**Warm-up Activity**: Working with 2 – 3 students sitting near you, discuss your answers to the “Lesson 4 Flipped Learning Assignment”. Share the summaries of the two peer-reviewed articles that you found. Working together, write a summary on phenological mismatches and migration. Be prepared to share with the class.

Give students 10 minutes to construct a summary.

**The Effect of Climate Change on Redhorse Migration**

Consider the figures to the right from Favrot and Kwak (2018). In this study, the authors tracked the movement of sicklefin redhorse upstream into tributaries of the Hiwassee River, including the Valley River. Based upon the figures, what factors may be related to the number of migrating sicklefin redhorse?

There are two peaks in the number of migrating sicklefin redhorse in 2006. These peaks seem to corresponds to two increases in the Valley River flow. They also correspond to daily temperatures reaching ~14°C. When spawning tributary temperature decreases suddenly, migration stopped. Both figures appear to be consistent in this finding.

What can be inferred about the factors influencing migration?

Flow may affect the timing of the migration, but it may also be related to temperatures. It can be difficult to determine which of these factors have a more significant effect on the timing of migration.

Favrot and Kwak (2018) also observed that migrating sicklefin redhorse fed over riverweed (*Podostemum ceratophyllum*), which contains aquatic insects,during their migration. Thus, riverweed may be critical habitat and a food source during the sicklefin redhorse migration. Consider the figure below that shows the number of migrating sicklefin redhorse observed over the 2017 spawning season and a hypothetical curve of riverweed abundance.



Summarize the relationship between riverweed abundance and sicklefin redhorse migration. Discuss the relationship in the context of phenology.

Riverweed abundance increases as the sicklefin redhorse become abundant in the spawning area. Thus, there is a match between the availability of riverweed and sicklefin redhorse.

Consider that riverweed abundance is based upon photoperiod, and sicklefin redhorse is affected by water temperature and stream flows. Construct a figure similar to the one above that illustrates a scenario of climate change.



Indicate the phenological mismatch on the figure that you construct. Describe the mismatch. Make a prediction on the future of the redhorse population in Brasstown Creek based upon the phenological mismatch.

Students should identify a shift in redhorse abundance (the peak migration) occurring earlier in the spring. If riverweed is cued by photoperiod, its abundance should not shift. This creates a mismatch between the abundance of sicklefin redhorse and the availability of riverweed. Thus, we might expect that redhorse populations may have fewer feeding opportunities during the energetically expensive migration. This could potentially result in reduced reproductive output, shorter duration migrations, shorter distance migrations, and mortality from migration due to the inability to successfully recover.

Based upon these results, consider the impact of climate change on the productivity of headwater streams in southern Appalachia in which redhorses and other suckers conduct significant migration events for spawning.

Students should reference the loss in nitrogen and other nutrient subsidies in the stream because of less abundant redhorse populations.

**Summative Assessment**

You have now completed four lessons in the Migration Case Study. This case study introduced energy flow and nutrient cycling in headwater streams and the contributions by migrating fishes in these ecosystems. Starting with the more familiar Pacific salmon, you applied this knowledge to an investigation of suckers and redhorses in southern Appalachian streams of the U.S. and their role of adding nitrogen to streams during their annual migrations. You then developed scientific skills in analyzing the results of data analysis to evaluate patterns in the migratory behavior of the sicklefin redhorse and made inferences about these patterns. Lastly, you considered the impact of climate change on migration and how this might affect migratory patterns of redhorses and stream productivity.

To assess your knowledge of ecological concepts related to this case study, you will construct a poster that describes the ecological value of the redhorse migration and draw connections between abiotic factors related to migration, energy flow, nutrient cycling, human-environment interactions, global climate change, and conservation biology. Posters will be evaluated based upon a provided rubric. You will work in assigned groups of 2 – 3 students to produce the poster. You are expected to use the resources of the case study along with sources you search out on your own to complete this assignment.

Poster Guidelines

Posters will be designed in Powerpoint with the 16:9 widescreen slide size. Each group is encouraged to embrace their creative tendencies in designing the poster. Groups should endeavor to use color and pictures in designing the poster. Posters should present information visually and reduce the amount of text as appropriate. Each poster is required to have a list of sources that supports the information presented in the poster.

Use the remaining class time to meet with your partner and to begin designing your poster. A rough draft of your design is due at the end of class.