PHOTO DIARY

An Overview of Pacific Salmon

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Pacific salmon *Oncorhynchus* spp. are an ecologically, culturally, and economically important group of fish. In Canada, the Fraser River system is the largest producer of salmon, with ~150 genetically distinct populations of Sockeye Salmon *O. nerka* alone. In this system, Sockeye Salmon is the most commercially valued, while Pink Salmon *O. gorbuscha* is the most numerically dominant. Pacific salmon are all anadromous (migrate from freshwater to saltwater as juveniles, and return to freshwater to spawn as adults) and semelparous (spawn once and then die). While migration in general is a very common strategy across animal taxa, semelparity is very rare in vertebrates other than bony fishes, and within the bony fishes few species outside of Pacific salmon show this strategy. To make these strategies more extreme, Pacific salmon also cease feeding as they enter freshwater, and in the Fraser River travel up to 1,400 km upstream, relying solely on stored body fat. During the initial phases of migration, the sexes are still indistinguishable. As they approach the spawning grounds, males undergo a morphological transformation that includes elongation of the snout and lower jaw and development of a cartilaginous hump, while females mainly undergo a slight head elongation. The development of these secondary sexual characteristics is most pronounced in male Pink Salmon, and it has been suggested that these males show the greatest secondary morphological changes in any species of fish.

Even though anadromy is the rule in Pacific salmon, there is a remarkable amount of variation in how this is carried out

Pictured are two Pink Salmon males after spawning. The top male has more extreme secondary sexual traits (larger hump, longer snout) than the bottom male, and likely had higher reproductive success.

Researchers tag a salmon in a trough equipped with a flow-through pump.

Salmon carcasses provide important marine-derived nutrients and organic material to stream ecosystems. Pictured above is a male Pink Salmon carcass.

A fence blocks off part of a spawning channel so researchers can assess spawning success in salmon. A male Pink Salmon has already finished contributing to the next generation.

both within and among species, especially in Sockeye Salmon. Sockeye Salmon fry typically spend 1–2 years rearing in lakes but in some populations will instead rear in streams, and in yet other populations they migrate to the sea in their first year. In general, this is followed by 2–3 years in the ocean, though sometimes males will return after only 1 year in the ocean as a small "jack" and sneak fertilizations from dominant, older males. However, some populations of Sockeye Salmon have become landlocked and now spend their entire life in freshwater, completely foregoing the anadromous lifestyle. Called

The Fraser River as it flows from Lillooet, British Columbia.

The Seton River in Lillooet, British Columbia—host to multiple species of salmon—flowing into the Fraser River.

A male Pink Salmon has been tagged for visual identification to assess individual behavior during spawning.

kokanee, these fish develop the same secondary sexual characteristics as migratory Sockeye and at the same age, but at a much smaller size—though recently a 7-year-old kokanee was caught, demonstrating the remarkable variability of life-history traits within this species. Variation in age at maturity within populations also means that there is some genetic exchange among the runs in different years, which are otherwise genetically isolated from each other. This tendency to have non-overlapping generations means that each run experiences different biotic and abiotic conditions that affect breeding success. For example, consider a hypothetical population of Sockeye Salmon where 4-year-old adults spawned in fall of 2013. Those eggs hatched in spring 2014 and the fry migrated to lakes for one year. In the summer of 2015, those smolts travelled downstream and entered the ocean. These juveniles stayed in the ocean for two years to return as spawning adults in 2017. However, imagine that in spring 2016 there were exceptionally warm ocean conditions. This will affect food availability in the ocean for juveniles of this cohort, but also maturing adults of the 2012 cohort. However, fry and smolts from the 2014 and 2015 cohorts, respectively, would be much less affected. On the other end of the variation continuum, Pink Salmon fry always migrate immediately to the sea and virtually always return to spawn as 2-year-olds. The lack of variation in the life cycle of Pink Salmon means there is no genetic exchange between the even-year run and the odd-year run, which is likely why in parts of their range there are only runs every other year.

Managers use various techniques to forecast the size of the upcoming Sockeye and Pink salmon run in the Fraser River, but there are often large discrepancies between estimated run sizes and actual abundances measured during migration. For example, in 2015, the Sockeye Salmon run was 29.7% of forecasted size—a discrepancy of over 4.7 million fish—while the Pink Salmon run had 8.2 million fish lower than forecasted. Additional issues include overall low numbers of adult salmon returning to the Fraser River (2016 had the lowest Sockeye Salmon return in recorded history) and the early return of adults (both for some Sockeye Salmon populations over the last 20 years, and for Pink Salmon that in 2017 tied for the earliest peak migration timing since records started almost 60 years ago). Early returns in Sockeye can result in high mortality during freshwater migration (en route mortality as high as 70%) and failure of females to spawn even when they have reached the spawning grounds (pre-spawn mortality up to 90%).

These Sockeye Salmon are near the end of their migration, in full reproductive coloration. Males are easily distinguishable from females at this stage.

Pictured are two male Sockeye Salmon. The elongated snouts and teeth are used to fight other males over access to females.

The reasons for the low survival, changes in migration date, and failure to reproduce likely involve complex interactions between physiology, behavior, and the environment. Thus, researchers are using a variety of techniques to understand how biotic and abiotic stressors affect these fish. This ranges from tagging salmon while still in the ocean and utilizing acoustic arrays to determine passage rate and time, to taking non-invasive biopsy samples to assess gene expression, disease and parasite prevalence, and physiological, nutritional and energetic status, to experimentally holding individuals to determine the effects of temperature and flow. By using multiple techniques at multiple time points in the ocean, during migration, and at the spawning grounds, researchers hope to elucidate which factors are more important in regulating individual survival, migration timing, and reproductive success. With species that exhibit such complex life-history strategies, effective management will have to combine sound science with practical mitigation strategies. Additionally, as new technologies become cheaper and more practical in the field, researchers will be able to increase our knowledge of salmon throughout both their freshwater and marine life-history phases. AFS