**WFSC 448 – Fish Ecophysiology**

(Week 2,3 – 2022)

Physiology of oxygen, statistical understanding, functional tradeoffs

Major point: *Physical and chemical properties of water dominate lives of aquatic organisms in ways largely alien to terrestrial vertebrates*

Molecular mechanisms of oxygen’s influence on physiology

Oxygen (& CO2) carriers transduce titer signal and impact gene expression and so altering physiology, including endocrine cascades that alter behavior, autonomous processes, and genetic regulation that induce plastic development or remodeling, or direct physiological shifts (e.g. profusion of epidermal capillaries), etc.

Developmental

* Gill volume plasticity. What else (longer fins, greater vascularization…)
* Lauren Chapman work (readings posted to web).
* Tips on reading scientific papers: nice lifehack [here](http://lifeafterphd.com/how-to-read-scientific-journal-articles/)

We left off talking about constraints of water for oxygen acquisition

Recall, water under good conditions has about 30× less oxygen than air. Under bad conditions there is little to no oxygen in water. How do fish deal with it?

Chapman

Review and synthesis:

Fish in low oxygen populations evolve larger gills and the capacity for phenotypic plasticity in gill size (why?)

Fish in *variable* oxygen environments evolve *developmental plasticity* of gills

– larger gills develop under oxygen stress (why is variability key?)

Fish with big brains evolve large gills (why?)

Fish in sulfidic environments evolve large gills (why?)

In a recent *Science* article, there is a [related vignette](http://www.theguardian.com/science/neurophilosophy/2015/sep/11/blind-cave-fish-evolved-an-energy-saving-shrunken-brain). (Understand how related to current topic, being sure to *carry it through*—think about it until you realize something no one else has thought.)

Fish with larger gills have smaller brains (give two hypotheses as to why)

New insights from Chapman’s broader work:

* Large gills may compromise trophic apparatus in African haplochromine cichlids (why?)
* Oxygen and water flow both affect morphology, suggesting complicated interactions (*interactions=tradeoffs!*). Examine these effects [here](http://people.tamu.edu/~tdewitt/Disentangling%20complex%20phenotype-environment%20relationships.ppt)
  + Carry it through – e.g. how do flow and oxygen relate in nature?
  + How might one adaptation interfere with (or facilitate) the other?
  + How might gill plasticity work?
  + Oxygen carriers transduce signal and impacts gene expression and physiology, including endocrine cascades that alter behavior, genetic switches that induce plastic development or remodeling, direct physiological shifts (e.g. profusion of epidermal capillaries), etc.

Tobler

Fish in sulfidic environments experience low oxygen availability even where

oxygen exists

Fish in sulfidic environmentes compensate as if they had low oxygen – gill plasticity

Fish in no-light environments have reduced eyes (why?

C.f., what would happen in low light? Why?)

There is a strong interaction between impacts of light and sulfide ([spreadsheet](http://people.tamu.edu/~tdewitt/wfsc448/what%20is%20an%20interaction.xlsx))

Practice describing the effects you see in the statistical output and graphs.

What are other likely constraints of large gills?

Hint: think through physical properties of water (esp. solvent properties, intimacy) physiological function of organ system (e.g. energetics), and the fish anatomy picture. [*Discuss*]

* Oxygen capacity—refresh points of emphasize last time
  + - Fish must pump a very heavy medium across their respiratory surfaces
    - Fish must pump a much greater volume of medium across their respiratory surfaces
    - What else do the physical and chemical properties of water imply for this pumping
    - Heat exchange (water has high *specific heat* capacity)
    - Chemical exchange (water is *polar*; universal solvent)

The readings and our discussion not only cover the ecology and physiology of oxygen but strongly demonstrate the need for holistic thinking about fish biology: lessons in phenotypic tapestry theory (DeWitt phrase) wherein if one tugs on one thread of the physiological tapestry, deformation of other processes will likely propagate. Recall Muir:

"When we try to pick out anything by itself, we find it hitched to everything else in the Universe."

—John Muir, My First Summer in the Sierra (1911 p. 110)

Other responses to low oxygen

Behavior

Aquatic surface respiration, **ASR**, increased ventilation, “anal breathing”, fin breathing (original idea—most likely true), habitat choice, activity change (e.g. reduction), egg fanning. See review by Reebs [here](http://www.howfishbehave.ca/pdf/oxygen.pdf).

During aquatic surface respiration (ASR), fish use the uppermost layer of water that is generally richer in oxygen than deeper in the water column. This widespread adaptation to hypoxia is present in many different fish families. Contrary to popular belief, ASR does not involve air-breathing.

—Photo and caption from USGS ([link](http://fl.biology.usgs.gov/projects/hypoxia_tolerance.html)).

Note that the ecology can drive one to physiological limits—use of fringing wetlands in African Great Lakes system (Chapman, of course).

Strictly physiological adaptations to low oxygen levels (verbatim from Reebs reading):

“Adaptations to low oxygen can be not only behavioural but also physiological. Fishes

that live in frequently hypoxic habitats may have more haemoglobin in their red blood

cells, and more of those cells in their blood, and therefore a higher blood capacity to

take up and transport oxygen. Their body tissues may contain more myoglobin, a

molecule that can bind up oxygen and therefore act as an oxygen store. But their

main adaptation is anaerobic metabolism, a set of biochemical pathways that do not

require oxygen to yield energy. This type of metabolism is not very efficient and can

lead to the accumulation of relatively toxic by-products, such as lactic acid, and

therefore when oxygen is present anaerobic metabolism is put aside in favour of its

more efficient aerobic counterpart. But when oxygen is rare and metabolic demand is

low, as in a cold water fish for example, anaerobic metabolism can contribute to

survival for days, weeks, or even months. For example, through the use of anaerobic

metabolism, goldfish can survive for up to 9 days at 4 °C in only 0.5 ppm of oxygen.

Similarly, from February to April there is virtually no oxygen at the bottom of

northern lakes, and yet crucian carp, *Carassius carassius*, survive there because of

their anaerobic metabolism and the cold winter temperatures that lower their energy

requirements. Finally, drought is another ecological condition that selects for

anoxia tolerance via anaerobic metabolism. For example, the killifish *Austrofundulus*

*limnaeus* lives in ephemeral ponds in Venezuela and the eggs it produces can enter

diapause and survive for up to 60 days in the complete absence of oxygen.”

Others you can posit on your own?

Hint: be sure to think through all trait types (behavior, morphology, physiology, life history) and at all levels of biological organization (molecular, genetic, developmental, cellular, organ systems, etc.) *and interactions*.

Sidebar:

Another creativity tool—Wilcoxian observation. Water strider, Portia examples. Tailbeat observation in fishes.

Schofield PJ, Loftus WF, Brown ME (2008) Hypoxia tolerance of two centrarchid sunfishes and an introduced cichlid from karstic Everglades wetlands of southern Florida, U.S.A. **J Fish Biol** 71: 87–99. DOI: 10.1111/j.1095-8649.2007.01686.x

Poster: Why ecophysiology matters in fisheries biology  
<https://www.researchgate.net/profile/W_Loftus/publication/267847445_Why_Ecophysiology_Matters_Tools_to_Assess_Invasiveness_of_Non-Native_Aquatic_Fauna_in_the_Everglades/links/54e20e6d0cf2edaea090705b.pdf>