NATIONAL CENTER FOR CASE STUDY TEACHING IN SCIENCE

The Shifty Salmon of Auke Creek

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Part I – Summer Work

Sofia Nelson was enjoying a beautiful spring day in the harbor of Auke Bay, Alaska, as she helped unload her family's boat after an afternoon fishing trip with her grandparents. As she walked the docks toward shore, Sofia saw schools of tiny juvenile salmon in the shallow water near the tide line. She knew the juvenile salmon would soon swim out to the open ocean. As she walked further, Sofia came across a newly posted flyer:

"WANTED! Field assistants to join local team of scientists investigating the migration timing of salmon and their relatives in Auke Creek. Auke Creek salmon, trout, and char are migrating earlier than they did historically. We seek research team members to assist in our study of Auke Creek salmon migration timing. If you are a student interested in an opportunity to participate in salmon research, contact Professor Rhonda Parker."

Sofia took down the contact information on the flyer and made it home in time for dinner with her parents.

"Hi Mom and Dad," said Sofia, walking through the door. "I have some interesting news."

"What's that, Sofia?" asked her father, setting dinner on the table.

"I saw a flyer posted at the harbor looking for research assistants for studies on changing migration timing of Auke Creek salmon, trout, and char. The flyer said that salmon seem to be migrating earlier than they used to. Why do you think salmon are leaving early?"

"That's a good question," said Sofia's mother. "There are several different Pacific salmon species, but they all hatch in freshwater and migrate out to the ocean, where they grow and gain most of their size, before eventually returning to their natal stream to spawn as adults and complete their life cycle. The timing of salmon returning from the ocean is really important to everybody because that's when the salmon are large and can be harvested."

"I've definitely heard elders talk about changes in the migration timing of salmon. And we've definitely seen some large scale changes in the ocean, like the 'warm blob' out in the Gulf of Alaska a few years ago," added Sofia's father, who was of Auk'w Kwaan Tlingit ancestry. "You should follow up on that research assistant position. You need a summer job and it sounds like interesting research."

After dinner, Sofia called and made an appointment to meet with Professor Parker, the salmon researcher, to find out more about the research and job opportunity.

Sofia met Professor Parker the following day at the Auke Creek weir. A weir is similar to a picket fence strung across a stream that completely blocks fish passage, but allows water to pass between the pickets. Scientists identify the life stage, sex, species, and other features of the fish before passing the fish over the weir to continue their migration. Since 1980, the Auke Creek weir has enabled scientists to count juvenile Pacific salmon moving out to sea each spring and to count adults returning from the sea each summer and fall.

"Nice to meet you, Sofia," said Professor Parker. "I'm glad you're interested in learning more about our work at the weir. What do you know about salmon and trout?"

"Well, I know that there are five species of Pacific salmon: sockeye, coho, pink, chum, and king salmon. And different streams have only some of these species and can also have steelhead trout, cutthroat trout, or Dolly Varden char, which are close relatives of salmon and often feed on juvenile salmon and salmon eggs. I also know that salmon return from the ocean to spawn in the stream they hatched in, and then they die after spawning. Also, adult salmon show up to spawn at their natal stream at predictable times of the year, which makes it easy to harvest them."

"That's all correct Sofia. How do you know so much about salmon?" asked Professor Parker.

"Well, I'm Auk'w Kwaan Tlingit on my Dad's side of the family, so my family has harvested salmon in southeast Alaska for generations. I've heard lots about salmon from my relatives over the years."

"That's really cool, Sofia. Let me show you what we've seen at the Auke Creek weir recently. If you take a look at this figure, you'll see some trends in the salmonids found in Auke Creek: pink, sockeye, and coho salmon, as well as trout and char. In fact, why don't you take this figure home and we can talk about it tomorrow at eight o'clock if you are still interested in the job and think you can start tomorrow."

"I'm definitely still interested! I'll see you tomorrow morning at eight o'clock," declared Sofia.

Professor Parker gave Sofia Figure 1 to take home. Get into small groups, examine Figure 1, and discuss how to interpret it. Next, answer the following questions in your groups.

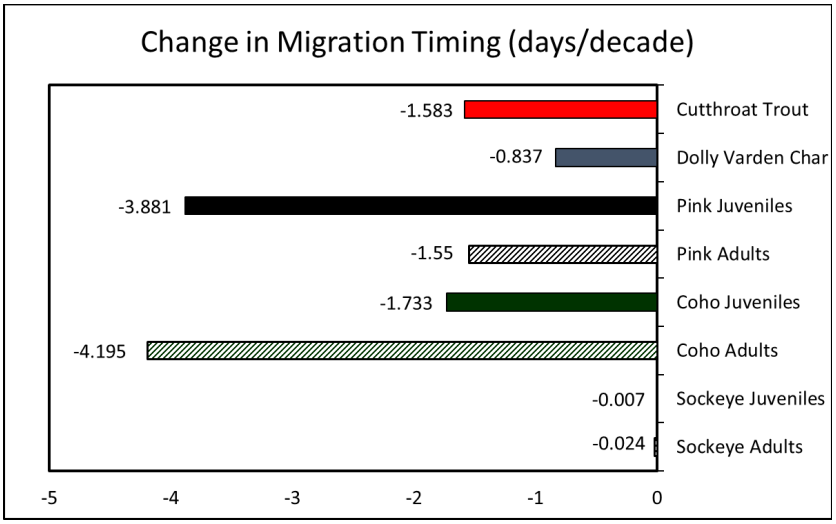

Figure 1. Migration timing changes of Auke Creek salmon, cutthroat trout, and char from 1980–2017 in days/decade. Included are data for outmigrants leaving freshwater on their way to the ocean (solid bars: cutthroat trout, Dolly Varden char, and juvenile salmon), and returning adult salmon swimming back upstream to spawn after maturing in the ocean (striped bars: pink, coho, and sockeye adults). Modified from Kovach *et al.,* 2013.

Questions

1. Based on Figure 1, what is the general trend in migration timing across Auke Creek fish over the last few decades?
2. Which juveniles outmigrating to the ocean and which returning adults from the ocean show the largest changes?
3. How would you calculate the total number of days that migration timing has changed for each reported value in Figure 1 from 1980-2017, a period of 38 years?
4. What are the results of this calculation for the extreme cases you identified in Question 1?

Part II – The Mystery Unfolds

When Sofia reported for work the next day, she donned waders and continued her conversation with Professor Parker as they counted and passed the juvenile salmon over the weir to continue their journey downstream to the ocean.

"So Professor Parker," began Sofia, "the figure you gave me to study shows that most species and life stages of salmon, trout, and char in Auke Creek are migrating earlier as time passes; earlier both in terms of going out to the ocean and coming back from the ocean to Auke Creek. Why is that?"

"That's right, good question," said Professor Parker. "Our analyses suggest warming temperatures affect salmon migration timing. We think it's likely that the trout and char are tracking the migrating salmon because they eat juvenile salmon and salmon eggs. One clear pattern is that temperatures in Auke Creek are increasing over time."

After they completed their work for the day, Professor Parker gave Sofia some additional background information about what had been happening at the weir. "Here's a figure showing the trend in mean annual stream temperature."

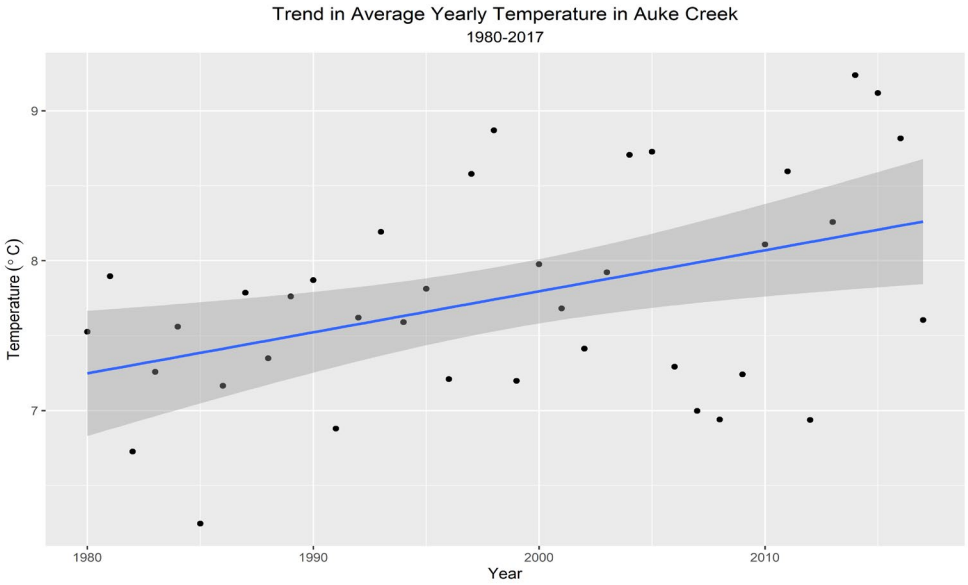

Figure 2. Trend in average yearly temperature in Auke Creek, Alaska, 1980–2017. Mean annual temperature trend (blue line) and +/- 1 standard error (dark gray). Modified from Kovach *et al.*, 2013.

"Wow, that's a pretty striking increase in mean stream temperature," exclaimed Sofia. "But it also looks like there's a fair amount of variation in temperature from year-to-year."

"Good observation. Not only do we see increases in average temperature over time, we also see fluctuations in temperature from year-to-year. Still, average annual stream temperature explains more variation in migration timing of juvenile salmon than any other predictor we have. In addition, we find that stream temperature is also a useful predictor of migration timing for adult salmon returning from the ocean."

Answer the following questions in your small discussion groups. Be ready to present your answers to the entire class.

Questions

5. By how much has mean temperature increased (in ^{0}C and in ^{0}F) from 1980 to 2017?
6. What is the effect of temperature on development and metabolism for ectotherms (like most fishes)? Would you expect it to have the same effects on endotherms (like mammals)?
7. What is a potential problem with simply measuring variables (e.g., temperature) correlated with an outcome (e.g., earlier migration of salmon) instead of directly manipulating those variables?
8. Could you design an experiment, rather than simply counting fish at the weir every year, to better test for factors that could be causing changes in the migration timing of juvenile and adult salmon? Describe the details of your study.

Part III – The Implications

"Have there been any other changes in the migration timing of Auke Creek salmon, trout, and char beyond earlier migration?" asked Sofia.

"Yes," replied Professor Parker. "We see not only earlier migration in most species and life history stages, but a smaller range of dates over which returning, adult salmon are observed at the weir. Here's a figure that shows this trend."

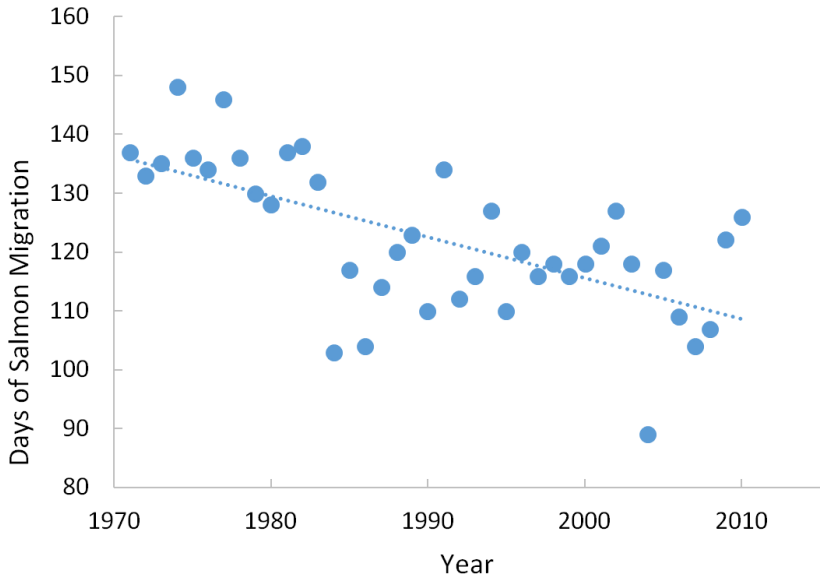

Figure 3. Intra-annual range of Auke Creek adult salmon migration. Trend in number of days per year (dotted line) over which adult salmon migrate past the Auke Creek weir on their way to spawn upstream. Modified from Kovach *et al.*, 2013.

"Wow," said Sofia. "So that means there are fewer days over which we can depend on adult salmon returning from the ocean to spawn in Auke Creek. It seems like that might have impacts on people who fish for a living and on other species that eat salmon."

"You're right," replied Professor Parker. "Another important question is how widespread across the range of salmon are the patterns we see for Auke Creek salmon."

Again, return to your discussion groups and answer the following questions.

Questions

9. The window of adult salmon migration in Auke Creek has shrunk by about 25 days. What are some possible effects on humans and non-human species of reduction in the range of days over which migrating salmon can be harvested? Make a list of species that might be affected and how.
10. Take your list of species from Question 9 and transform it into a figure showing connections and interactions with salmon for the species you listed.
11. What might be the effects of a narrower range of dates over which salmon migrate if this pattern holds across a regional scale?

Reference

Kovach, R.P., J.E. Joyce, J.D. Echave, M.S. Lindberg, and D.A. Tallmon. 2013. Earlier migration timing, decreasing phenotypic variation, and biocomplexity for multiple salmonid species. *PLoS ONE* 8(1): e53807. <https://doi.org/10.1371/journal.pone.0053807>