Since its inception, the National Park Service (NPS) has operated under a mandate to “preserve unimpaired the natural and cultural resources” under its stewardship. 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 hyperabundance (i.e., abundance far beyond the established range of densities) of a native species, due to shifting regional trends in habitat suitability, direct (and often anthropogenic) intervention, or a combination of the two.

For example, in Yellowstone National Park, native Mountain Pine Beetles (*Dendroctonus ponderosae*) 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 have led to unprecedented densities of White-Tailed Deer (*Odocoileus virginianus*), 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 a species exceeds their natural range of abundance 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” hyperabundance, or is it representative of a new natural state? Park managers across the NPS are confronted with these issues as they seek to make careful and informed decisions using the best scientific information available to preserve natural resources. These ideas are central to the research presented in this article. At the Indian River in Sitka National Historical Park, recent decades have seen annual abundances of native Pink Salmon (*Oncorhynchus gorbuscha*, Sti’moon, cháas’) increase dramatically, putting other resident aquatic species at risk due to the depletion of dissolved oxygen concentrations. Some believe these highly abundant runs may be influenced by the operations of a nearby hatchery rearing and releasing pink salmon, some of which inevitably stray into Indian River and thereby supplement natural abundances. However, monitoring efforts from the Alaska Department of Fish and Game (ADFG) show Pink Salmon abundance on the rise throughout southeast Alaska, meaning the conditions in the Indian River may be reflective of the current natural state. The intention of this work is to parse this question, and to determine what if any impact hatchery releases have had on Indian River Pink Salmon abundances in the context of broader regional trends.

Sitka National Historical Park is a small coastal park in southeastern Alaska. It was designated a national monument in 1910 and a national park in 1972 to conserve the site of an 1804 battle between native Tlingit peoples and Russian colonizers. The park receives nearly four hundred thousand visitors each year who learn about the history of Sitka and Tlingit culture, and view totem poles along designated trails as well as active traditional totem carving activities. Along with the preservation of cultural resources related to the site, the park is also managed to preserve approximately 120 acres of 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 Tlingit name for 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 permanent and winter villages, as well as for hosting runs of Pacific salmon species, including chum (*O. keta,* Gaynii, téel), coho (*O. kisutch*, ÜÜx, l’ook), Chinook (*O. tshawytscha*, Yee, t’á) and Pink Salmon (Thornton 1998). Pink Salmon, the most abundant species of salmon, typically return to spawn in late summer (Ruggerone et al. 2025). 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 (Quinn 2018). This leads to two genetically distinct runs occurring in even numbered and odd numbered years, each with its own characteristic abundance (Alaska Department of Fish and Game 2024a).

Pink Salmon in southeast Alaska are an important food resource for predators and scavenging wildlife, providing a vector for marine-derived nutrients to make their way into riparian ecosystems (Brandt et al. 2024). Historically, Indian River Pink Salmon held special importance for Kiks.ádi fishers, as they were the first salmon to appear each year (Thornton 1998). Today these fish provide a coveted viewing experience for visitors to the park who observe the spawning salmon from a footbridge that spans the river. Although Pink Salmon have always been abundant in the Indian River, their numbers have increased rapidly in the last several decades. 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). 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 abundance of salmon (Knudsen et al. 2021). As part of typical hatchery operations, fish embryos are protected from natural mortality during incubation, and juvenile salmon are reared in relatively low-mortality 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. Therefore, 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 however, 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 aim to minimize straying rates, both to maximize the returns to the hatchery and 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 (May and Westley 2024).

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. 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 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).

Fisheries managers and biologists are able to identify hatchery-produced salmon through otolith marking, a process in which small carbonate bodies located in the inner “ears” of fish are marked with a distinct pattern produced during incubation. To produce these markings hatchery technicians expose salmon eggs to carefully controlled regimes 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 to determine whether the adult fish sampled are of hatchery or wild origin. Not surprisingly, surveying efforts in Indian River have at times noted high numbers of stray Pink Salmon from the hatchery, however these rates vary depending on year and sampling period. For example, in 2015 hatchery strays made up approximately 33% of all individuals Pink Salmon sampled, while in 2011 hatchery strays represented less than 5%. (Gende and Carter 2015). Likewise, sampling of fish returning to the hatchery has recorded large percentages of wild-born fish, and while these wild fish with no otolith marks cannot be said to have conclusively originated in the Indian River the proximity and linkages between the two sites makes this the most likely scenario.

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 distinct genetic lineage 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 both through the direct consumption of oxygen while alive and through the respiration of decomposing microbes following their death (Sergeant et al. 2023). High salmon abundances occurring during periods of low river flows can reduce dissolved oxygen concentrations to levels below what is needed for resident fish and other aquatic life to survive, especially if these low flows coincide with warm temperatures (Sergeant et al. 2017). 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. Hypoxia events are also not limited to stream systems in which natural abundances are supplemented by hatchery strays. In such an instance, females may die before spawning due to lowered oxygen levels (Tillotson and Quinn 2017). In either of these scenarios, the numbers of spawners returning in subsequent years would be subsequently constrained. These constraints weaken with the introduction of straying fish from hatcheries, and the question becomes whether these natural processes, and resulting 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 riverbed, as well as from a wooded island at the river’s mouth, to build fortifications and an airport 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, and anecdotal accounts suggest the river may at times have been restocked with fish from other streams during this period. 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. It is worth nothing that 1960 is the first year following the banning of salmon fish traps in Alaska, suggesting that salmon abundance may have been at a historical low point throughout the region (Colt 1999). 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 Chichagof and Baranof islands (where Sitka is located), as well as a few smaller islands in the vicinity.

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 in the Indian River and to compare those estimates to Pink Salmon abundance in neighboring streams. The project will also explore the Indian River system in greater detail, with the goal of identifying what if any 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 native 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.

**Introduction**

Since its inception, the National Park Service (NPS) has operated under a mandate to preserve the resources under their stewardship such that they represent ‘vignettes of primitive America’. For natural resources, particularly those that vary in space and time, the management target has always been to maintain abundances within a ‘natural range of variation’. Pursuant to this, park managers are often confronted with either the scarcity of endemic plant or animal species or an abundance of non-native (exotic, invasive) species that may damage park ecosystems (National Park Service 2025a). However, harm to ecosystems can also be driven by a hyperabundance of an endemic species, due either to shifting regional trends in habitat suitability, to direct (and often anthropogenic) intervention, or to a combination of the two (Sambaraju and Goodsman 2021, Beckett et al. 2022, Moore et al. 2023). While there is little debate that these occurrences generate a need for management action, the question of when a hyperabundance of some endemic species exceeds the natural range of variation, thereby triggering a need for management action, can be difficult to ascertain. 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.

With these ideas in mind, my research focuses on Sitka National Historical Park (SITK) in Sitka, Alaska, a small 112-acre coastal park located in the state’s southern panhandle. SITK was designated a National Monument in 1910 and park in 1972, primarily to conserve the site of an 1804 battle between the native Tlingit Kiks.ádi clan and Russian colonizers (National Park Service 2025b). The park, which features a series of totem poles along designated trails and active traditional totem carving activities, is visited by tens of thousands of tourists each year who learn about the history of Sitka and Tlingit culture. While its foundational purpose is the preservation of a historical event, today the park is managed to preserve the natural resources present in the surrounding area, ecosystems which include mature spruce-hemlock forests and the Indian River, the main reach and intertidal area of which fall within park boundaries

Since time immemorial Kaasda Héen (the Indian River) has been the location of a fishing camp and harvesting site for the Kiks.ádi clan, and particularly valued for its close proximity to the clan’s winter villages, as well as for hosting runs of a variety 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 are the most numerically abundant species at Indian River, and typically return to spawn in August. Eggs hatch the following spring and juveniles immediately enter the ocean, with all members of a brood returning to spawn two years later. This leads to two genetically distinct runs of salmon inhabiting the same stream in even numbered and odd numbered years. Unlike in regions further north or south, the rivers of northern southeast Alaska see even- and odd-year pink salmon runs that are approximately equal in abundance (Alaska Department of Fish and Game 2024a).

Although pink salmon have always been abundant at Indian River, their numbers have increased rapidly in the last thirty years. The Alaska Department of Fish and Game (ADFG) peak escapement surveys have estimated that, since 1980, pink salmon abundance has increased from several thousand to regularly exceeding 100,000 fish annually (Stopha 2015). High abundances of salmon are concerning to park managers because, particularly when occurring at the same time as low in-stream flows, the high fish densities can impact the Indian River’s ability to sustain other resident fish species by crashing in-stream dissolved oxygen concentrations (Sergeant et al. 2023). High salmon densities are a naturally occurring phenomenal across the Pacific Rim, and incidences of ‘overescapement’, whereby females may die before spawning owing to high densities, or of fish contributing to depleted dissolved oxygen levels have been recorded (Sergeant et al. 2017, Tillotson and Quinn 2017).

Coincident with the initial increases in pink salmon observed in the 1980s was the commencement of operations at Sheldon Jackson Hatchery (SJH), a pink salmon hatchery located less than a mile from the mouth of the Indian River. The hatchery is currently operated by the not-for-profit Sitka Sound Science Center but was originally established in 1975 by the Sheldon Jackson College. The college, founded in 1888 as a hybrid Indian re-education facility and utopian planned community, was at its inception granted water rights from the Indian River. Today, water is taken from a diversion upriver of the park’s boundary to maintain the hatchery operations. This water is used to rear salmon fry, which imprint on its distinct chemical signature, and also used during spawning season, when more of this diverted Indian River water is released into the bay near the hatchery in order to attract returning fish. In late summer returning hatchery fish tend to aggregate in large schools just offshore, where commercial fisherman partnered with the hatchery purse seine the fish for the purposes of cost recovery. In recent years the hatchery has been permitted to propagate 3 million eggs, which equate to releasing millions of fry to the ocean each year. While these eggs are extracted from hatchery broodstock, the original stock of eggs was taken primarily from pink salmon from the Indian River (even years) and nearby Starrigavan Creek (odd years).

If all pink salmon that were reared in the hatchery returned to the hatchery, the population dynamics of salmon in the Indian River would be unaffected. However, homing by salmon isn’t perfect, and in fact is likely an evolved trait that allows fish to colonize new habitats when they become suitable for spawning (Quinn 2018). Straying, whereby a juvenile salmon that was produced in one stream (or hatchery) strays into a different stream as an adult to spawn, is likely a common phenomenon for hatchery fish (Knudsen et al. 2021). Evidence suggests that the Indian River is no exception, and indeed it seems probable that the Indian River may see higher than average levels of straying due to the proximity of SJH and the hatchery fish being reared in Indian River water. It is possible to distinguish hatchery-origin fish at Indian River 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 fishes 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, leaving a pattern on the otoliths of each fish (Alaska Department of Fish and Game 2024b) reflecting a specific hatchery of origin (Stopha 2015). When salmon return to spawn as adults, biologists can collect the otoliths and determine whether the adult fish sampled in the Indian River are of hatchery or wild origin. Surveying efforts at Indian river have at times found stray pink salmon from Sheldon Jackson Hatchery making up one third of all individuals sampled in a given year. However, rates observed vary considerably, perhaps due to the time of year pink salmon are sampled, with some surveys observing rates of straying closer to 10% (Gende and Carter 2015).

**Objectives**

This research seeks to assess whether the abundances of pink salmon observed in recent decades at Indian River exist within a natural range of variation relative to pink salmon streams elsewhere in the vicinity of Sitka. In addition, this research seeks to quantify the effect SJH operations has had on abundances of pink salmon at Indian River over time.

**Interpretation and Significance**

The results of this work are intended first and foremost to provide management at SITK with a comprehensive description of both the impacts of SJH operations and of the population dynamics of pink salmon throughout the broader region. Understanding whether or not pink salmon at Indian River exist within a ‘natural range of variation’ requires context, and placing Indian River within this context will enable park officials to better understand their duties with regard to a potential overabundance of these fish. Additionally, estimating the effects of various levels of straying on pink salmon abundance may enable park officials to better understanding of when abundances are being driven by hatchery strays and when they are reflecting regional trends (although this would require more robust monitoring of stray rates).