Straying rates of pink salmon into the Indian River, Sitka National Historical Park

Final Report

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Abstract

Otoliths were collected from senescent dead pink salmon from 2013-2015 with the objective of better understanding the rate of straying from the Sheldon Jackson hatchery (SJH) into the Indian River, Sitka National Historical Park. The ratio of SJH hatchery-marked otoliths to total readable otoliths was used as a measure of straying rate. A total of 700 pairs of otoliths were collected across 7 sampling efforts including 2 occasions each in 2013 (30 August, 27 September; N = 200) and 2014 (2 and 16 September; N = 200), and on 3 occasions in 2015 (26 August, 16 and 28 September; N = 300). Otoliths were immediately sent to the ADF&G Mark Lab for reading. 17 otolith pairs were unreadable and 5 otoliths were assigned to the Port Armstrong hatchery. As the primary objective was to understand the rate of straying from the SJH, Port Armstrong otoliths were dropped from analysis. Thus, total sample size was 678 otoliths across all years (N = 338 females, N = 340 males).

Pooling all years, sampling periods, and sexes revealed that, in addition to in situ production, a sizable fraction of the adult pink salmon population spawning in the Indian River originates in the SJH. Overall straying rate was 24.2% (females: 24.3%; males: 24.1%). Sex-specific straying rates varied among sampling periods from 0% (0 marks of 48 female otoliths collected on September 28, 2015) to 62% (32 of 50 females on 26 August, 2015). Straying rates increased across years from an average of 10.1% in 2013 to 33.3% in 2015, and appeared to be higher earlier in the summer. Stray rates averaged 33.7%, 30.1%, and 3.7% for otoliths collected during the 14-day periods of August 26-September 9th, September 10th – September 24th, and September 25th – October 9th, respectively (years pooled).

Hatchery fish are likely contributing to the high densities of pink salmon present in the Indian River over the past few decades. In addition to running counter to the NPS mandate of managing for 'natural abundances', high densities of salmon can deleteriously impact other park resources. For example, in 2013, low flows coupled with high pink salmon abundance dropped dissolved oxygen (DO) levels in the river to below 7mg/L for much of August, and below 5mg/L for over a week. Dead Dolly Varden and cutthroat trout were discovered in the Indian River during that period, and over 90% of female salmon sampled for otoliths had died prior to spawning their eggs. In light of these results, we recommend that NPS, ADF&G, and SSSC managers adopt measures to reduce straying and consider achievable actions that meet the management goals of all stakeholders.

Introduction

Salmon are considered a keystone species in small coastal streams in Alaska (Gende et al. 2002), naturally influencing stream geomorphology (Schindler et al. 2003), water chemistry (Holtgrieve and Schindler 2011), and a myriad of trophic dynamics both in the stream (Gende et al. 2002, Schindler et al. 2003) and in adjacent riparian areas (Gende et al. 2004, Gende et al. 2007). In the Indian River, Sitka National Historical Park (SITK), pink salmon (*Oncorhynchus gorbuscha*) are the most abundant species of spawning salmon, and represent an important viewing experience for visitors. The Indian River also supports diverse riverine and estuarine communities typical of a small coastal ecosystem including resident and anadromous rainbow trout (steelhead), Dolly Varden charr, cutthroat trout, and other common coastal fish species. Native runs of coho and chum salmon, with occasional sockeye and chinook salmon, also occur in the river (Stark et al. 2012).

Both ANILCA and the NPS Management Policies of 2006 have language that requires parks to manage resources "..at levels they would occur absent human domination over the landscape" and in their 'natural' condition. While pink salmon have increased regionally over the past several decades, spawning runs in the Indian River have exhibited exponential growth (Figure 1). For example, in the 1980s, peak abundance estimates, conducted by the Alaska Department of Fish and Game (ADF&G) varied between several hundred and 20,000 fish. In the mid-1990s, however, peak abundances regularly exceeded 100,000 and have approached 400,000 in recent years, three orders of magnitude higher than peak runs in the 1970s (Figure 1).

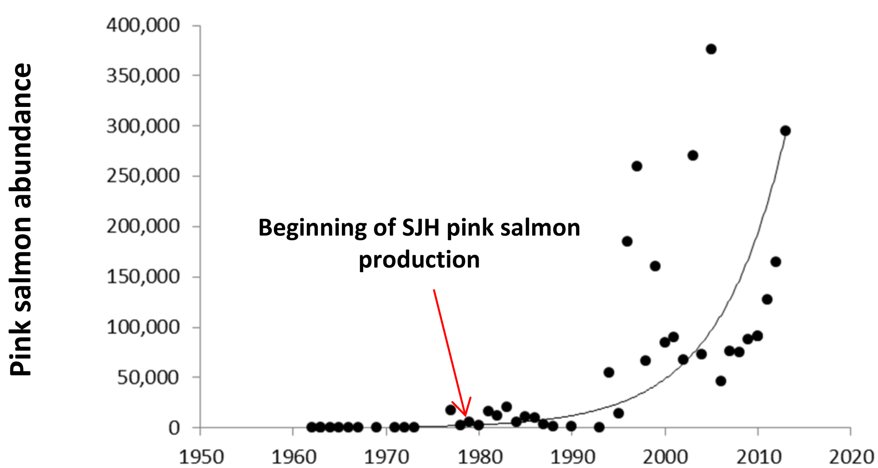

Figure 1. Peak escapement counts in the Indian River, 1962 – 2013. Data: Sheldon Jacks Hatchery Management Plan (2015).

There are two lines of evidence to suggest that the operations of the Sheldon Jackson College salmon hatchery (SJH), located adjacent to SITK, has contributed to the increase in abundance of pink salmon in the Indian River. First, the exponential increases in pink salmon returns to the Indian River coincide with hatchery operations over the same period. The SJH, which began operations in 1975 as part of the Environmental Science Program at the now defunct Sheldon Jackson College, has produced and released large numbers of pink salmon fry for four decades. For example, during the period 1980-2009, when the number of pink salmon spawning in the Indian River increased dramatically, the hatchery released an average of over 5.5 million pink salmon fry annually (Figure 2), most of which were reared in marine net pens and released adjacent to SJH in Crescent Bay.

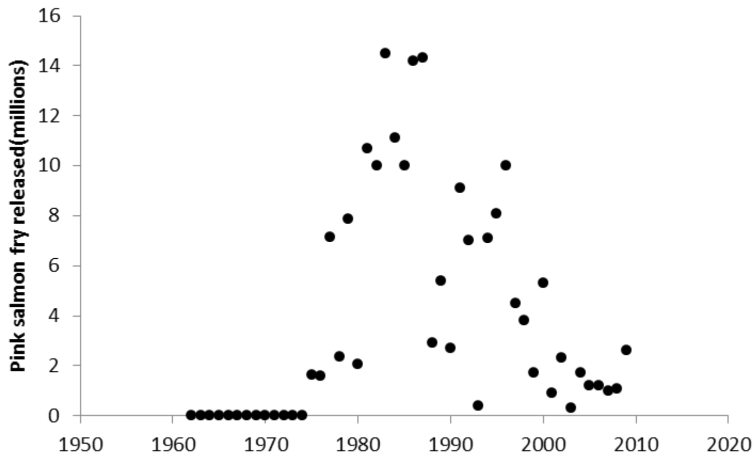

Figure 2. Pink salmon fry released by the Sheldon Jackson Hatchery 1975-2010. Source: Sheldon Jackson Hatchery Management Plan (2015).

Second, SJH operations are particularly favorable for high rates of 'straying' into the Indian River, i.e., juvenile pink salmon that are produced in the hatchery 'stray' into the Indian River when returning to spawn as adults. Straying is a natural phenomenon of wild salmon, having evolved to allow populations to colonize new habitats, and previous studies suggest that pink and chum salmon have the highest propensity for straying (Quinn 2005). The SJH, now operated by the Sitka Sound Science Center (SSSC), uses water for hatchery operations diverted directly from the Indian River. This diversion, located approximately 1.3 km upstream of the estuary, occurs based on a State of Alaska water right originally granted to Sheldon Jackson College in 1914, which is now exercised through a 42" and a 12" pipe diversion at up-to 30 cubic feet per second (cfs). Thus, juvenile pink salmon will have imprinted on olfactory cues identical (or nearly identical) to the water in the Indian River. Consequently, ADF&G does not use the Indian River as part of their pink salmon escapement indexing effort owing to concerns from straying from the SJH. In other systems, straying has been demonstrated to substantially increase the number of spawning salmon in rivers near hatcheries (Zhivotovsky et al. 2012; Brenner et al. 2012; Piston and Heinl 2012).

In 2011, the SJH was granted a permit to triple their egg 'take' and thus the number of pink salmon fry produced, from 1 million to 3 million annually, with the goal of releasing nearly 2.7 million pink salmon fry per year. As part of the permit, the Alaska Department of Fish and Game (ADF&G) required the SJH to estimate the straying rate by collecting otoliths from spawned pink salmon in the Indian River. Estimates of straying rate are possible because all pink salmon produced in the SJH (since the 2005 brood year) have been thermal marked whereby salmon are subjected to a varying temperature regime during incubation that produces a recognizable pattern of alternating rings in the center of their otoliths (pair of ear bones). When the otolith is viewed (read) under a microscope, the dark and light rings, reflecting cold and warm temperatures, can be attributed to a specific hatchery, as each hatchery in Alaska uses a different temperature regime to produce a unique pattern in the otoliths. By comparing the ratio of marked to total otoliths collected, stray rates from the SJH to the Indian River were estimated at 3%, 5% and 13% for 2011-2013, respectively (SSSC 2015).

In 2013, the National Park Service implemented a multi-year study with the goal of supplementing the existing otolith collections to better understand the rates of straying into the Indian River. The SJH has collected an average of nearly 140 otoliths per year, 2011-2013, to evaluate the rate of straying. Thus the goal of the NPS project was to diversify the sample dates (early, mid, late in the run), sample locations (from estuary to Sawmill Creek bridge), and overall sample size (minimum of 200 collected each year). This report summarizes the results of those sampling efforts, and considers next steps for monitoring and management.

Methods

From 2013-2015, the Indian River was walked from the estuary to the Sawmill Creek bridge (park boundary) on at least 2 occasions per year to collect pink salmon otoliths. A total of 700 pairs of otoliths were collected across 7 sampling efforts including 2 occasions each in 2013 (30 August, 27 September; N = 200) and 2014 (2 and 16 September; N = 200), and on 3 occasions in 2015 (26 August, 16 and 28 September; N = 300). Otoliths were extracted from fish gathered from three general areas along the Indian River spanning the park boundaries to insure spatial balance of samples. The first sampling location was around the gravel bar just upriver from the estuary. The second and third sampling locations were located around the foot bridge and the Sawmill Creek (road) bridge, respectively.

Figure 3. The lower portion of the Indian River and locations where otoliths were collected. For each sampling date, a total of 100 otoliths were collected (50 males and 50 females). When possible, approximately equal numbers were collected from each of the three sampling sites.

At each of the three general sampling areas, salmon that appeared to have died recently, i.e., not covered in fungus, were collected from the stream bottom or along the banks of the river and carried to a location where otoliths were extracted using a knife and small forceps. Otoliths were placed in trays provided by the ADF&G MARK lab, and the sampling location, date, salmon sex, and salmon spawning status (ripe with eggs remaining or spawned out) was recorded in a notebook with corresponding tray number. Trays were then delivered to the Mark Lab within several days of collection.

Figure 4. Pink salmon pulled from the Indian River and placed at a sampling location for otolith extraction (top). Pink salmon head cut open with arrows point to the pair of otoliths (bottom).

Results

A total of 700 otolith pairs were collected. Of the 700, 17 were unreadable and 5 otoliths had marks assigned to the Port Armstrong hatchery, located near the southern tip of Baranof Island. As the primary objective was to understand the rate of straying from the SJH, Port Armstrong otoliths were dropped from analysis, resulting in a total sample size of 678 otoliths across all years (N = 338 females, N = 340 males).

Pooling all years, sampling periods, and sexes revealed that, in addition to natural production, a sizable fraction of the adult pink salmon population spawning in the Indian River originates in the SJH (Table 1).

Table 1. Sample sizes of readable pink salmon otoliths collected in the Indian River and total otoliths with marks indicating their origination from the Sheldon Jackson Hatchery (SJH) for 2 sample dates in 2013 and 2014, and 3 sample dates in 2015.

		Males	Females	Males	Females	Males	Females	Total	Stray Rt
2013		***30 Aug***		***27 Sept***					
	Otoliths Read	44	49	49	47			189	10.1%
	SJH Marks	10	5	1	3			19	
2014		***2 Sept 2014***		***16 Sept***					
	Otoliths Read	53	45	50	50			198	24.2%
	SJH Marks	14	8	11	15			48	
2015		***26 Aug***		***16 Sept***		***28 Sept***			
	Otoliths Read	50	50	47	49	47	48	291	33.3%
	SJH Marks	30	31	13	20	3	0	97	

Overall straying rate was 24.2% (164 SJH marks of 678 readable otoliths). Female stray rates were nearly identical to males (females: 24.3%; males: 24.1%). Stray rates varied among individual sampling events from 0% (0 marks of 48 female otoliths collected on September 28, 2015) to 62% (32 of 50 females on 26 August, 2015; Table 1). Straying rates increased across years from an average of 10.1% in 2013 to 33.3% in 2015 (Figure 5). There also appeared to be higher straying rates for sampling periods that occurred earlier in the summer. Stray rates averaged 33.7%, 30.1%, and 3.7% for otoliths collected during the 14-day periods of August 26-September 9th, September 10th – September 24th, and September 25th – October 9th, respectively (years pooled).

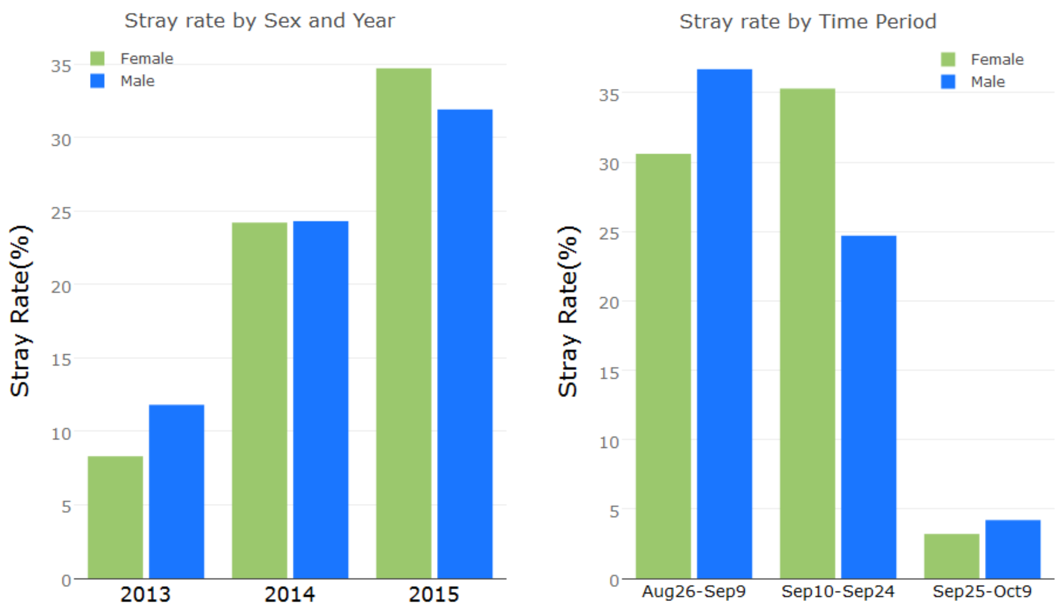

Figure 5. Left graph: Stray rates of SJH pink salmon into the Indian River by sex and year (all sampling dates within years pooled). Right graph: Stray rates of SJH pink salmon into the Indian River by 2-week period (all years pooled).

Discussion

The National Park Service has a mandate to manage park units in such a manner that populations and processes are, to the extent possible, free of anthropogenic control. Both ANILCA and the NPS Management Policies of 2006 have language that requires parks to manage resources "..at levels they would occur absent human domination over the landscape" and in their 'natural' condition. While concern over 'unnatural' abundances of park resources often focus on rare or depleted resources (endangered wildlife, rare fish, soundscape, wilderness), equally important is managing unnaturally overabundant resources, even if they are a natural component of park ecosystems. For example, white-tailed deer are a naturally occurring, keystone species in many Midwestern national parks (e.g., Waller and Alverson 1997). Yet wide-scale habitat alterations and reduction of natural predators outside park boundaries have resulted in an overabundance of deer populations within park boundaries that are now negatively impacting biodiversity in some parks, with cascading, multi-species impacts (e.g., Frerker et al. 2013).

Owing to average straying rates of nearly 25% across 3 years, it's clear that SJH fish are contributing to the large increase in abundance, and possibly prolonged run-timing, documented in the Indian River over the past few decades. Salmon are naturally subject to many sources of mortality including during the freshwater component of their life-history. Eggs, alevins, and fry are subject to sediment transport and scour, disease due to fungus and viral outbreaks, and predation, all of which can dramatically influence freshwater survival and the number of juvenile fish that enter the ocean. The hatchery, by definition, produces millions of offspring with the intent of reducing mortality during the freshwater stage of salmon (target survival: ~90%) from egg take to release. Thus the natural mortality events that would typically limit the abundance of wild salmon populations during their freshwater phase are absent (or unnaturally reduced) in hatchery populations, allowing them to annually supplement the population of spawning fish in the river. In addition, the hatchery fish that stray into the Indian River will spawn, thereby further increasing the number of fish year over year. After 15+ generations (30+ years of hatchery production of pink salmon), it's likely that the number of fish in the Indian River has been significantly supplemented by the hatchery.

In addition to the management goals of 'natural' abundances of fish and wildlife, the NPS also has a mandate to manage processes in such a manner that reduces impacts to other park resources. There are periods and conditions when the abundance of pink salmon in the Indian River may have adversely affected other park resources. For example, the August 2013 otolith sampling effort occurred during a protracted period of dry weather. The resulting low flows, coupled with a high abundance of pink salmon, produced levels of dissolved oxygen (DO) in the river under 7 mg/L for a 37-day period during which time hypoxic conditions were present during 91% of hourly measurements (Sergeant et al. in review). The threshold of 7 mg/L is below ADF&G's threshold level for supporting salmon and other native fish species. In fact, during a nearly 1 week period, average DO levels dropped below 5mg/L. While walking the river to collect otoliths, a large number of dead Dolly Varden charr and cutthroat trout were discovered (Figure 6). What's more, 89% of female salmon sampled for otoliths had died prior to spawning some or all of their eggs.

Figure 6. Dead Dolly Varden seen during an otolith collection effort during August, 2013 (top). Dead resident fish collected from a single pool in the lower Indian River, August 2013 (bottom).

Field observations and simulation modeling results clearly demonstrate that the high density of salmon in the river contributed to decreased dissolved oxygen (DO) through respiration (Holtgrieve and Schindler 2011; Sergeant et al. in review).

It's difficult to infer what the carrying capacity of the Indian River would be for a naturally-sized pink salmon run, i.e., absent the influence of the hatchery. Nevertheless, the Basic Management Plan for the Sheldon Jackson Hatchery states (5.3 Escapement Monitoring) that "…if stray rates are determined to be excessive or detrimental by the department, release strategies will be reevaluated and production may be reduced or curtailed". It remains unclear what constitutes 'excessive' but our results should invoke discussions with ADFG, the hatchery, and the NPS for defining management goals of the Indian River and possibilities for research on carrying capacity and river impacts.

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