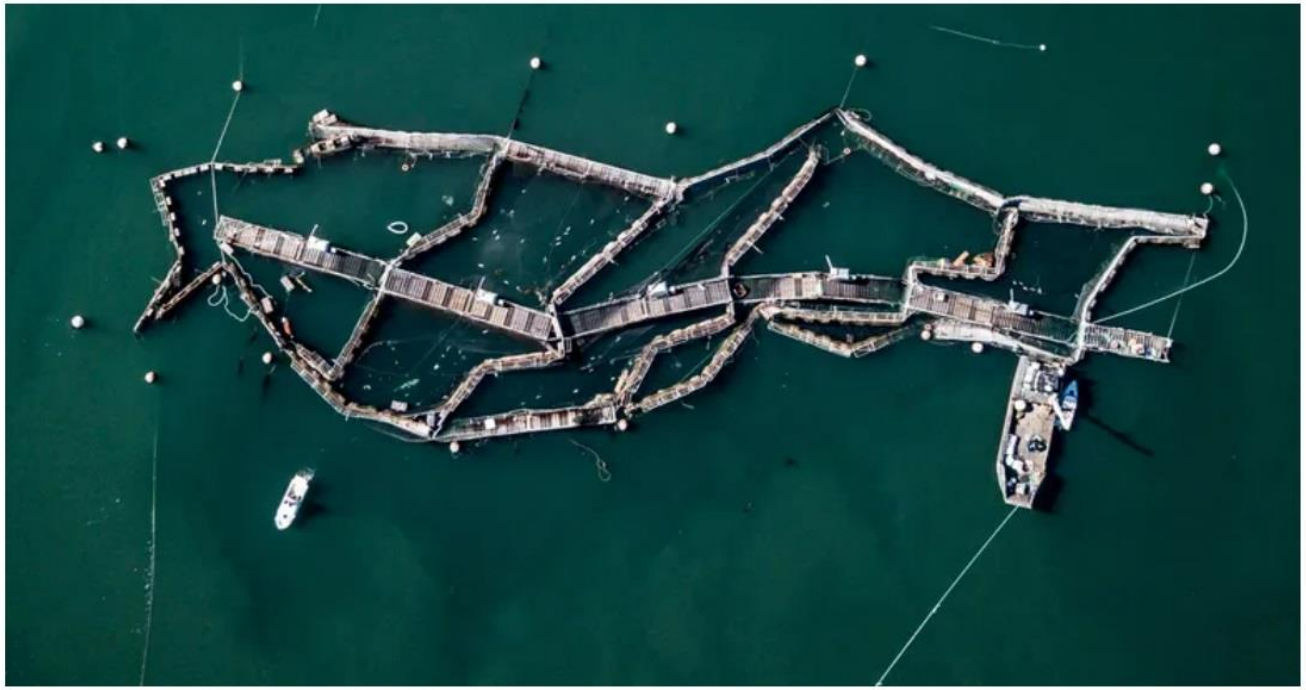


Disadvantages

Escape of domesticated species

Fish farm caused Atlantic salmon spill near San Juans, then tried to hide how bad it was, state says

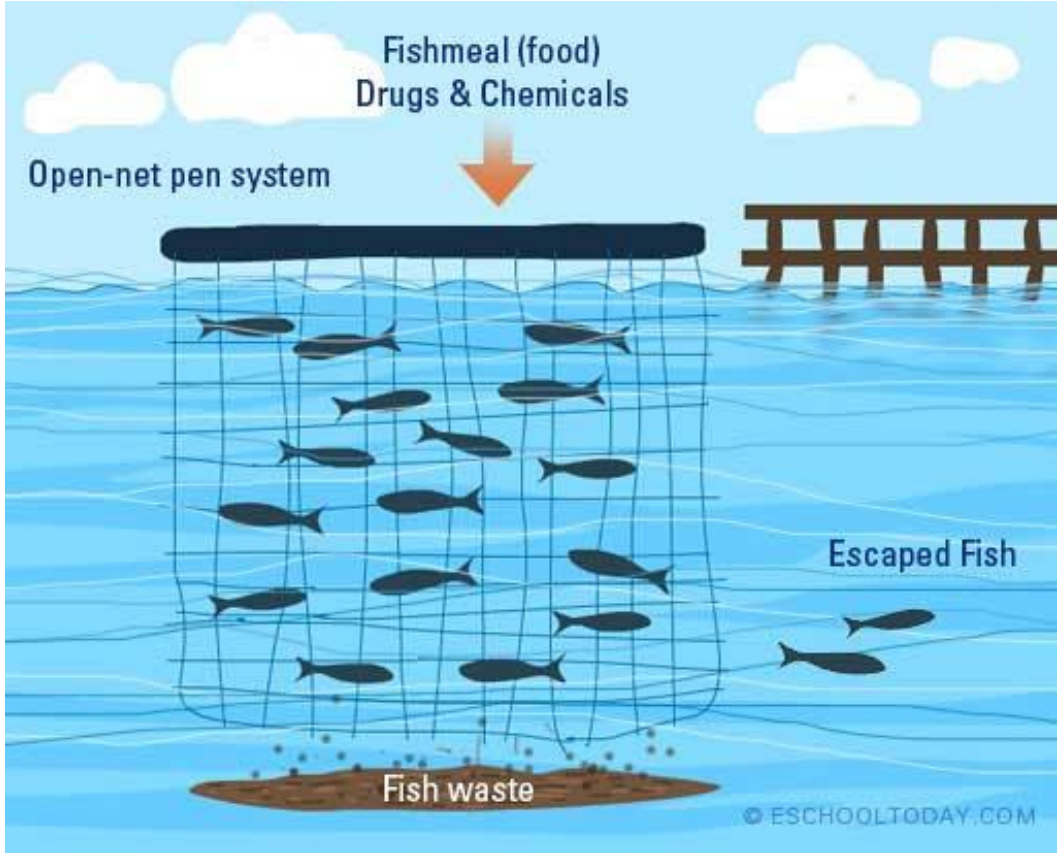
Originally published January 30, 2018 at 11:00 am | *Updated February 2, 2018 at 11:23 pm*



Disadvantages

Escape of domesticated species

Pollution from excess effluent



Disadvantages

Escape of domesticated species

Pollution from excess effluent

Disease Transfer

Advantages

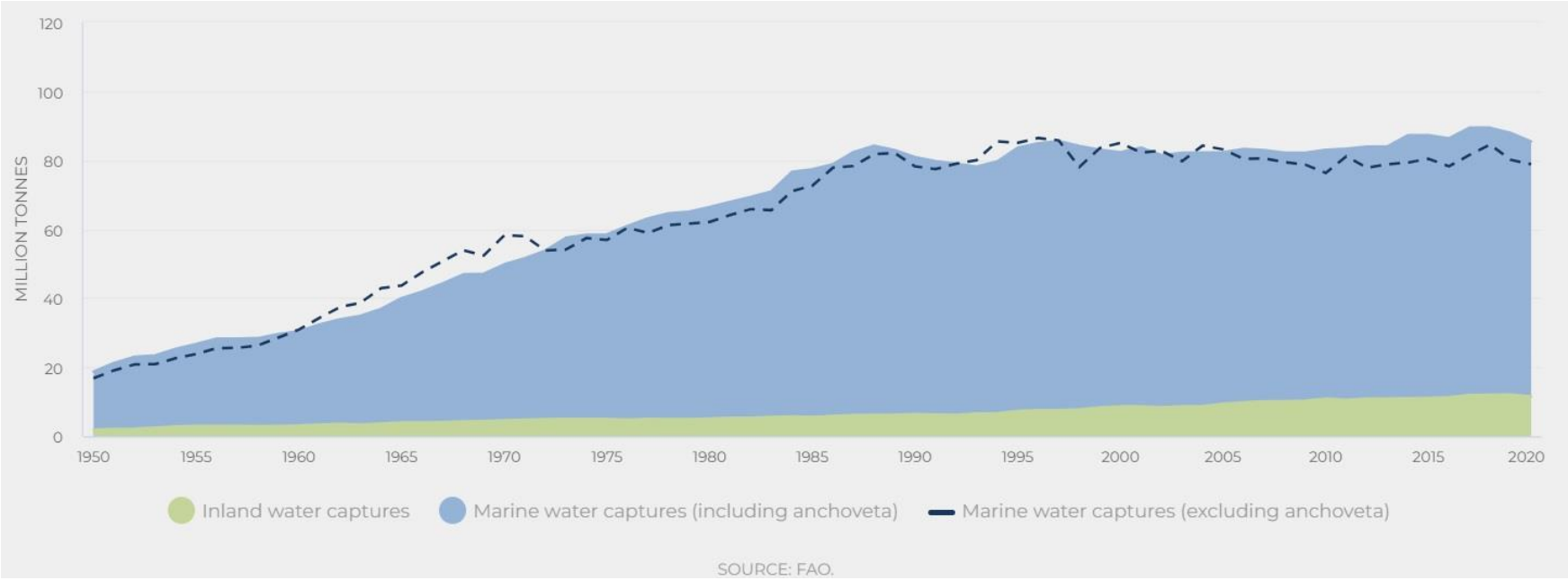
Most disadvantages can be addressed through species choice, reducing stress, and vigilant monitoring.

When done appropriately, aquaculture can provide **high quality food** while **reducing fishing pressure** and overall impact of food production on the environment.

Restoration Aquaculture can also help rebuild degraded ecosystems by supplementing wild populations and expanding the range of threatened aquatic organisms

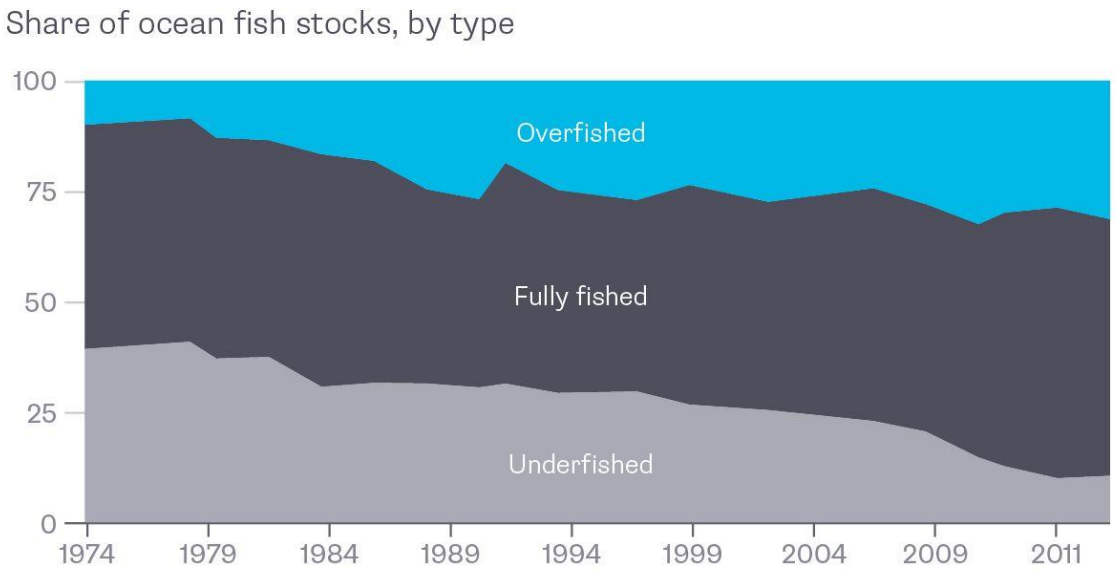
Fishing pressure

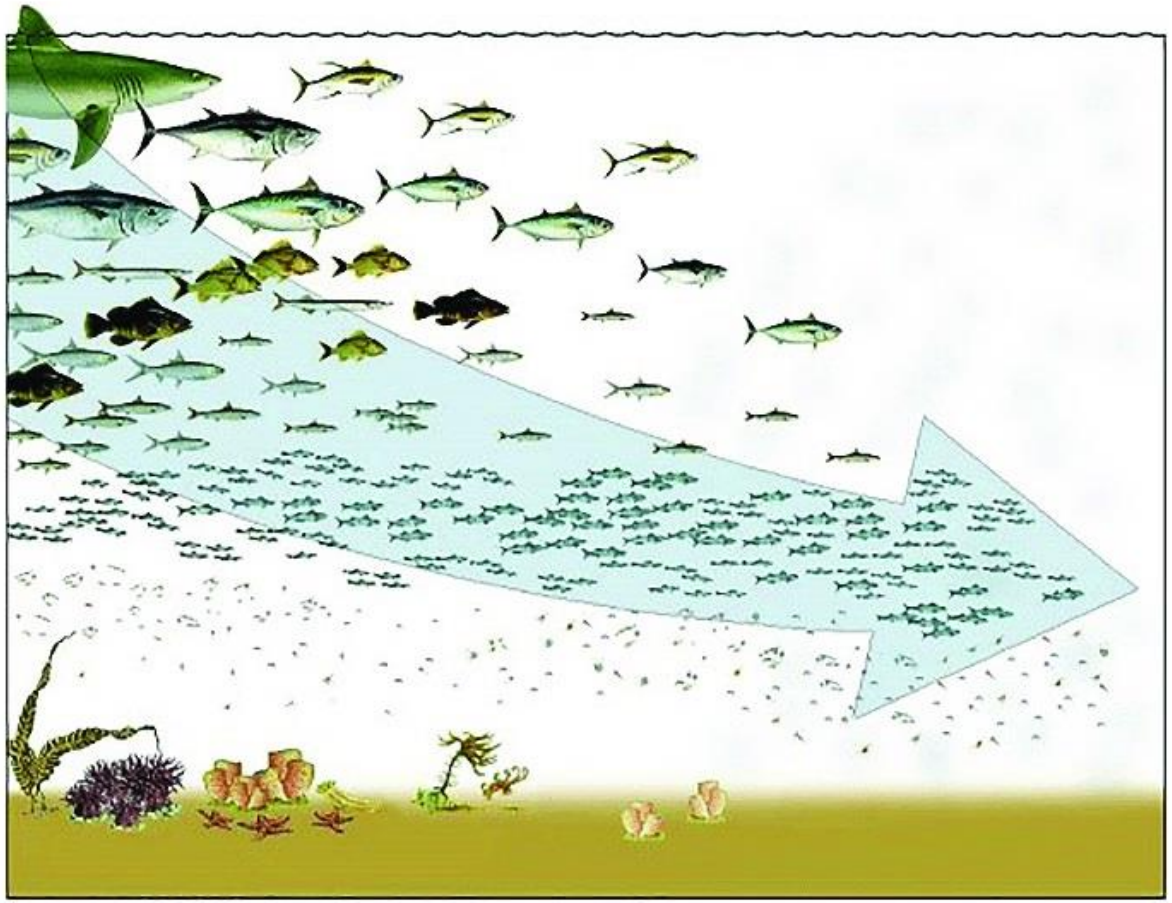
Global Wild Fish Catch



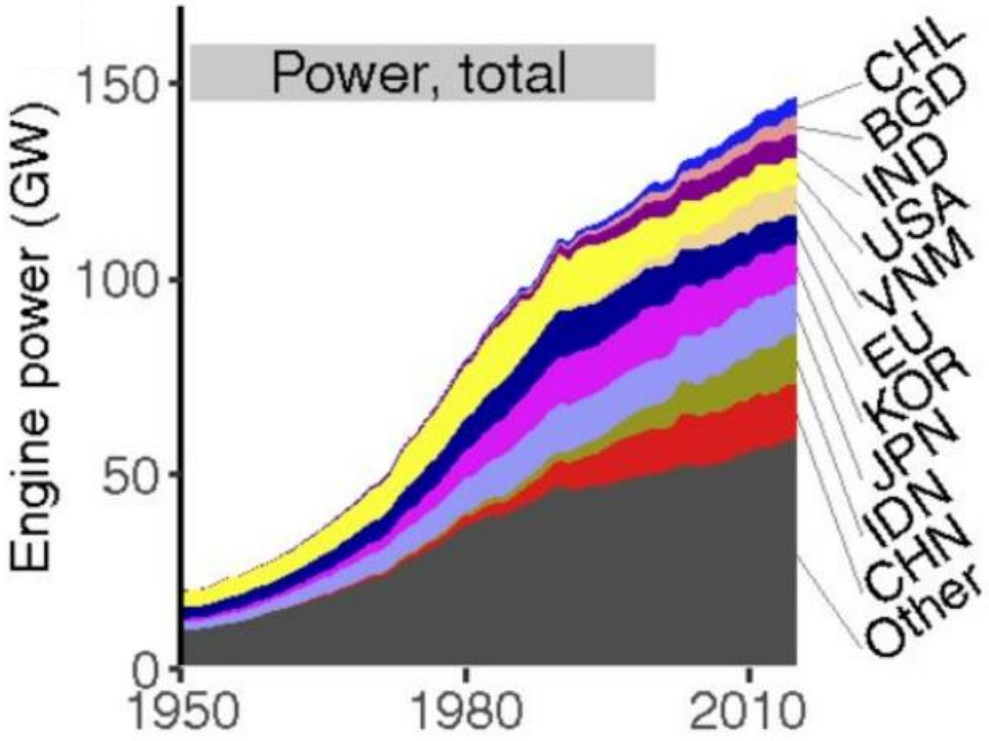
Fishers switch to different species as populations become more exploited.

Overfishing has greater impacts on larger carnivorous fish, narrowing the trophic web.





The number of powered industrial fishing vessels grew from 167,000 to 440,000+ since 1980



Increased fishing leads to greater CO_2 from gas powered engines

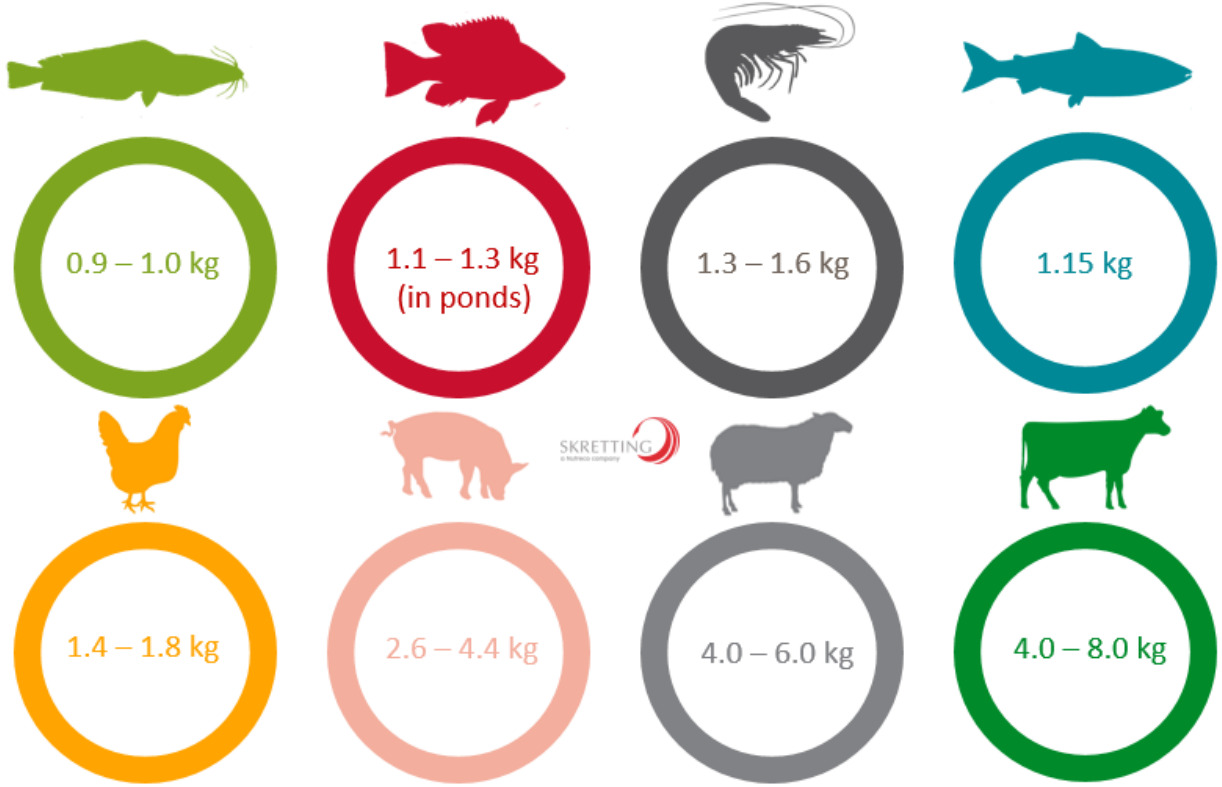
Additionally, bottom trawling has been shown to release CO_2 by stirring up carbon rich seabed sediments. This has been estimated to release carbon equivalent to the global aviation industry annually

Aquaculture Goal 1
Produce seafood more efficiently and sustainably

Case study: brackish water tilapia production

Tilapia is the second most produced aquaculture finfish in the world:

- Easy to grow
- Comfortable at high stocking density
- Grows quickly
- Favorable taste and texture
- Efficient feed conversion
- Omnivorous



Feed conversion ratio for different farmed animals
(kg food/kg weight gain)

Salinity tolerance in aquaculture

Growing fish in saline waters allows for minimizing reliance on scarce freshwater resources, and salt tolerant animals are safer from extreme weather such as storm surges

Understanding stress is also important in many aspects of aquaculture for improved animal welfare and production

Stress Physiology

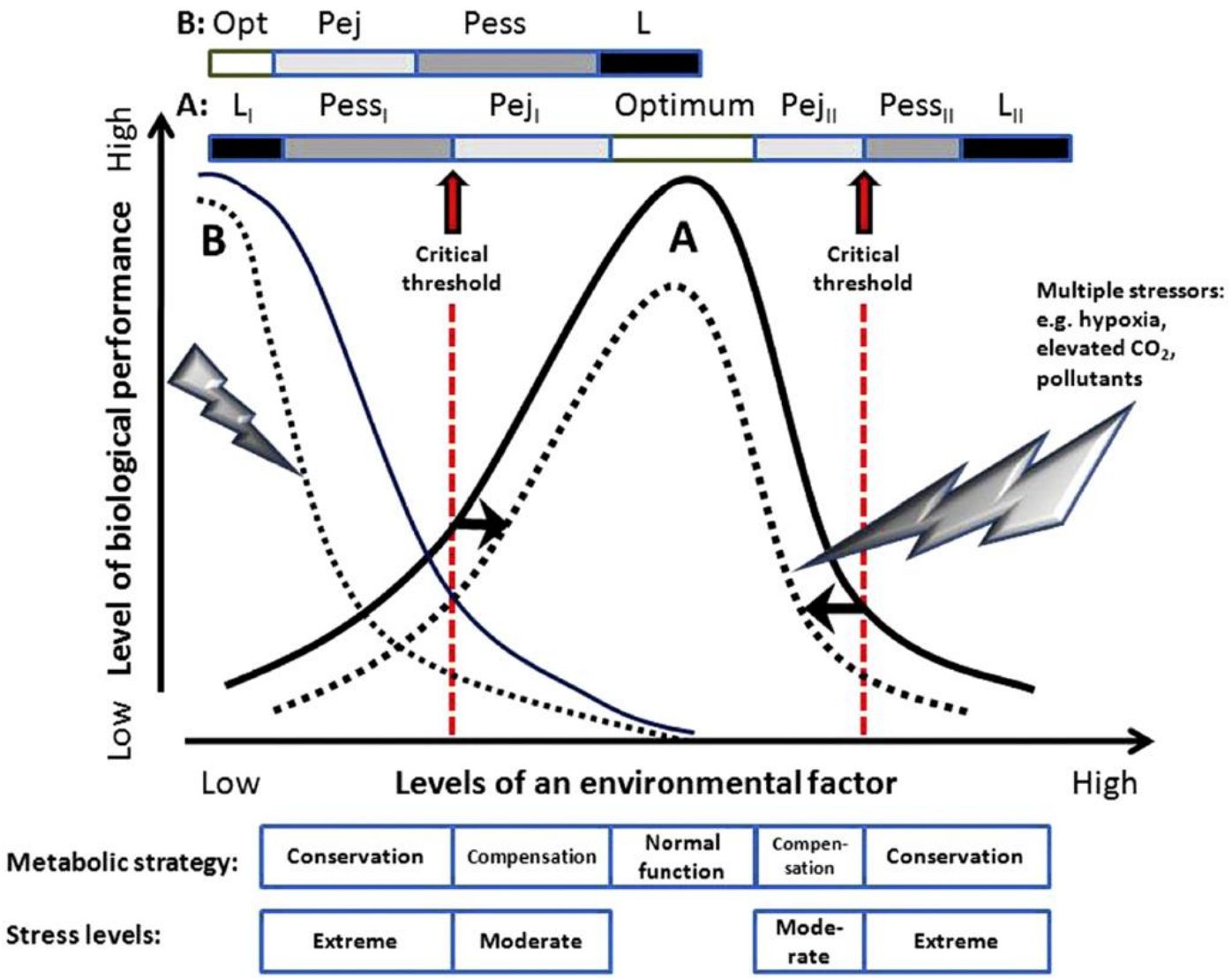
Energy Homeostasis Theory:

Animals have an optimum range for any given environmental parameter

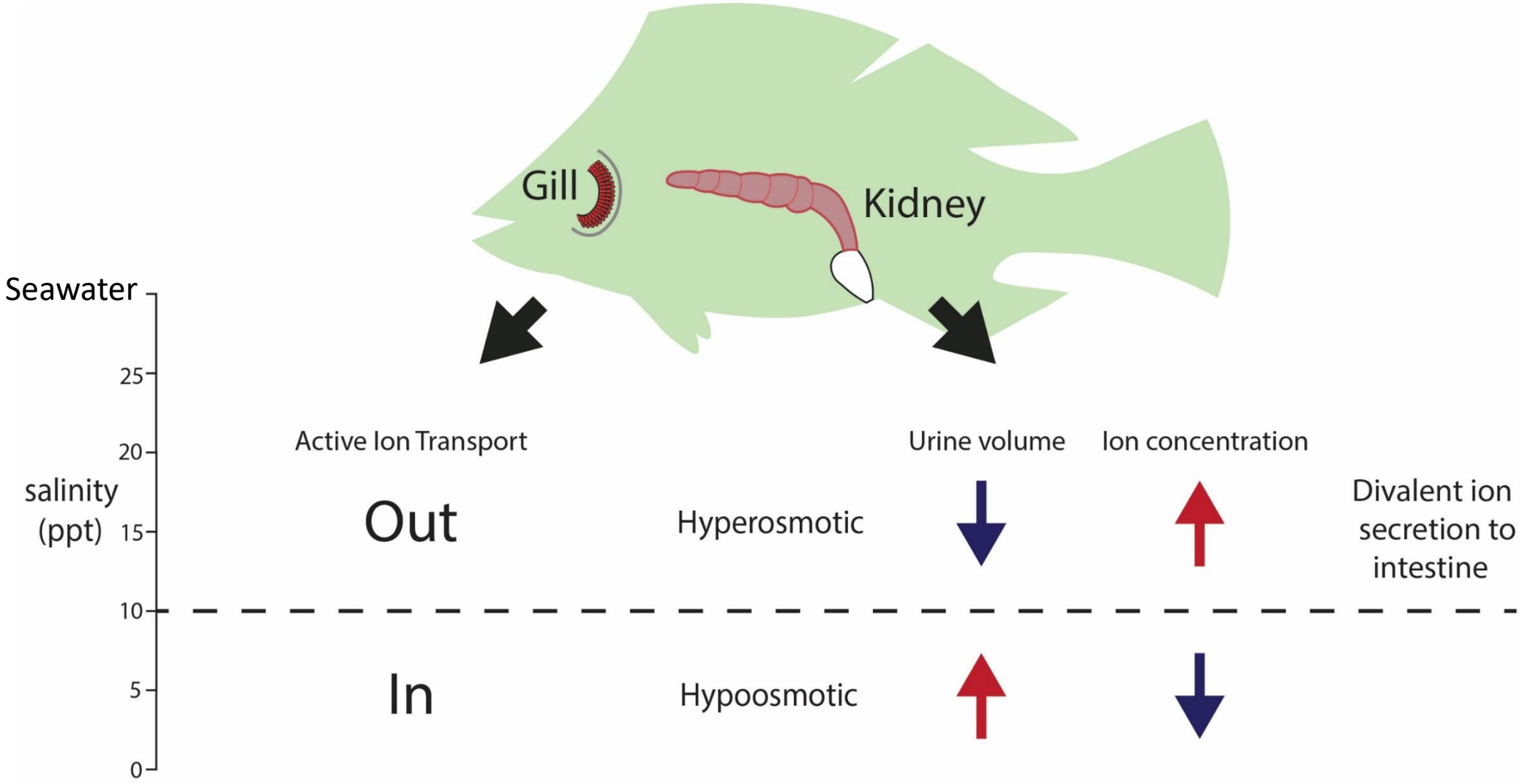
Outside of this range, biological performance (growth, reproduction) decreases.

Past a critical threshold, animals are not able to maintain homeostasis and will eventually die

Each portion of the performance curve has specific metabolic and stress coping mechanisms

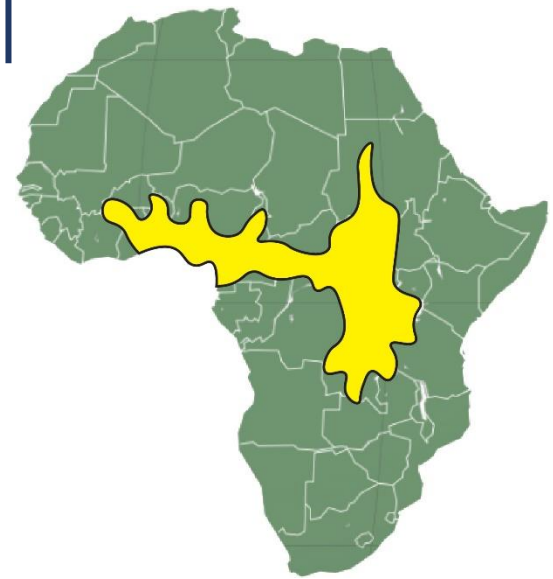


Osmoregulation



Tilapia species

Nile Tilapia
Oreochromis niloticus

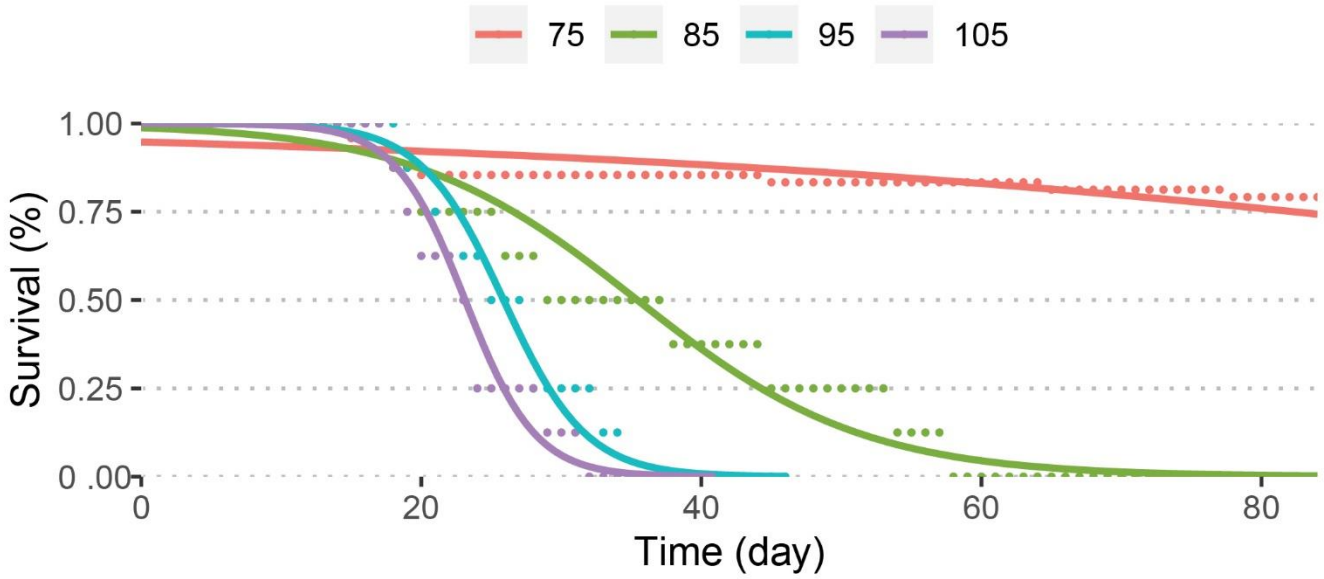


Mozambique Tilapia
O. mossambicus

Mozambique Tilapia tolerance limits

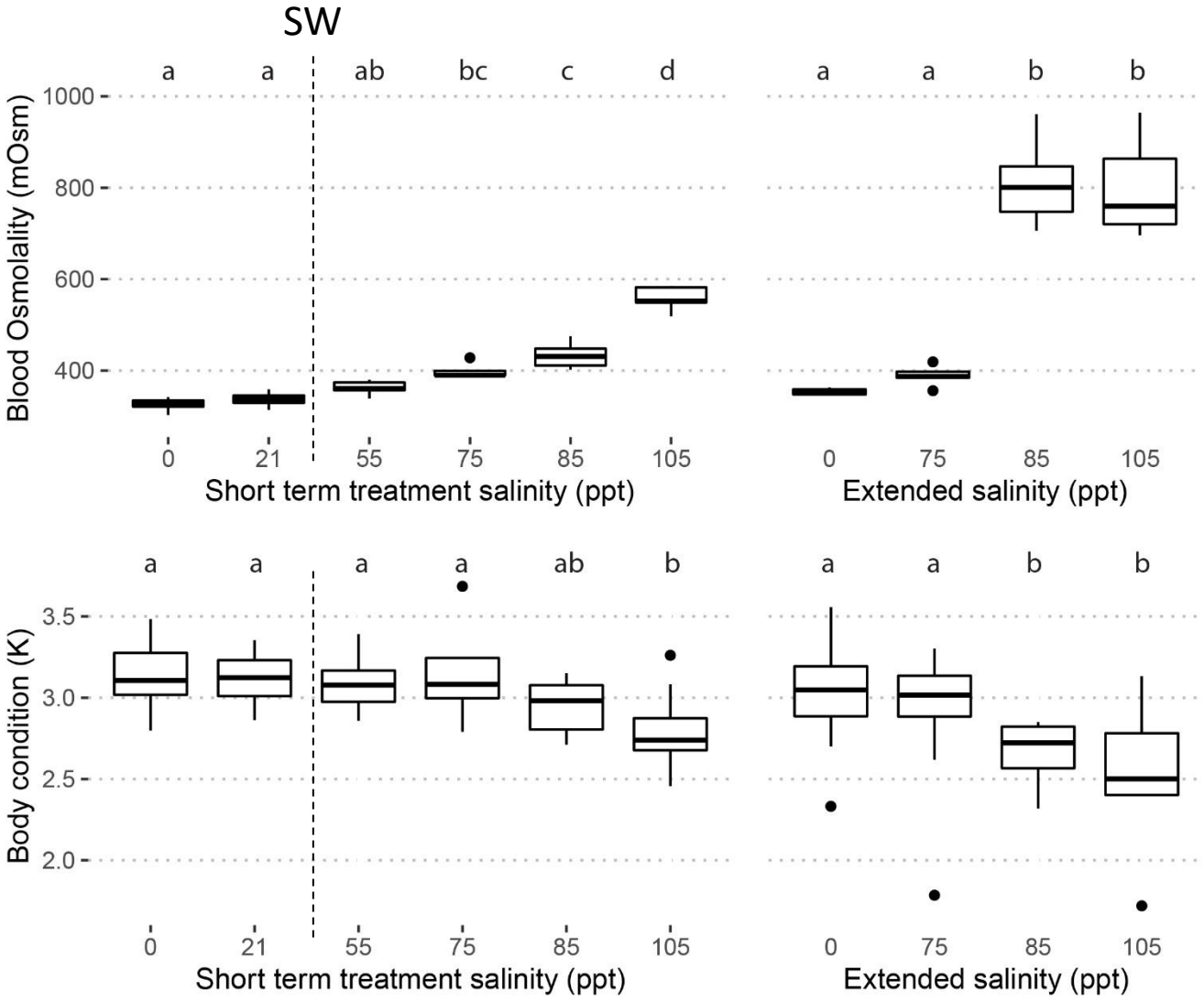
A series of acclimations showed that Mozambique Tilapia can acclimate to salt levels around 120 ppt, which is approximately four times higher than seawater

Even at very high salinity, they can still survive for weeks to months



Survival over time at extreme salinity

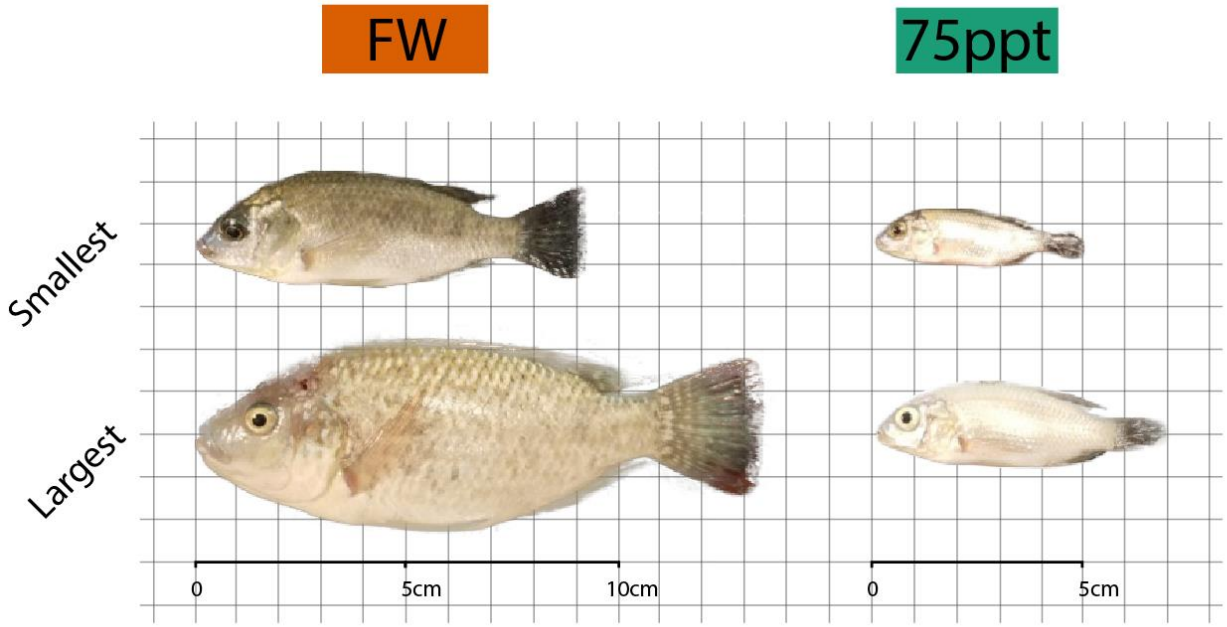
Physiological measurements

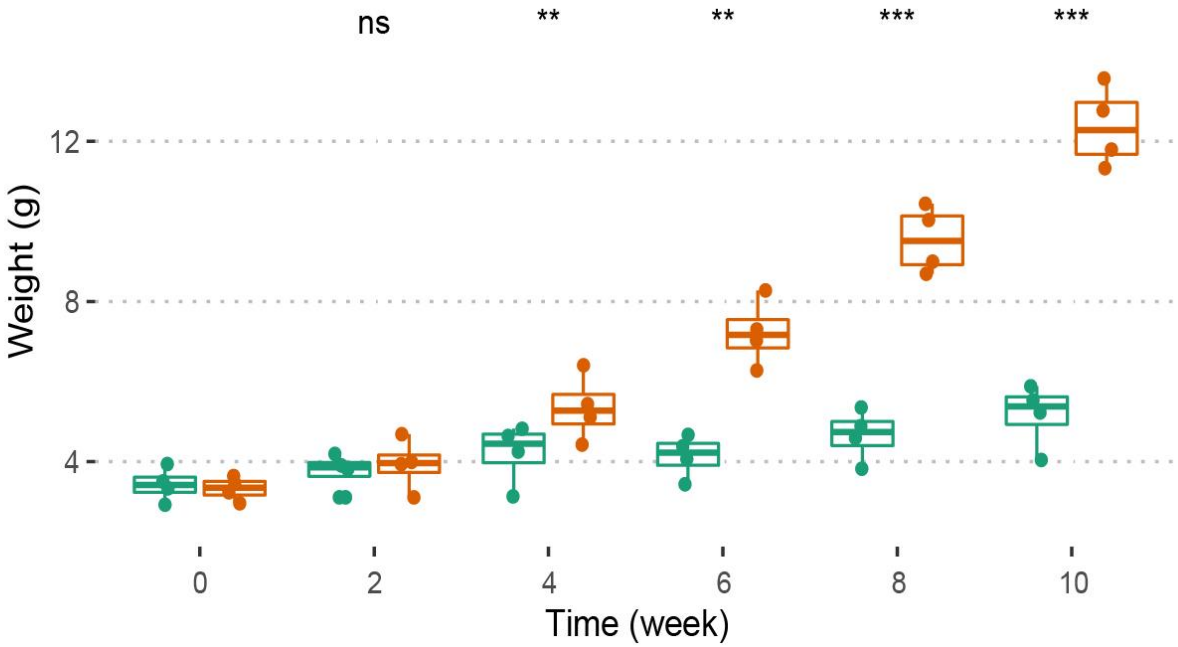


Blood osmolality increased slightly and body condition was unaffected up to 75 ppt

Above 75 ppt, blood osmolality began to increase and body condition to decrease. Over long time periods, the differences in these parameters becomes quite large versus fish in freshwater

Impacts on growth



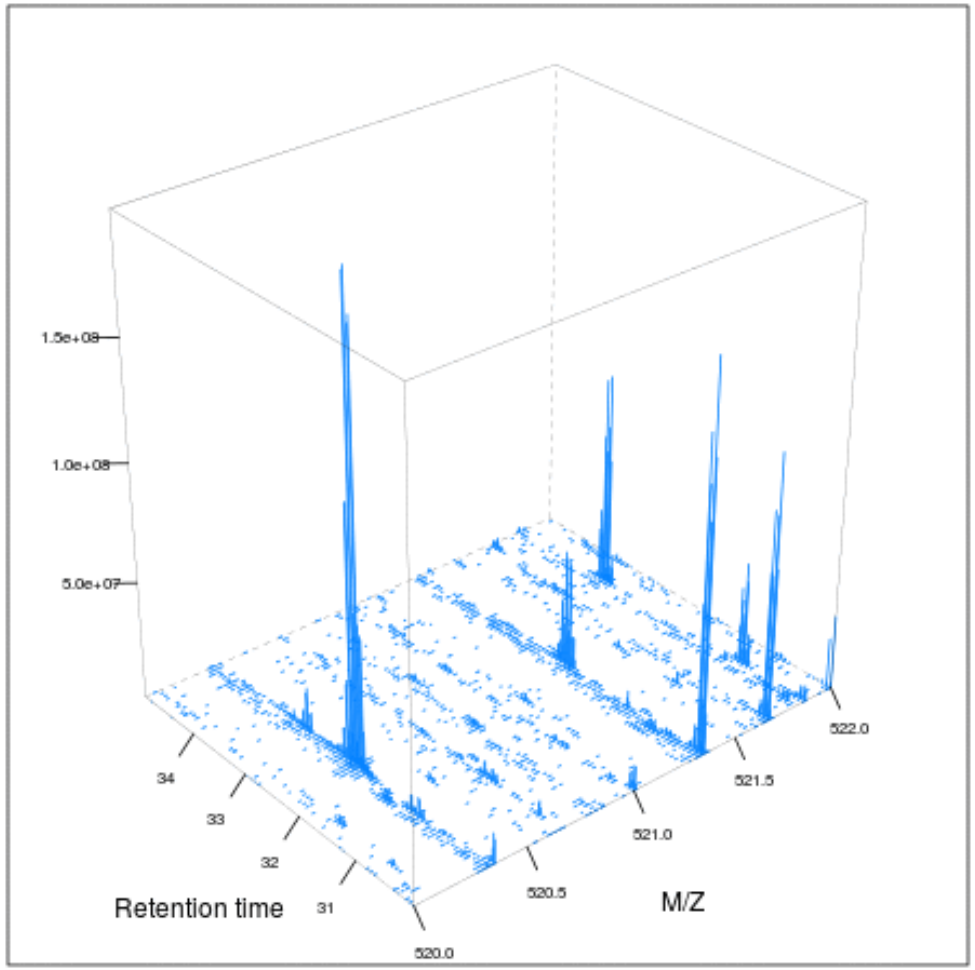


Quantitative Proteomics

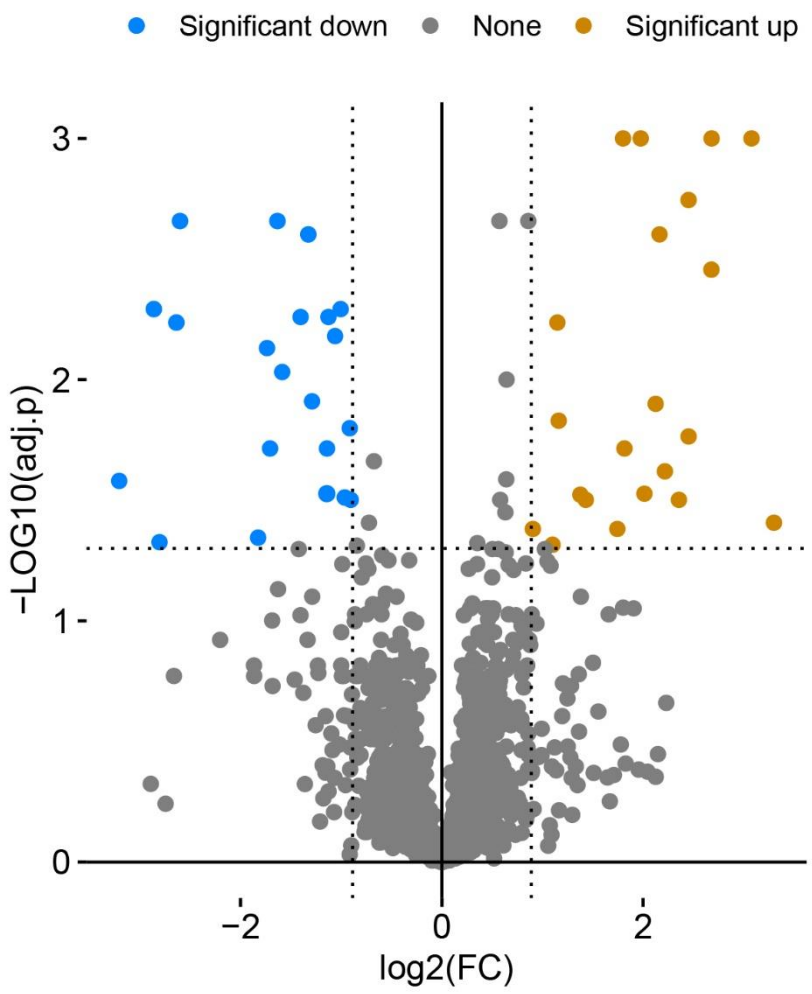
All proteins in a sample are first identified and then quantified by comparing relative abundance between a control and treatment.

The difference in abundance identifies proteins which differentially regulated based on a treatment, i.e. which go up and which go down.

This can be used to find specific important proteins or general biological processes



Data Analysis



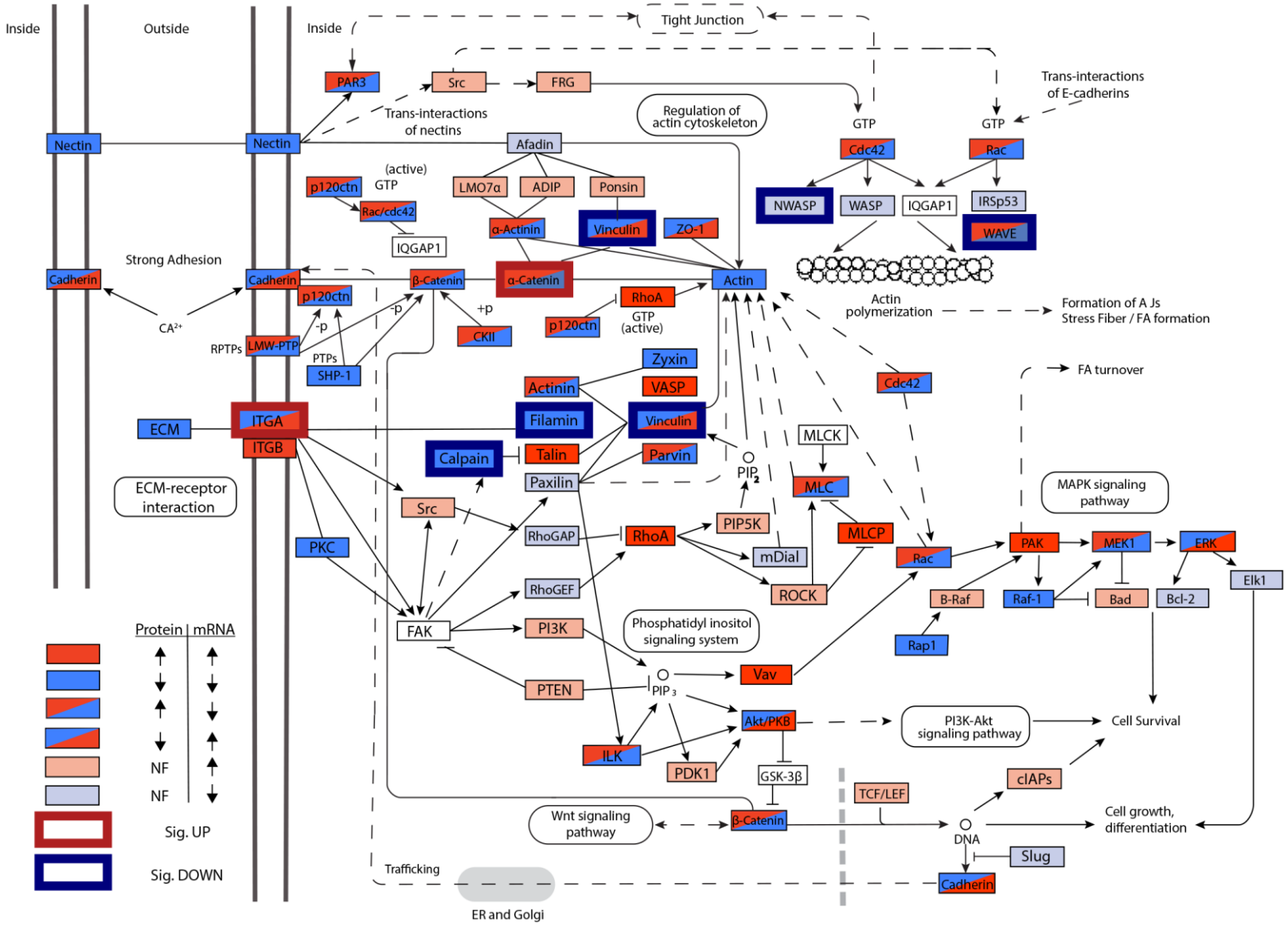
Significant proteins are identified based on a fold-change value between control and treatment, and p-value based on consistency among replicates

Further analysis can involve:

- Non-biased clustering of proteins based on expression patterns of each replicate
- Pathway analysis
- Protein association networks

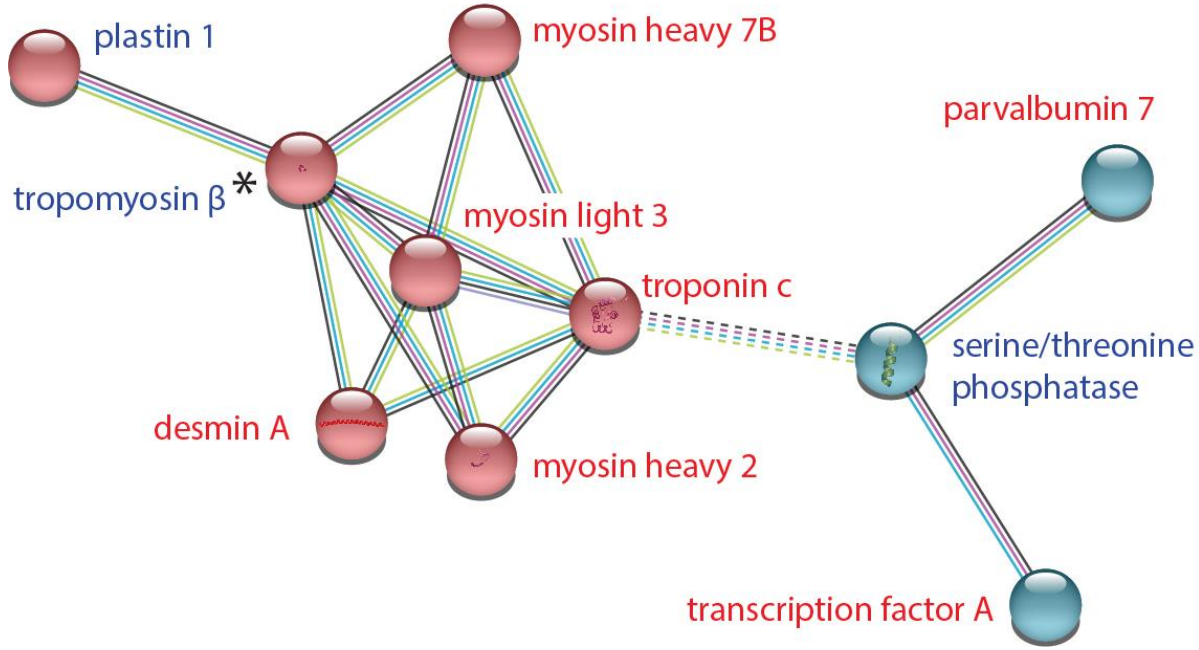
Cytoskeleton and extracellular matrix

Pathway Analysis

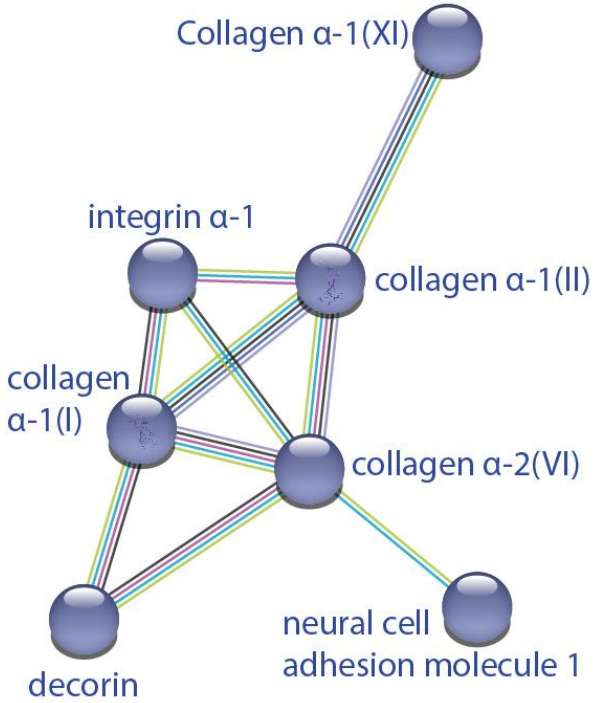


Cytoskeleton and extracellular matrix

Acclimation to high salinity



Extreme salinity stress



Protein association networks

Cytoskeleton and extracellular matrix

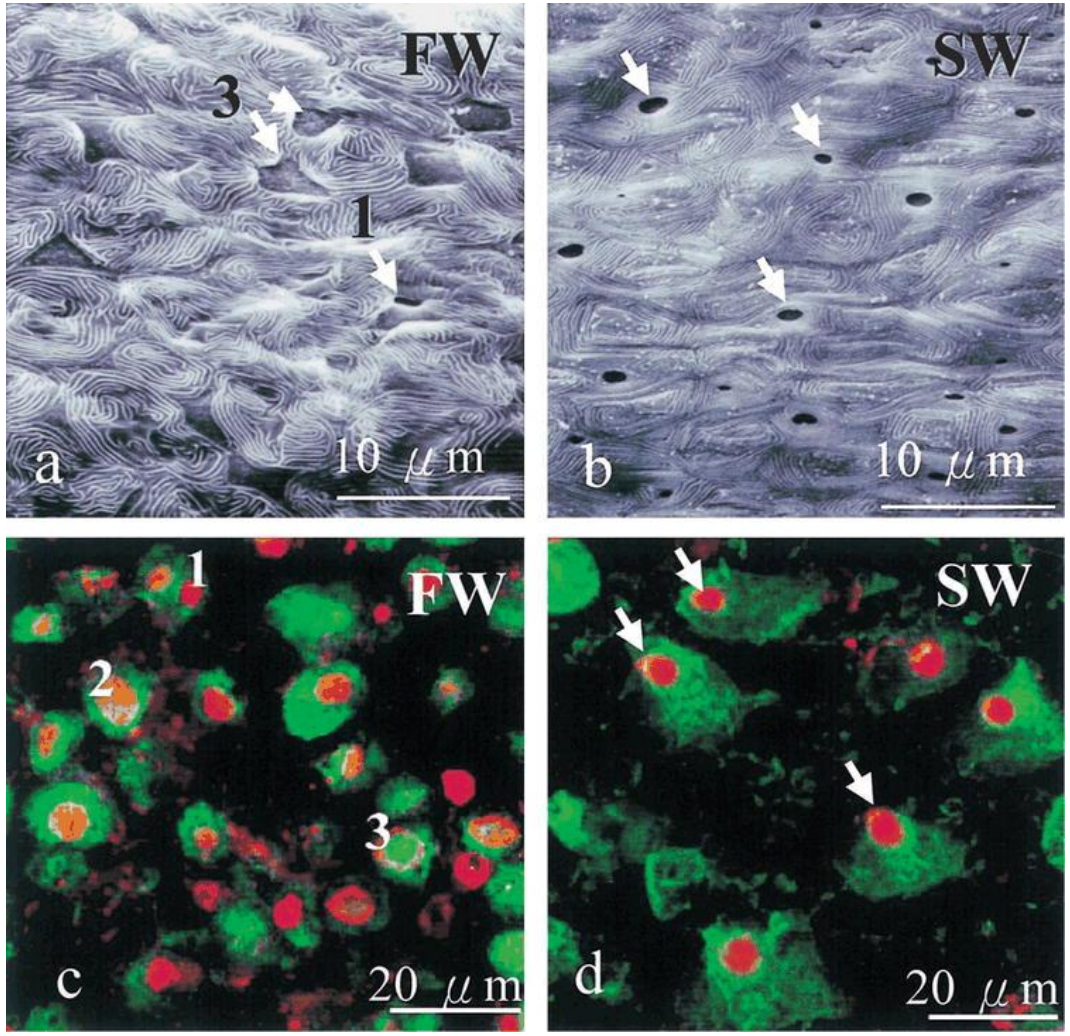


Image credit: Lee, Tsung-Han, et al. *Zoological science* 20.1 (2003): 29-36.

Case study takeaways

Mozambique Tilapia have a distinct Critical Salinity Threshold near 80ppt

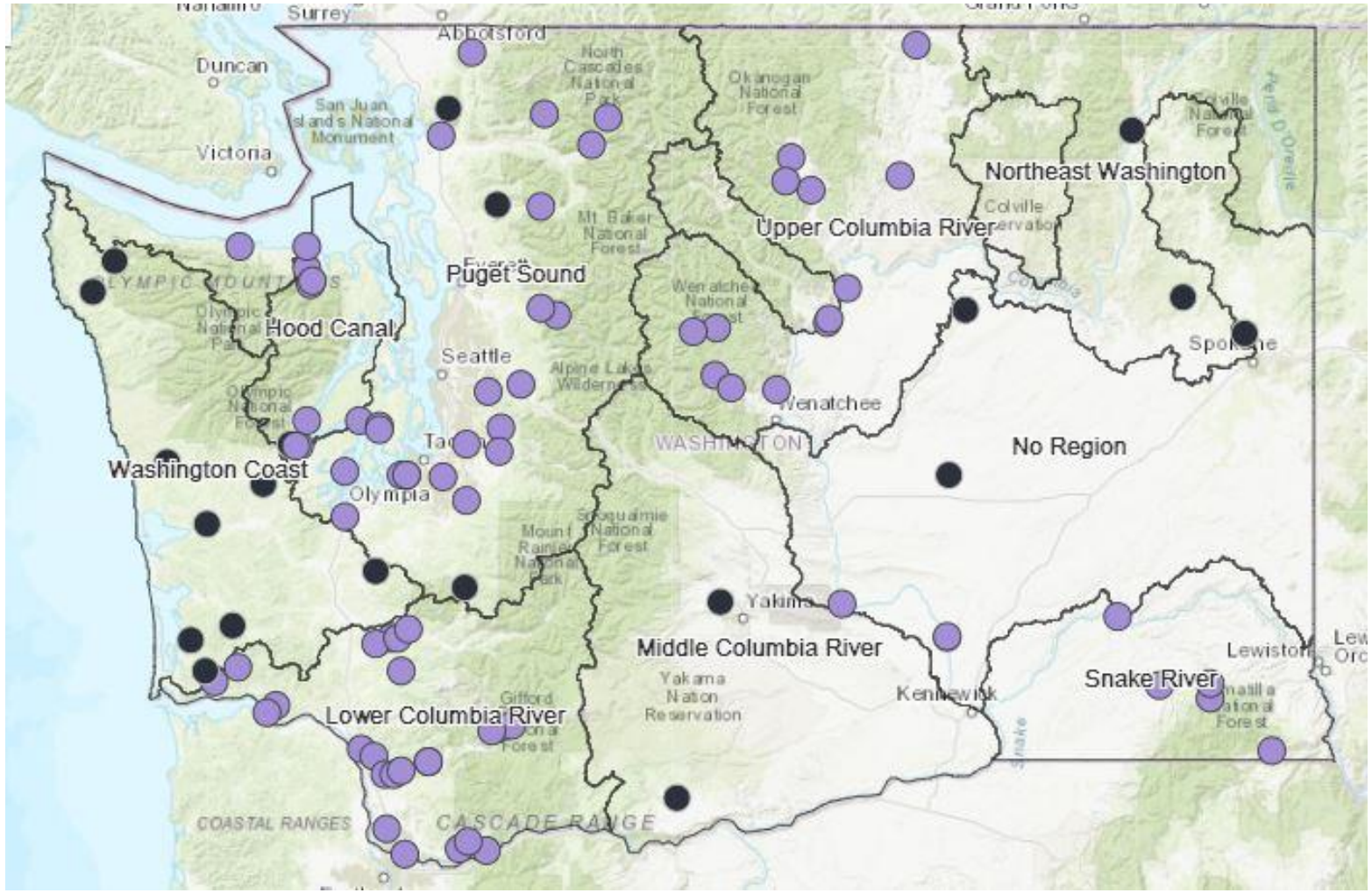
At high salinity, this species can modify the structure of the gills to facilitate high capacity ion transport to counteract passive diffusion.

Understanding the specific molecular pathways involved in salinity tolerance can help in breeding tilapia to live in brackish water, and can also be used to identify wild populations currently experiencing salinity stress

Aquaculture Goal 2
Supplement wild populations through Restoration Aquaculture

Restoration Aquaculture

Salmon Hatcheries



Impact of Climate Change

Increasing Temperature

Average temperature increasing leads to poleward shifts in marine populations, and freshwater populations where possible.

Increasing CO_2

CO_2 concentration in ocean water increases, leading to decreasing pH (acidification)

Ability of shellfish to form and maintain calcium carbonate exoskeleton is affected. Acid-base balance is also impacted in all marine organisms.

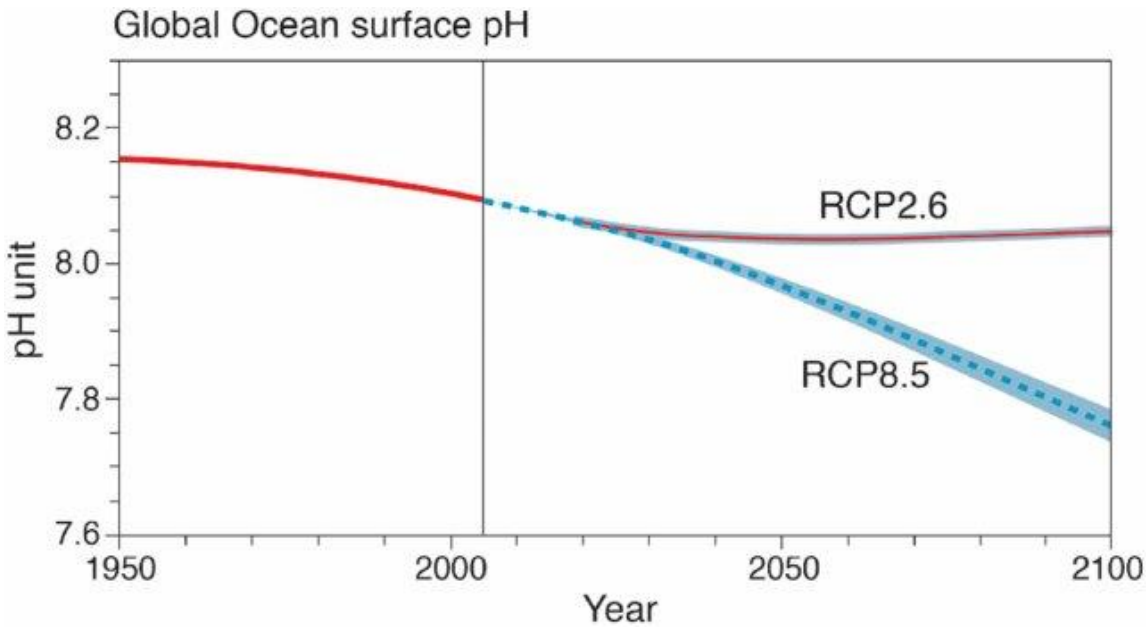
Greater variability in weather patterns

Changing rainfall can lead to desiccation and changing salinity regimes

Extreme events lead to physical damage and can cause extreme short term changes in temperature, salinity, or acidity.

Case Study: local clams and ocean acidification

Ocean acidification (OA)



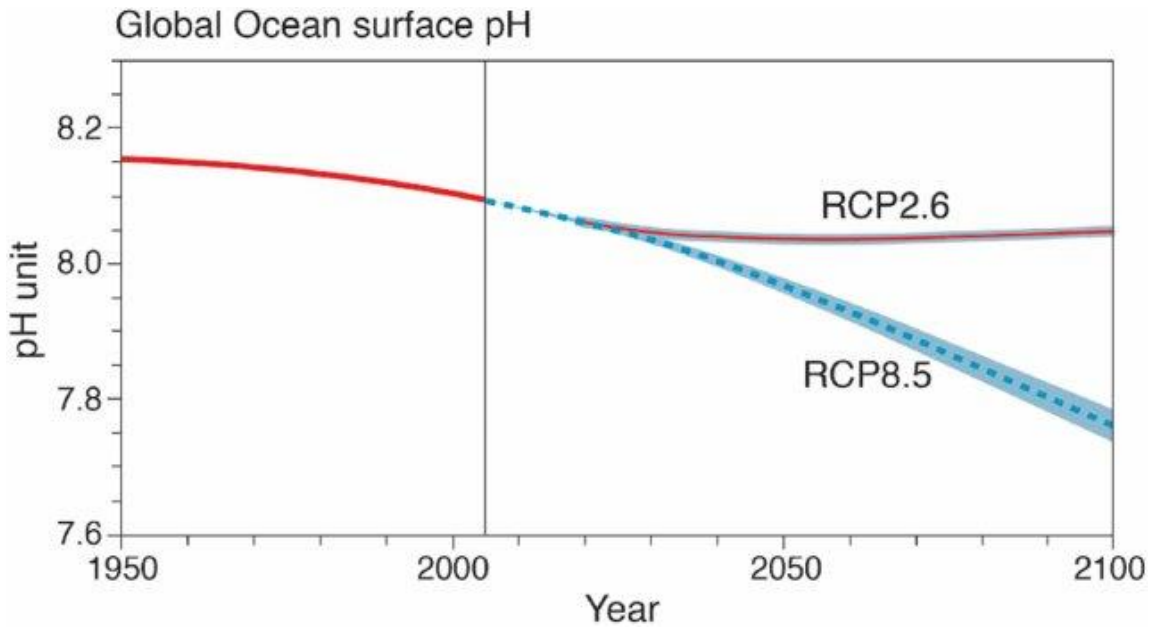
From Maslin, 2019

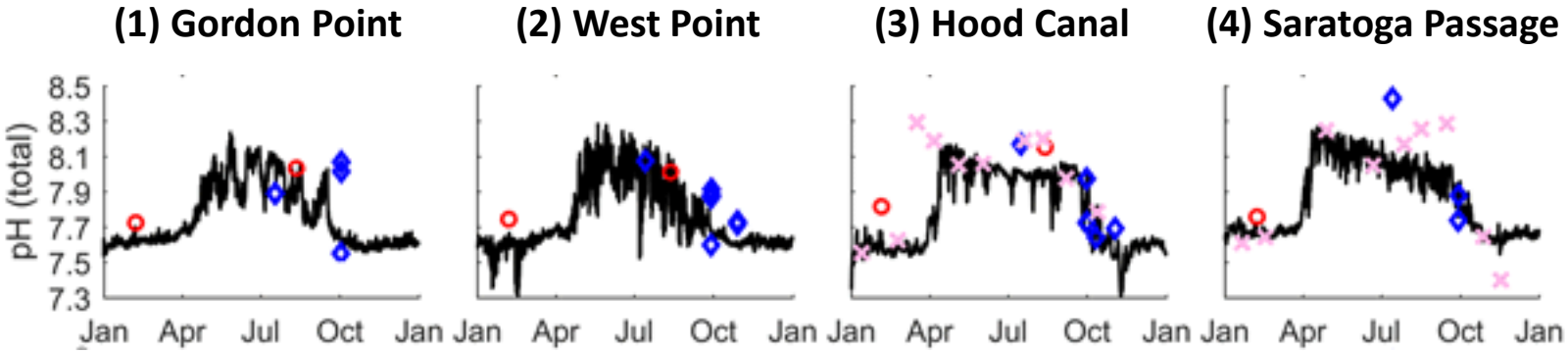
Increasing carbon dioxide in the atmosphere leads to increased concentration in oceans due to diffusion.

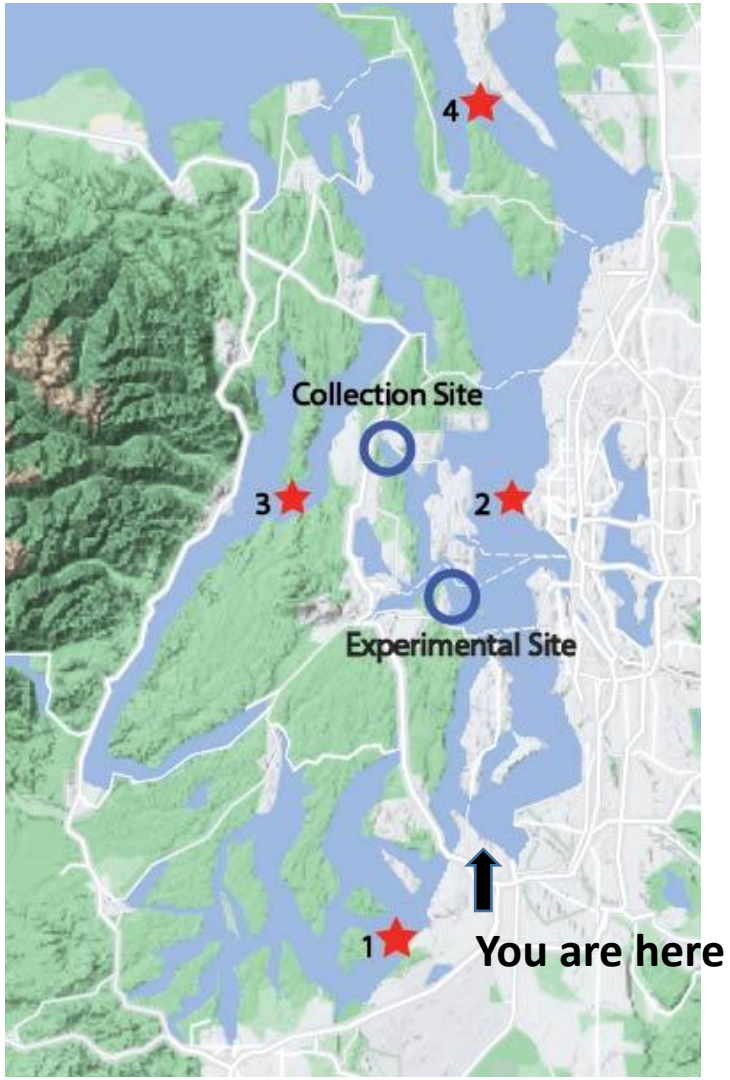
Increased pCO_2 leads to lowering pH through a series of reactions with water

Ocean pH is projected to decrease by up to 0.4 units by 2100

Ocean acidification (OA)







From Bianucci et al. 2018

Impact on clams

Research has identified several potential impacts of OA conditions on shellfish, including:

- Biomineralization – the ability of an animal to precipitate and incorporate calcium into the shell.
- Energetics – changes in energy requirements and the impact on growth
- Larval development and growth – impacts on early life stages

Clams are likely most impacted in <u>larval growth</u>

Clam species

Littleneck Clams are native to the Pacific coast, an important traditional food source and a potential target for restoration aquaculture due to declining wild stocks.

Manila Clams are non-native, but a major product for aquaculture in Puget Sound and an important food source.

Clams collected in Liberty Bay

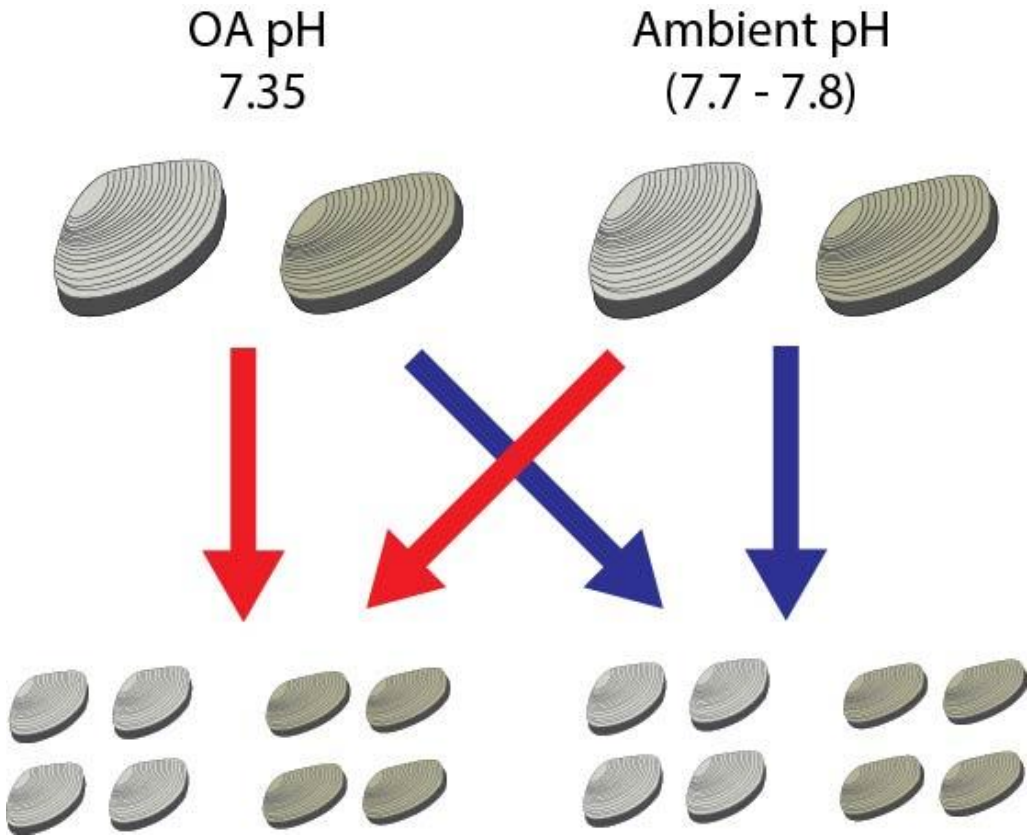
Research questions

Adults

Are native clams more tolerant of OA conditions, as seen in other bivalve species native to the Puget Sound?

Larvae

Can exposure of adults to OA conditions “prime” subsequent larvae to be more tolerant?



Can alternative **species** or **husbandry practices** improve resiliency to OA?

Results - overview

Treatment	Survival	Spawning
Littleneck – C	90.9%	20%
Littleneck – T	88.6%	29.5%
Manila – C	97.7%	25.6%
Manila – T	93.2%	11.6%

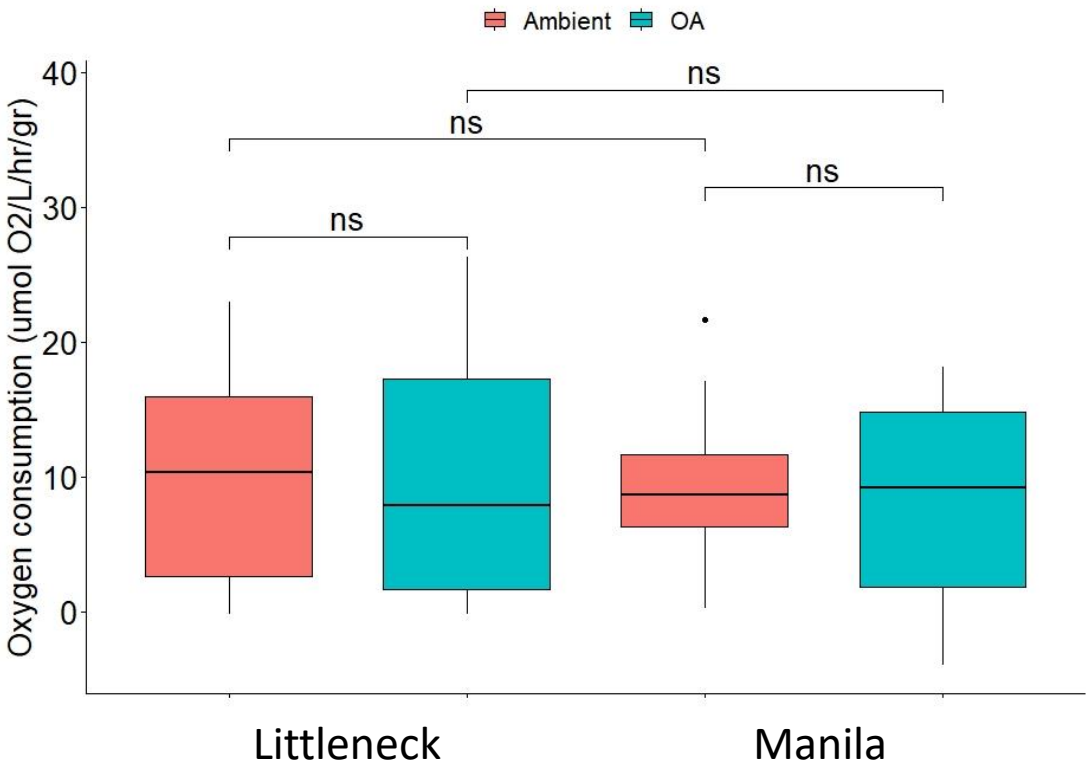
Survival was high in all groups, indicating that adults from both species of clams are capable of living for extended times at low pH.

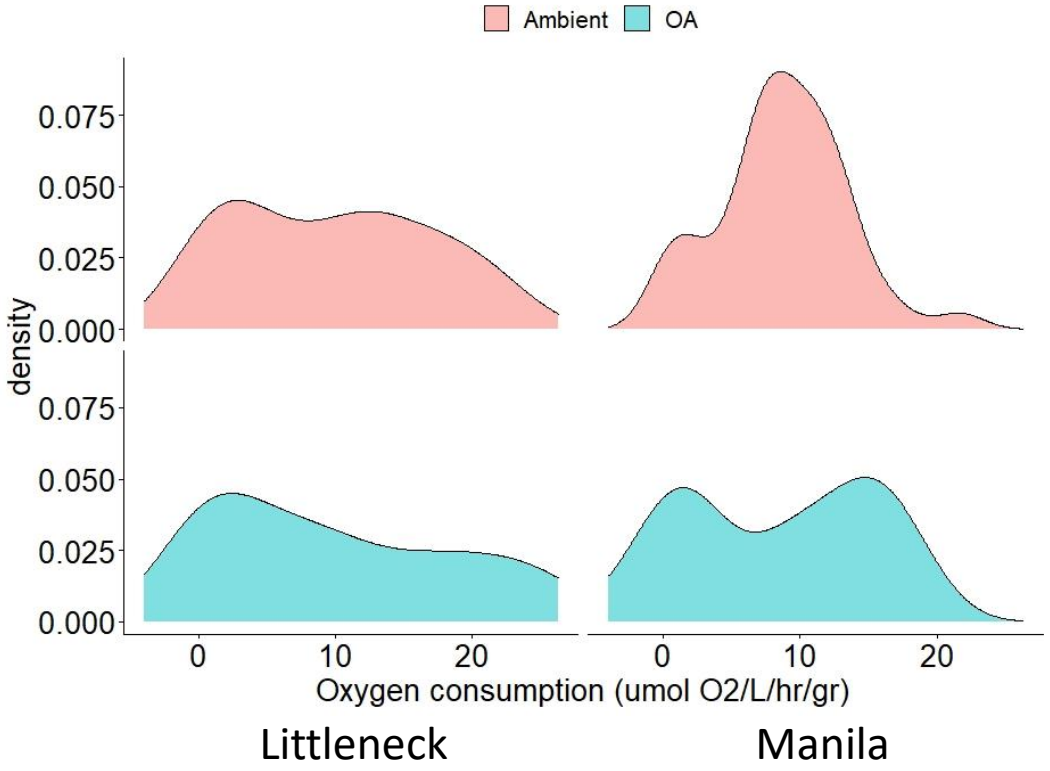
Spawning success was low, likely due either to insufficient maturation or issues with the methodology. Further analysis of histological sections can help clear this up

Respirometry

Respirometry measures oxygen consumption by individual clams over one hour

No difference was seen between treatments or species, but data distributions show more "closed" behavior in littlenecks and treatment groups





Early conclusions and next steps

So far, there is little evidence that either species is more tolerant of low pH, or that either is very sensitive as adults.

Further investigation of gene expression may reveal differential responses, as well as comparing response based on reproductive maturation.

Larval rearing protocols are still in development. Results at the larval stages are more likely to show OA impacts, and developing this process can be implemented in future restoration aquaculture.

Take home messages

Aquatic ecosystems are faced with a wide variety of threats from overharvesting to pollution to climate change.

Aquaculture production is becoming the dominant source of seafood, and if done correctly can help rather than hurt ecosystems.

Biology research can reveal the threats faced by aquatic animals, and the ways in which to improve aquaculture efficiency, sustainability, and its role in aquatic restoration.

Many thanks to the many people who have contributed to this research:

Tilapia research (2017-2021)

Dietmar Kueltz, UC Davis

Leah MacNiven, UC Davis

Avner Cnaani, Israel Agriculture Research Organization

Pazit Con, Israel ARO

Aurora Campo, Israel ARO

Clam research (2022)

Mackenzie Gavery, NOAA

Mollie Middleton, NOAA

Ryan Crim, Puget Sound Restoration Fund

Steven Roberts, UW

Matt George, UW

Delany Lawson, UW

Eileen Bates, UW

Elizabeth Unsell, Suquamish Tribe

Alexa Romersa, Pacific Hybreed

Questions?