Since its inception, the National Park Service has operated under a mandate to preserve resources under their stewardship within a natural range of variation. Pursuant to this, park service officials often find themselves concerned either due to the scarcity of endemic plant or animal species or due to an abundance of non-native species damaging park ecosystems. However, harm to ecosystems can also be driven by hyperabundance of an endemic species due to the removal of some downward population pressure. This may result from shifting regional trends in habitat suitability, from some more direct (and often anthropogenic) intervention, or from a combination of the two. In Yellowstone National Park, endemic mountain pine beetles have recently decimated coniferous forests due to a lack of cold winter temperatures which have traditionally limited the insects’ numbers (Gibson et al. 2008). In many Midwestern and eastern national parks and monuments, habitat alterations and the culling of natural predators outside park boundaries has led to historically high densities of endemic white-tailed deer, capable of intense foraging on vegetation and the depletion of resources on which other endemic species depend (Porter 1991, Waller and Alverson 1997). The question of when a hyperabundance of some endemic species exceeds the natural range of variation is borderline philosophical. 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? In either case, how should park service officials interpret the service’s mandate to preserve resources in a natural condition? These ideas are central to the research presented in this article which focuses on a small stream in a small National Historical Park in Sitka, Alaska. In recent decades, park managers have observed what may be unnaturally high abundances of pink salmon (Oncorhynchus gorbuscha) arriving to spawn in late summer. These fish bring with them the potential to strain their ecosystem’s ability to sustain other resident fish species by crashing in-stream dissolved oxygen concentrations (Sergeant et al. 2023). There exists the possibility that these high abundances of pink salmon are driven in part or in whole by the presence of a nearby salmon hatchery which rears and releases 3 million of these fish each year. Alternatively, their numbers could be the result of shifting/climate and habitat trends impacting pink salmon in the broader region. This work seeks to build a picture of pink salmon populations in the vicinity of Sitka against which the numbers observed at the stream of interest may be compared, as well as to determine the of impact local hatchery releases on the annual abundance of spawning pink salmon in this stream.

The Indian River, Kaasda Héen in native Tlingit, is a short, innocuous stream immediately south of Sitka, Alaska. For thousands of years, Indian River has been home to pink salmon appearing to spawn in large numbers every August, providing nourishment for the forest and the local Kiks.ádi clan (Thornton 1998). In this regard Indian River is unexceptional, as a great many streams in the region host large runs of these fish. Like all pink salmon, the pink salmon of Indian River hatch and enter the ocean in the same year, with all members of a brood returning to spawn two years later. This leads to two genetically distinct runs 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 suns that are approximately equal in abundance (Alaska Department of Fish and Game 2024a). In addition to pink salmon, the Indian River is home to many other resident fish species, including a large run of chum salmon (Oncorhynchus keta) and smaller numbers of coho and Chinook salmon (Oncorhynchus kisutch and Oncorhynchus tshawytscha), as well as year-round resident cutthroat and rainbow trout (Oncorhynchus clarkii and Oncorhynchus mykiss) and Dolly Varden char (Salvelinus malma). These fish in turn provide food for resident species, including bald eagles (Haliaeetus leucocephalus), blue herons (Ardea herodias), river otters (Lontra canadensis), and grizzly bears (Ursus arctos horribilis), among others (National Park Service 2024). Today, the river’s lower reaches flow through Sitka National Historical Park, a small national park established both in order to preserve the river and the surrounding forests as a resource for indigenous traditional uses, as well as due to the area’s history as a site of conflict between the Kiks.ádi clan and Russian colonizers in the 19th century.

Although pink salmon have always been abundant at Indian River, their numbers have increased rapidly in the last thirty years, straining the river’s capacity to sustain not only themselves, but also other endemic aquatic species. Alaska Department of Fish and Game (ADFG) surveys have estimated that, since 1980, pink salmon abundance has increased from between several hundred to 20,000 fish returning per year to regularly exceeding 100,000 fish annually and never less than 66,000 fish after 1996 (Stopha 2015). Large numbers of pink salmon returning in late summer when flows are often at their lowest can lead to significant reductions in dissolved oxygen concentrations in a stream, presenting a risk to other resident species and to those non-aquatic species dependent on Indian River’s productivity (Holtgrieve and Schindler 2011).

Less than a mile from the mouth of the Indian River, the not-for-profit Sitka Sound Science Center operates the Sheldon Jackson Hatchery. The hatchery was originally established in 1975 by the Sheldon Jackson College, the final iteration of a hybrid Indian re-education facility and utopian planned community adjacent to the Indian River, founded in 1888 by the Presbyterian missionary Sheldon Jackson (Thornton 1998). The hatchery rears and releases 3 million pink, 3 million chum, and 250,000 coho salmon on site each year. The linkages between these hatchery-bred pink salmon and the wild populations at Indian River run deep. The initial broodstock of hatchery pink salmon were sourced from the Indian River (even years) and nearby Starrigavan Creek (odd years). The hatchery owns senior rights to divert water from Indian River, upstream of Sitka National Historical Park, dating back to the college’s establishment. This water is used to rear salmon fry, which imprint on its distinct chemical signature, and during spawning season, when more of this diverted Indian River water is released into the bay near the hatchery in order to attract returning hatchery fish for the purposes of cost recovery. All pink salmon released by the hatchery are subject to a process called otolith marking, in which small carbonate bodies located in the inner of fishes are marked with a distinct pattern corresponding to their hatchery of origin (Stopha 2015). During their incubation, salmon eggs are exposed to a carefully controlled regime of dry periods and periods submerged in water, which leaves the desired pattern on the otoliths of each fish (Alaska Department of Fish and Game 2024b). Through these marked otoliths, biologists are able to determine whether 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 33.3% 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).

The history of the Indian River and of Sitka National Historical Park is of particular relevance to this work. Since time immemorial the stream has been a fishing camp and harvesting site for the Kiks.ádi clan, particularly valued for its close proximity to the clan’s winter villages, as well as for hosting runs of four Pacific salmon species (Thornton 1998). In 1804 a battle occurred near the mouth of Indian River between native Tlingit and Russian colonizers. The eventual Tlingit retreat led to the establishment of a Russian presence in Sitka until the cessation of Alaska to the United States in 1867 (National Park Service 2024). By the time of the cessation, tensions between Russians and Tlingit had relaxed, with clan members once again making use of the river and surrounding area for subsistence. After 1867, white settlers from the United States established homesteads along the Indian River, dug mines in the upper reaches of the river valley, and built roads and bridges along its course. It is during this period that Sheldon Jackson College is established. These disparate uses of the area surrounding Indian River led to conflict between whites and native Alaskans, and eventually necessitated legislation in 1890 which set aside 50 acres along the lower reached of the stream as a public park, before being declared a National Monument in 1910 and then a National Historical Park in 1972 (Thornton 1998, Antonson and Hanable 1987).

The relatively low numbers of spawning pink salmon observed at Indian River in the 1980s may themselves be historically atypical. 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, in order 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 said military fortifications, gravel removal would continue in the Indian River delta intermittently until 1960. This gravel removal and the accompanying floods had profound effects on the geomorphology of the reaches of Indian River located 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, prior to 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 service officials 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 behavior in the wider region would provide a useful basis of comparison. Happily, ADFG has monitored pink salmon streams in southeast Alaska as far back as 1960, for the purpose of managing escapement and regulating the fishery. This monitoring effort surveys 714 pink salmon index streams throughout the Alaska panhandle 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 neighborhood of Sitka and the Indian River which includes the ocean-facing coasts of Baranof and Chicagof Islands, as well as a few smaller islands in the vicinity. Broadly speaking, peak pink salmon escapement has been on the rise throughout this subregion since approximately 1990, while relative variability in year-to-year returns has declined during the same time period.

Using statistical modeling, it is possible to dig deeper into what these ADFG say about the state of pink salmon populations in the vicinity of Sitka. Multivariate autoregressive state-space (MARSS) models are particularly well suited for parsing long running time series data like ADFG’s pink salmon surveys for two reasons. First, MARSS models are designed to mathematically distinguish inconsistencies in observations from variation in the underlying state of a system (in this case the underlying state refers to the actual population of pink salmon in a stream). This is useful when parsing data collected by different observers operating in differing conditions (weather, time of day, time of year, etc.), where those conditions likely bias the observations being made. Second, MARSS models allow for gaps in the time series of observations to occur, while retaining the ability to make inferences about the underlying state (Holmes et al. 2012). While ADFG’s surveys of pink salmon index streams are consistent from 1960 onward, records of pink salmon at Indian River contain some years with no observations, making this second feature of MARSS models especially valuable to this research. MARSS models make it possible to estimate the annual abundance of pink salmon at Indian River and to then 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. MARSS models also make it possible to explore the Indian River system in greater detail, the goal being to identify what measurable impact hatchery releases have on abundance of spawning pink salmon entering the stream each year. Controlling for stream level characteristics (temperature and flow rate) and ocean climate allows these statistical models to isolate the effect of hatchery straying on pinks salmon populations.

Part of the management challenge when confronted with hyperabundant endemic species is assessing whether or not the abundances observed are occurring 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 unsustainable proliferation of endemic species. 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, the modeling approaches presented above will provide context and clarity to park officials evaluating what actions to undertake in order to sustain pink salmon populations while maintaining the healthy riverine ecosystem on which so many other resident species depend.

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