Title

Hyperabundance of endemic species and pink salmon in Sitka National Historical Park

Reviewer Comments

AUTHOR COMMENTS IN RED

Reviewer #1:

1) This is nicely written and easy to follow! It's great to watch this project unfold.

Why thank you

2) Readers would benefit from a better road map in the article. It would help to have a more explicit goals and objectives statement early on. For example, a well-defined research question or (questions) would fit well around Lines 23-24.

This is a really good suggestion. The third paragraph has been heavily reworked to clearly lay out research goals and the stakes regarding hyperabundance of these fish at Indian River.

3) I don't think this has to be brought up in the article, unless you would like to, but I was wondering whether you will consider closely analyzing other rivers near pink salmon release sites in both SE Alaska and Prince William Sound. There are a couple of articles (e.g., Brenner et al. 2012 below) that demonstrate how hatchery salmon are more likely to stray into systems that are closer to the hatchery release point. So, hypothetically, you could separately look at trends in surveyed systems closer to hatchery sites (say, <25 km from release site) to see if their abundance trends differ from sites that are further from a hatchery release site. That could give you greater interpretive value over just looking at Indian River on its own.

Example of paper on straying as a function of distance from hatchery release site:

*Brenner, R. E., Moffitt, S. D., & Grant, W. S. (2012). Straying of hatchery salmon in Prince William sound, Alaska. Environmental Biology of Fishes, 94, 179-195.*

This is an excellent suggestion for inclusion in a results oriented analysis. To my knowledge pink salmon hatcheries are few and far between in southeast Alaska but quite plentiful in Prince William sound. It would be very interesting to observe how trends in systems close to hatcheries in PWS compare to those seen at Indian River. Of course, exogenous pressures on all pink salmon may differ somewhat in PWS at the more northern end of their range than in se Alaska.

4) In discussing the pink salmon management options in front of the Park Service, the Resist-Accept-Direct Framework might be good to mention and discuss; but, I haven't been an NPS employee for a while now, so I'm not sure how this framework is viewed by the agency

Example of paper on RAD framework, including Alaska salmon case study:

*Lynch, A. J., Rahel, F. J., Limpinsel, D., Sethi, S. A., Engman, A. C., Lawrence, D. J., ... & Porath, M. T. (2022). Ecological and social strategies for managing fisheries using the Resist‐Accept‐Direct (RAD) framework. Fisheries Management and Ecology, 29(4), 329-345*

Also an excellent suggestion. Potential management actions aren’t discussed in this article draft but will certainly play a role in the discussion of this work when completed and in communications with both representatives of the park as well as with ADFG and the SSSC hatchery. Understanding this framework will be helpful in facilitating this communication.

Reviewer #2:

My review edits and comments are attached. I layered them on top of Chris'; figured that would be easier for you than dealing with multiple copies. Broadly I find that Chris made excellent points I agreed with, leaving me with little to add. My one new larger point (not contained in my edits on the document) is that I think it would benefit general readership if you went into slightly more detail about the importance of pink salmon to the region. You allude to some of this around Line 40, but I think 3 or so more sentences in that vicinity about the importance of these fish culturally, economically, recreationally, and ecologically would really help underscore the importance of the work.

Built out commentary on the cultural value of pink salmon in the region, both historically and at present, and with regards to the ecological importance of the species. While there is an active fishery, pink salmon are not as commercially valuable in se Alaska as they are elsewhere in their range (further north at Prince William sound for example). I do discuss the value to park visitors of being able to see these fish migrating in the summer and connecting with ideas of stewardship and conservation through that experience.

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Abstract

Hyperabundance of endemic species within their native range can pose a difficult management challenge. Whether due to direct human influence on their environments, or from indirect human influence due to shifting climate regimes, hyperabundance of native species can be as perilous to an ecosystem as incursion from an invasive species. This study examines the case of pink salmon (*Oncorhynchus gorbuscha*) in Sitka National Historical Park’s Indian River. Though native to the river, numbers of pink salmon returning in late summer to spawn have grown exponentially in recent decades, putting other fish species reliant on the river at risk. This is of concern to park managers, as the National Park Service mandates the maintenance of conditions such as they would occur “absent human domination over the landscape.” Some observers believe that the activity of a nearby hatchery, which releases 3 million pink salmon fry each year, is directly contributing to the abundance of pink salmon seen at Indian River. This study seeks to determine whether this is indeed the case, or whether the increased numbers of pink salmon observed at Indian River are reflective of trends in the wider region. An assessment of pink salmon escapement data collected by the Alaska Department of Fish & Game at known pink salmon streams in the region provides a basis for such a comparison.

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 hyper-abundance (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 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, 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 exceed the natural range of abundance and trigger 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” 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 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 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 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 river with fish in it

AI-generated content may be incorrect.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,

*Pink salmon spawning at Indian River, Sitka National Historical Park*

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. 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). 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 A branch in a stream

AI-generated content may be incorrect.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 A graph showing the average number of salmon peak returns

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*Pink salmon spawning in the Indian River, Sitka National Historical Park*

*Pink salmon population abundance at 35 streams in southeast Alaska*

*(Alaska Department of Fish and Game)*

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

A map of a park

AI-generated content may be incorrect.pink salmon annually, a number that was increased to 3 million in 2010. The hatchery utilizes

*Location of Indian River mouth (red circle) and Sitka Sound Science Center (red square)*

*(National Park Service)*

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. This is a A close-up of a circular object

AI-generated content may be incorrect.process in which small carbonate bodies located in the inner “ears” of fish are marked with a distinct pattern produced during incubation, when hatchery 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 to determine whether the adult fish sampled in the Indian River 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, making up one-third of all individuals sampled in some years, although rates vary depending upon sampling period (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.

*Otolith of a pink salmon fry from Wally Noerenberg Hatchery in Prince William Sound showing the regular rings produced by systematic changes in temperature to mark the fish.*

*(Dion Oxman – Alaska Department of Fish and Game)*

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 through the direct consumption of oxygen while alive and through the respiration of decomposiing 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 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. 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 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.

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