Since its inception, the National Park Service (NPS) has operated under a mandate to preserve the resources under its stewardship such that they represent ‘vignettes of primitive America’. For fish, wildlife, and other natural resources, this mandate calls for maintaining abundances within a ‘natural range of variation’ (National Park Service 2025a). Pursuant to this, park managers are often confronted with either the scarcity of native plant or animal species or an abundance of non-native (exotic, invasive) species that may damage park ecosystems. However, ecosystems can also experience the hyper-abundance (i.e., abundance far beyond the normal range of densities) of a native species, due either to shifting regional trends in habitat suitability, to direct (and often anthropogenic) intervention, or to a combination of the two.

For example, in Yellowstone National Park, native mountain pine beetles have recently decimated coniferous forests due to a lack of cold winter temperatures, which have traditionally limited the insects’ numbers and, by extension, their impacts on forests (Gibson et al. 2008). Likewise, in many Midwestern and Eastern NPS units, habitat alterations and the extirpation of natural predators outside park boundaries has led to unprecedented densities of white-tailed deer, capable of intense foraging on vegetation and the depletion of resources on which other species depend (Miller et al. 2023).

While there is little debate that these issues generate a need for management action, the question of when some species exceeds the natural range of abundance and qualifies as hyper-abundant, thereby triggering a need for management action, can be difficult to ascertain. In the case of the mountain pine beetle, numbers of the insects are on the rise throughout the Rocky Mountains due to shifting climate patterns (Gibson et al. 2008). Is this then an ‘unnatural’ overabundance, or is it representative of a new natural state? Park managers across the NPS are confronted with these issues as they seek to interpret and implement the mandate to preserve resources in a natural condition. These ideas are central to the research question presented in this article, which focuses on a river in a small National Historical Park in Sitka, Alaska.

Sitka National Historical Park is a small 112-acre coastal park in southeastern Alaska. It was designated a national monument in 1910 and a national park in 1972 to conserve the site of a 1804 battle between native Tlingit and Russian colonizers. The park receives tens of thousands of visitors each year who learn about the history of Sitka and Tlingit culture and view totem poles along designated trails and active traditional totem carving activities. Along with the preservation of cultural resources related to the site, the park is also managed to preserve the spruce-hemlock forest, riparian ecosystem, and the Indian River, which includes a section of the main reach and the intertidal area that falls within the park boundaries (National Park Service 2025b).

Since time immemorial Kaasda Héen (the Indian River) has been the location of a fishing camp and harvesting site for the Kiks.ádi clan. The river was particularly valued for its proximity to the clan’s winter villages, as well as for hosting runs of Pacific salmon species, including chum (*Oncorhynchus keta,* Gaynii, téel), coho (*O. kisutch*, ÜÜx, l’ook), Chinook (*O. tshawytscha*, Yee, t’á) and pink salmon (*O. gorbuscha*, Sti’moon, cháas’) (Thornton 1998). Pink salmon, the most abundant species of salmon, typically return to spawn in late summer. When the eggs hatch in the spring, juvenile pink salmon emerge from the river gravel and immediately migrate to the ocean, with all members of a brood returning to spawn as adults two years later. This leads to two numerically and genetically distinct runs in even numbered and odd numbered years. Unlike regions farther north and south in the range of the species, the Indian River and others in this area see little variation in abundance between the even and odd cycles (Alaska Department of Fish and Game 2024a).

Pink salmon are an important food resource for predators and scavenging wildlife, a source of ‘marine-derived’ nutrients and energy for river and riparian ecosystems, and a coveted viewing experience for visitors to the park who observe the spawning and migrating fish from a footbridge that spans the river. [photos of fish in Indian River] Although pink salmon have always been abundant in the Indian River, their numbers have increased rapidly in the last several decades. The Alaska Department of Fish and Game (ADFG) peak escapement surveys (numbers of fish that have ‘escaped’ the fishery and returned to spawn in the river) demonstrate that, since 1980, pink salmon abundance has increased from several thousand to regularly exceeding 100,000 fish annually (Stopha 2015). [graph showing populations of pink salmon on the rise throughout NSE - outer] Moreover, there are indications that the duration of pink salmon spawning, formerly limited to August and September, now regularly spans July through October.

High salmon densities in the river are not necessarily a cause for management concern, as they may be naturally occurring phenomena influenced by variation in stream conditions, ocean productivity, predation intensity, and commercial harvests, among other factors (Manhard et al. 2017). However, salmon hatcheries can also influence the abundances of wild salmon (Knudsen et al. 2021). As part of typical hatchery operations, embryos are protected from natural mortality during incubation, and juvenile salmon are reared in raceways and net pens before they are released into the ocean to feed, grow, and later return. The hatchery utilizes the natural homing ability of salmon that imprint on the chemical cues in the water in which they are reared to return to the hatchery as adults. If all salmon reared in a hatchery returned to that hatchery as adults, then population dynamics of salmon in adjacent stream systems would be independent of hatchery operations. In practice, homing by salmon isn’t perfect, and some fish produced in the hatchery will inevitably ‘stray’ into nearby streams and rivers when returning as adults. While it is difficult to infer whether straying is more or less likely in hatchery-origin fish, homing imperfection is likely an evolved trait as it allows a few fish to colonize new habitats when they become suitable for spawning (Quinn 2018). Nevertheless, hatchery and fishery managers typically want to minimize straying rates, both to maximize the returns to the hatchery and also to reduce the chances of hybridizing hatchery and wild fish, as hybridization can produce offspring that are less adapted to local conditions and thus have lower fitness.

At Sitka National Historical Park, the possibility of hatchery pink salmon straying into the Indian River is particularly high. The not-for-profit Sitka Sound Science Center operates a hatchery immediately adjacent to the park boundary, less than a mile from the Indian River estuary. [map of hatchery position relative to Indian River] In general, the rate of straying is influenced by spatial proximity, as the closer a hatchery is to a stream, the greater the chance hatchery fish will stray into that stream (Knudsen et al. 2021). The hatchery has been in operation since 1975. Coincidentally or not, hatchery operations began shortly before initial increases in pink salmon abundances observed in the 1980s. The hatchery initially was permitted to rear and release 1 million pink salmon annually, a number that was increased to 3 million in 2010. The hatchery utilizes water from the Indian River, via a diversion upriver of the park’s boundary, as the source of water for operations. This water is used to rear salmon fry, which imprint on its chemical signature, and is also released into the bay near the hatchery to attract returning adult fish, only a few hundred meters from the mouth of the Indian River. Some portion of returning adults are retained each year by hatchery technicians as broodstock, from which the eggs that will grow into the next year’s cohort of juveniles are extracted. Initial broodstock at the onset of hatchery operations came from the Indian River (even years) and nearby Starrigavan Creek (odd years) (Stopha 2015).

Not surprisingly, surveying efforts in Indian River have at times unusually high numbers of stray pink salmon from the hatchery, making up one-third of all individuals sampled in a given year, although rates vary depending upon sampling period (Gende and Carter 2015). Managers can identify adults that were produced in the hatchery because all pink salmon released by the hatchery are subject to a process called otolith marking, in which small carbonate bodies located in the inner ‘ears’ of fish are marked with a distinct pattern. This pattern is produced during incubation when salmon eggs are exposed to a carefully controlled regime of dry periods and periods submerged in water (Alaska Department of Fish and Game 2024b; Stopha 2015). When salmon return to spawn as adults, the otoliths from the carcasses can be collected and sent to a lab [OTOLITH IMAGE] to determine whether the adult fish sampled in the Indian River are of hatchery or wild origin.

Assuming that hatchery and Indian River fish have been straying for decades, and that both these lineages come from similar genetic stock, there is little (if any) concern about preserving the genetically ‘pure’ line of salmon that are adapted to the conditions of the Indian River. Instead, the concern is that the abundance of pink salmon originating from the hatchery but spawning in the river may be contributing to such high densities of salmon that they may deleteriously impact the river’s ecosystem. When salmon spawn, they remove dissolved oxygen from the water through the direct consumption of O2 while alive and through their decomposition following death (Sergeant et al. 2023). High abundances occurring during periods of low river flows are capable of reducing dissolved oxygen concentrations to levels below what is needed for resident fish to survive, especially if these low flows coincide with warm temperatures. In stream systems free of hatchery influence, there are natural regulators (density-dependence) that bring the population back into balance when the number of returning spawners exceeds a stream’s carrying capacity. For example, at very high densities, females arriving later in a spawning season dig up nests (redds) made by early arriving females, so the stream has a natural limit to production. In other instances, females die before spawning if the stream is too crowded and oxygen levels are low. The question is whether these natural processes, resulting and swings in salmon abundance, are exaggerated by strays from nearby hatcheries to the point where the stream ecosystem is disturbed.

While fish originating from the hatchery may be contributing to the great abundance of pink salmon observed in recent decades at Indian River, it is also possible that the relatively low numbers of spawning pink salmon observed before 1980 may themselves have been historically atypical, and current densities are within the natural range. During World War II, US Navy contractors began dredging sand and gravel from the river bed, as well as from a wooded island at the river’s mouth, to build fortifications on nearby Japonski Island. Park service officials at the time believed that the removal of gravel contributed to several severe floods between 1940 and 1960 (Antonson and Hanable 1987). Even with the completion of those fortifications, gravel removal continued in the Indian River delta intermittently until 1960. This gravel removal and the accompanying floods profoundly affected the geomorphology of the reaches of Indian River in what is now Sitka National Historical Park, shifting the mouth of the river and stripping away lowlands near the river’s banks, impacting the quality of riparian habitat. Kiks.ádi elders have recalled that, before these dredging operations, the pink salmon runs at Indian River were so numerous that “it seemed like you should just be able to walk across the river on the humpies [pink salmon]” (Thornton 1998). It is altogether possible that high pink salmon abundances observed in recent years are not an exception but a return to historic levels.

With all this in mind, how might park managers determine whether the abundances of pink salmon observed in recent years at Indian River are within some natural range of variation? Building a baseline picture of pink salmon abundance in the wider region could provide a useful basis of comparison. ADFG has monitored pink salmon streams in southeast Alaska as far back as 1960 in order to manage escapement and regulate fisheries. This monitoring effort surveys 714 pink salmon index streams throughout southeastern Alaska via fixed-wing aircraft, with a randomly selected subset of those streams surveyed subject to foot counts for validation (A. Dupuis, personal communication, August 19, 2024). Of these 714 index streams, ADFG places 35 within the “Northern Southeast – Outside” subregion - the ocean-facing coasts of Baranof and Chicagof islands, as well as a few smaller islands in the vicinity (a region which includes Sitka and the Indian River). In 2023, the NPS entered into a partnership with USGS and the University of Washington to evaluate Indian River pink salmon populations in the context of the broader region. Using statistical modeling, it is possible to estimate the annual abundance of pink salmon at Indian River and to compare those estimates to pink salmon abundance in neighboring streams. These models also allow the year-to-year variation in pink salmon returning to spawn at Indian River to be likewise compared to the variation seen elsewhere in the area. The project will also explore the Indian River system in greater detail, with the goal of identifying what measurable impact hatchery releases have on abundances of spawning pink salmon entering the stream each year.

Part of the management challenge when confronted with hyper-abundant native species is assessing whether or not the abundances observed occur within some natural range of variation. The cases of the pine mountain beetle and white-tailed deer illustrate that many factors both local and global may drive the proliferation of endemic species within a national park. Pink salmon have returned to Indian River in large numbers every summer since time immemorial, but whether the density of spawning salmon observed recently is exceptional requires understanding both the general behavior of pink salmon in the region as well as the potential impact of direct influences such as hatchery releases. Taken together, we hope to provide context and clarity to park officials regarding the pink salmon population in the Indian River and the ability to maintain the healthy riverine ecosystem on which so many other resident species depend.

References

Alaska Department of Fish and Game. 2024a. Commercial Salmon Fisheries – Southeast Alaska & Yakutat Research: Pink Salmon. Available at: <https://www.adfg.alaska.gov/index.cfm?adfg=commercialbyareasoutheast.salmon_research_pink> (accessed December 14, 2024)

Alaska Department of Fish and Game. 2024b. Mark Recovery Laboratory – Otolith Marking. Available at: <https://mtalab.adfg.alaska.gov/OTO/marking.aspx> (accessed December 14, 2024)

Antonson, J. M. and W. S. Hanable. 1987. *An Administrative History of Sitka National Historical Park*. National Park Service. Available at: <https://www.nps.gov/parkhistory/online_books/sitk/adhi/index.htm> (accessed December 17, 2024).

Gende, S. and B. Carter. 2015. *Straying rates of pink salmon into the Indian River, Sitka National Historical Park. Final Report – ADF&G Permit # SF2015-225.* National Park Service, 11 pp.

Gibson, K., K. Skov, S. Kegley, C. Jorgensen, S. Smith, and J. Witcosky. 2008. *Mountain Pine Beetle Impacts in High-Elevation Five-Needle Pines: Current Trends and Challenges.* USDA Forest Service – Forest Health Protection, 40 pp.

Holmes, E. E., E. J. Ward, and K. Wills. 2012. MARSS: Multivariate Autoregressive State-space Models for Analyzing Time-series Data. *The R Journal* 4(1): 11-19.

Knudsen, E. E., P. S. Rand, K. B. Gorman, D. R. Bernard, and W. D. Templin. 2021. Hatchery-origin stray rates and total run characteristics for Pink Salmon and Chum Salmon returning to Prince William Sound, Alaska in 2013-2015. *Marine and Coastal Fisheries* 13(1): 41-68.

Manhard, C. V., J. E. Joyce, W. W. Smoker, and A. J. Gharrett. 2017. Ecological factors influencing lifetime productivity of pink salmon (*Oncorhynchus gorbuscha*) in an Alaskan stream. *Canadian Journal of Fisheries and Aquatic Sciences* 74(9): 1325-1336.

Miller, K. M., S. J. Perles, J. P. Schmit, E. R. Matthews, A. S. Weed, J. A. Comiskey, M. R. Marshall, P. Nelson, N. A. Fisichelli. 2023. Overabundant deer and invasive plants drive widespread regeneration debt in eastern United States national parks. *Ecological Applications* 33: 24pp.

National Park Service. 2025a. Organic Act of 1916. Available at: https://www.nps.gov/grba/learn/management/organic-act-of-1916.htm (accessed March 27, 2025)

National Park Service. 2025b. Sitka National Historical Park. Available at: https://www.nps.gov/sitk/index.htm (accessed March 18, 2025)

Quinn, T. P. 2018. *The Behavior and Ecology of Pacific Salmon and Trout, Second Edition.* University of Washington Press, 547 pp.

Sergeant, C. J., J. R. Bellmore, C. McConnell, J. W. Moore. 2017. High salmon density and low discharge create periodic hypoxia in coastal rivers. *Ecosphere* 8(6):e01846.

Sergeant, C. J., J. R. Bellmore, R. A. Bellmore, J. A. Falke, F. J. Mueter, and P. A. H. Westley. 2023. Hypoxia vulnerability in the salmon watersheds of Southeast Alaska. *Science of the Total Environment* 896: 165247.

Stopha, M. 2015. *An Evaluation of the Sheldon Jackson Salmon Hatchery for Consistency with Statewide Policies and Prescribed Management Practices.* Alaska Department of Fish and Game, Division of Commercial Fisheries, 42 pp.

Thornton, T. F. 1998. *Traditional Tlingit Use of Sitka National Historical Park*. National Park Service, 170 pp.

Tillotson, M. D., T. P. Quinn. 2017. Climate and conspecific density trigger pre-spawning mortality in sockeye salmon (*Oncorhynchus nerka*). *Fisheries Research* 188: 138-148.