“Fish Treadmills”
Impacts of crude oil on organisms in the environment
How does crude oil impact fish swimming performance?

Relevant topic areas: Environmental Science, Biology, Life science, Marine science, Ecology

Relevant standards

- C-Palms SC.912.L.17.16
  Discuss the large-scale environmental impacts resulting from human activity, including waste spills, oil spills, runoff, greenhouse gases, ozone depletion, and surface and groundwater pollution.

- NGSS HS-ESS3-2 Earth and Human Activity

Objectives

- Students will learn about 2010 Deepwater Horizon oil spill, the largest oil spill in U.S. history
- Students will understand how oil can impact fish in the environment
- Students will examine how scientists perform research on fish in the laboratory using swim tunnel respirometers
- Students will learn the basics of using oxygen consumption to measure metabolic rate

Prior knowledge

Our virtual lab is designed to be flexible. With minimal background knowledge, students can interact with the virtual lab, and take a short multiple choice assessment quiz following the lab. This virtual lab could be assigned out of the classroom. A short list of key terms can be printed below if necessary.
Estimated time to complete lab and assessment: 20 minutes

Alternatively, our virtual lab is relevant to a number of topics in life and environmental science, and also addresses certain common core science standards. We suggest referring to the following website http://ocean.si.edu/gulf-oil-spill hosted by the Smithsonian Natural Museum of Natural History for an in-depth look at the 2010 Deepwater Horizon oil spill. Please also reference our list of key terms and frequently asked questions, and discussion topics below.

KEY TERMS, FREQUENTLY ASKED QUESTIONS, DISCUSSION TOPICS

TERMS

Crude oil: Liquid consisting mostly of hydrocarbon compounds and small amounts of compounds containing oxygen, sulfur, and nitrogen. Extracted from underground accumulations, it is sent to oil refineries, where it is converted to heating oil, diesel fuel, gasoline, tar, and other materials[1]

Pelagic: Open-ocean

Estuary: Partially enclosed coastal area at the mouth of a river where freshwater, carrying fertile silt and runoff from the land, mixes with salty water[1]

Fitness: Ability of an organism to survive and reproduce in a given environment

Water velocity: water speed

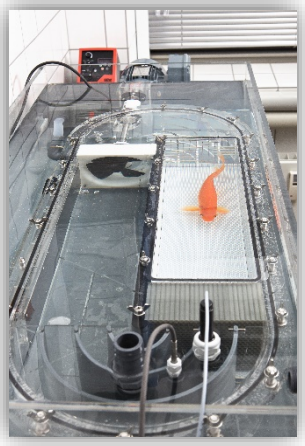
Acclimate: This term often has multiple meanings. In our virtual lab, we use this term to describe an animal in a laboratory experiment that has gotten used to their surroundings in the swim tunnel, and are no longer stressed from being handled.

Physiology: the branch of biology that deals with the functions and activities of life or of living matter (ex. organs, tissues, or cells) and of the physical and chemical phenomena involved[2]

Metabolic rate: rate of energy consumption; the rate at which an animal converts chemical energy to heat and external work. Oxygen consumption is an indirect measurement of metabolic. Measuring oxygen consumption is used as a measure because it is often easier to measure than direct caloric measurements and closely represents the production of heat and external work by an animal.[3]

[1]Textbook: Living in the environment, G. Tyler Miller, Jr, 15th edition, 2007.

SWIM TUNNEL RESPIROMETRY: a closer look



What is a swim chamber respirometer and why do researchers use it? A swim chamber is similar to treadmills for humans. Fish are placed in a chamber where the water flow is controlled by the researcher. The researcher can control the speed at which the fish is swimming. At the same time, the researcher can measure how much oxygen the fish is consuming at each swim speed, allowing them to estimate the metabolic rate of the fish at each swimming speed. Swim tunnels are a great tool to assess general animal performance. Photo credit (left): Loligo systems

View a video about swim chambers here:
https://vimeopro.com/user20324571/loligo-systems-videos/video/72805729

A swim tunnel respirometer can be used to estimate or measure the following:

Standard (basal) metabolic rate: the energy needed to sustain basic life processes in a resting and fasted fish[3]. In fish, this value must be calculated, since a resting fish usually has some degree of spontaneous activity

Maximum metabolic rate: Maximum rate or aerobic metabolism[3] measured indirectly by the maximum rate of oxygen consumption.

Aerobic scope Standard (basal) metabolic rate subtracted from maximum metabolic rate (measured indirectly by oxygen consumption rate) at a given temperature[3]. Energy available for all life processes beyond baseline metabolism (Basal standard metabolic rate). For example, aerobic scope is how much energy is available for processes such as growth and reproduction.

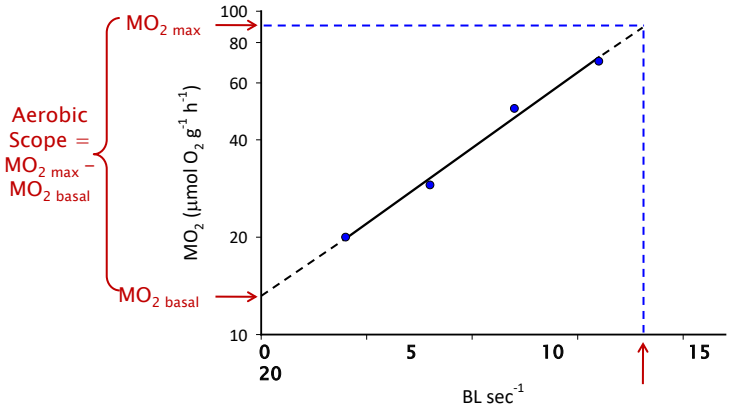
[2] Merriam-webster online dictionary: https://www.merriam-webster.com/dictionary/physiology
[3]Textbook: Animal Physiology, Hill, Wyse and Anderson, 1st edition, 2004.

Basic steps in performing swim tunnel respirometry

1) Fish are put in chamber to acclimate until oxygen consumption stabilizes. This is performed at a low water velocity so the fish will relax, but can still extract sufficient oxygen from the water.

2) Swim speeds are gradually increased over a set interval. For example, a fish may start at 1 body length per second for a 20 minute interval. During this interval the fish will gradually use oxygen from the water. This decline in oxygen can be measured and is used to assess metabolic rate at each swim speed.

3) Swim speeds increase after each interval until the fish can no longer sustain a given swim speed. If a fish begins to fall against the back of the chamber, it is considered a fail. At this point, the fish is exhausted. It would be similar to a human that can no longer continue to run on a treadmill. Scientists note the speed at which the fish "fails" to figure out the maximum sustained swimming speed, or what scientists often refer as U_{crit}. This speed can be compared across fish in an experiment to assess their maximum performance ability.



4) By knowing the swim velocity at which the fish has “failed”, it is also possible to know the maximum rate of oxygen consumption, which is the fish’s maximum metabolic rate. Using the maximum metabolic rate, along with the metabolic rate taken at each swimming speed, scientists can calculate the standard (basal) metabolic rate. By subtracting these two values, scientists can calculate aerobic scope, or the amount of energy resources available for all other life processes, such as growth, reproduction, finding food, and avoiding predators.

Topics and questions for further discussion:

Why is it important to compare maximum sustained swimming speeds in fish exposed to oil to fish that have not been exposed?

Can you think of other stressors in the environment that may cause a reduction in swimming speed?
Example: temperatures that are too hot or too cold, other pollution in the environment

What are some ways in which we can reduce our dependence on fossil fuels such as oil?

What other types of species likely have a high aerobic scope? Which species would likely have a lower aerobic scope?

How could a weakened immune system impact aerobic scope?

How can humans prevent oil spills from occurring in the future?

References:

To learn more, please explore the publications that contributed to this lesson

Red drum data and footage provided by Jacob Johansen

Website and Publications

www.JLJohansen.com

Mahi-mahi data and footage provided by John Stieglitz

Publications

Stieglitz, J. D., Mager, E. M., Hoenig, R. H., Benetti, D. D. and Grosell, M. (2016), Impacts of *Deepwater Horizon* crude oil exposure on adult mahi-mahi (*Coryphaena hippurus*) swim performance. Environ Toxicol Chem, 35: 2613–2622. doi:10.1002/etc.3436