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Black Lake habitat changes and potential impacts on Chignik sockeye
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Early rearing conditions in freshwater and marine habitats are critical for juvenile salmon growth and survival[1–3]. Two issues may have contributed to lower survival for sockeye salmon returning to Black and Chignik Lakes in 2018; habitat changes in Black Lake and sub-optimal rearing conditions in the Gulf of Alaska, 2014-2015. Smolt monitoring studies show lower condition factor for Chignik juveniles out migrating those years while other GOA sockeye populations also experienced anomalous timing or low run sizes in 2018.

Black Lake Habitat Issues

Several gradual changes to the Black Lake watershed raise concerns over impacts to sockeye salmon populations in Black and Chignik Lakes. Issues which may be negatively affecting smolt-rearing habitat in this system are:

- increased outlet erosion in Black Lake reducing the depth and volume of water, lowering the water surface elevation (WSE)[4];
- a combination of shallowing water and rising air surface temperature allows for high-wind mixing of warm surface water, resulting in an overall rise in water temperature[5];
- hydrological shifts are causing a progressively larger portion of the Alec River to drain into a lower area of the Black River that is near the outlet[6];
- the spit extending from the Alec Delta near the outlet is inhibiting water circulation, nutrient and sediment transport, and reducing quality habitat for juvenile salmon - combined with the lowering WSE this may also isolate habitat entirely[6].
- Estimates of overall reduction in Black Lake water volume range between 1 and 6.5 feet [4,5,7]23% and 44%[6].

These issues have had important impacts on out migrating smolts. The shallow, warm water of Black Lake allows for productivity earlier in the year, and confers a growth advantage over Chignik Lake juveniles of the same age[8]. Juvenile fry in Black Lake have access to better resources for a longer period of time which accelerates growth, and allows them to out-compete their counterparts in Chignik Lake after emigrating[6]. Typically, Black Lake juvenile fry overwinter in Black Lake, delaying emigration to Chignik Lake until the following spring in May. However, Black Lake residents are increasingly out-migrating earlier and/or overwintering in Chignik Lake, increasing competition and resulting in deleterious impacts on Chignik juveniles[7,9–12].

Loewen and Henslee (2017) found smolt outmigration in 2015 was dominated by freshwater age-1 (76%) and age-2 fish (22%), which is unusual. Typically, proportions of age-2 fish are higher than age-1, since, larger, older fish outmigrate before smaller, younger ones. Fish were also reported to be below average by length, weight and body condition in 2014[13] and 2015, with body condition being the lowest two years on record since monitoring began in 1994 (Figure 1)[14]. Although there is interannual variability, the long-term trend shows a steady decline for all three metrics[14].

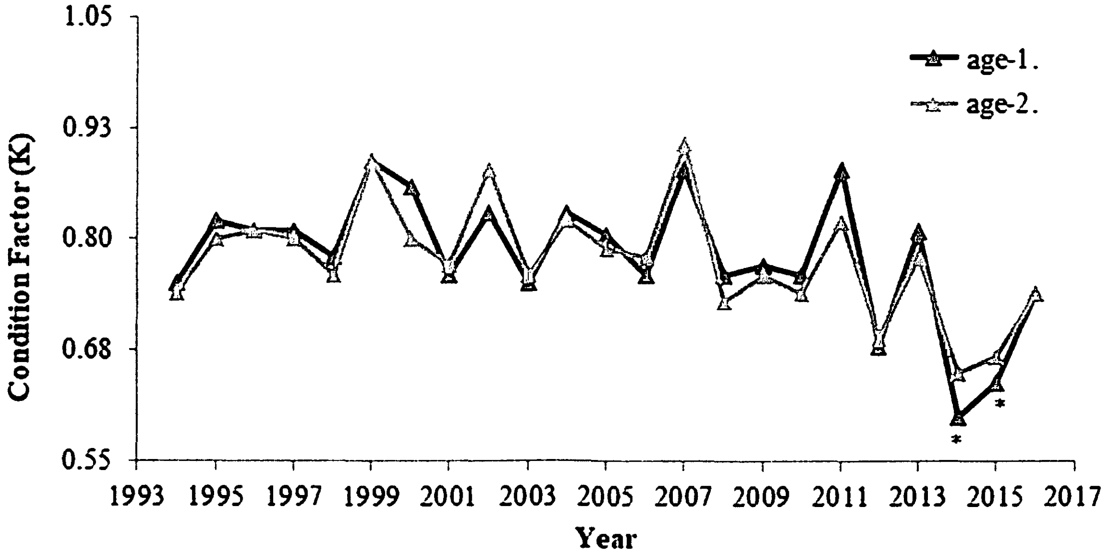

Figure 1. Condition factor (K) of emigrating smolts from Chignik River 1994-2016 year classes contributing to 2018 adult returns denoted by red asterisk. Data: Loewen and Henslee 2017.

Changes in Gulf of Alaska

The Gulf of Alaska has experienced dramatic change in recent years. Beginning in 2013, a climate anomaly known as "the blob" began to take form; a large mass of water between 1°C and 4°C warmer than usual that occurred along the Pacific west coast[15]. This is generally attributed to a slower-than-normal rate of heat loss from the ocean to the atmosphere[15,16] compounded by a massive static high pressure-ridge that blocked winds, reducing ocean mixing- which is the process that brings cold nutrient-rich waters into the upper layer of the water column.

This phenomenon was not just a localized event impacting one species or one area; effects were felt throughout the trophic chain in the Gulf of Alaska; in 2015/2016 there was an unexplained mortality event of dozens of whales, and thousands of seabirds, and sea otters. Declines in lipid-rich northern copepods and increases in smaller lipid-poor southern copepods[15] were observed. There were decreases in average size of euphausiids[17] which serve as a primary source of prey for Western Gulf of Alaska (WGOA) juvenile sockeye[18,19]. Higher temperatures can cause stress or increased metabolic rates of salmon, in turn increasing energy needs and diet requirements[20] for juvenile salmon. In general, Chignik sockeye returns are primarily age-1.3 and 2.3; age classes that entered the marine environment during the peak of "the blob" in 2014 and 2015. Unusually high early ocean mortality (low marine survival) is often invoked to explain poor salmon returns[2,3].

While the impacts of these changes on specific salmon populations are uncertain, in addition to the small 2018 Chignik sockeye run, several other cases of unusual run-timing or smaller run sizes have been noted among stocks which rear in GOA. Notable examples include:

Upper Cook Inlet (UCI)

- UCI sockeye harvest was 70% less than the 2008-2017 average, making it the 7th smallest on record and smallest since 1975.
- UCI total run was 32% less than the forecast, with age-1.3 and age-2.3 sockeye constituting the largest deviation from the forecast.
- Kenai River sockeye 50% return date was 11 days later than the 10-year average.

Copper River/Prince William Sound

- Copper River sockeye harvest was lowest on record and 97% less than the 10-year average; the 2018 sockeye harvest was 44,318 compared to the 2007-2016 average of 1.43 million.
- Copper River sockeye returned in three distinct pulses

Kodiak

- Sockeye, pink, Chinook and king were well below forecast and the 10-year average

Complex environmental forcing on a large scale may have important impacts on individual salmon stocks rearing in GOA. Chignik stocks in particular are known to have high natural variability in returns from year-to-year. Changing ocean and climate conditions, and loss of quality rearing habitat increases uncertainty in these stocks.

Literature Cited

1. Ruggerone, G. T., Nielsen, J. L. & Bumgarner, J. Linkages between Alaskan sockeye salmon abundance, growth at sea, and climate, 1955–2002. *Deep Sea Res. Part 2 Top. Stud. Oceanogr.* (2007).
2. Farley, E. V. *et al.* Early marine growth in relation to marine-stage survival rates for Alaska sockeye salmon (Oncorhynchus nerka). *Fish. Bull.* **105**, 121–130 (2007).
3. HARTT & C, A. Juvenile salmonids in the oceanic ecosystem-the critical first summer. *Salmonid Ecosystems of the North Pacific* (1980).
4. Elhakeem, M. & Papanicolaou, A. N. Evaluation of the reduction in the water storage capacity of Black Lake, AK. *International Journal of River Basin Management* **6**, 63–77 (2008).
5. Griffiths, J. R., Schindler, D. E., Balistrieri, L. S. & Ruggerone, G. T. Effects of simultaneous climate change and geomorphic evolution on thermal characteristics of a

shallow Alaskan lake. *Limnol. Oceanogr.* **56**, 193–205 (2011).

6. USACE. Black Lake Technical Report October 2012. (2012).
7. Ruggerone, G. T. Rapid natural habitat degradation and consequences for sockeye salmon production in the Chignik Lakes system, Alaska. (2003).
8. Griffiths, J. R., Schindler, D. E. & Seeb, L. W. How stock of origin affects performance of individuals across a meta-ecosystem: an example from sockeye salmon. *PLoS One* **8**, e58584 (2013).
9. Simmons, R. K., Quinn, T. P., Seeb, L. W., Schindler, D. E. & Hilborn, R. Summer emigration and resource acquisition within a shared nursery lake by sockeye salmon (Oncorhynchus nerka) from historically discrete rearing environments. *Can. J. Fish. Aquat. Sci.* **70**, 57–63 (2013).
10. Westley, P. A. H. & Hilborn, R. W. Chignik Salmon Studies Investigations of Salmon Populations, Hydrology, and Limnology of the Chignik Lakes, Alaska, During 2004-2005. Annual rep. to National Marine Fisheries Service and final rep. to Chignik Aquaculture Association. (2006).
11. Loewen, M. & Baechler, N. The 2015 Chignik River Sockeye Salmon Smolt Outmigration: An Analysis of the Population and Lake Rearing Conditions.
12. Westley, P. A. H., Hilborn, R., Quinn, T. P., Ruggerone, G. T. & Schindler, D. E. Long-term changes in rearing habitat and downstream movement by juvenile sockeye salmon (Oncorhynchus nerka) in an interconnected Alaska lake system. *Ecol. Freshw. Fish* **17**, 443–454 (2008).
13. Loewen, M. E. & Baechler, N. *The 2014 Chignik River Sockeye Salmon Smolt Outmigration: An Analysis of the Population and Lake Rearing Conditions.* (Alaska Department of Fish and Game, Division of Sport Fish, Research and …, 2015).
14. Loewen, M. & Henslee, L. The Chignik River Sockeye Salmon Smolt Outmigration.
15. Kintisch, E. 'The Blob' invades Pacific, flummoxing climate experts. *Science* **348**, 17–18 (2015).
16. Bond, N. A., Cronin, M. F., Freeland, H. & Mantua, N. Causes and impacts of the 2014 warm anomaly in the NE Pacific. *Geophys. Res. Lett.* **42**, 3414–3420 (2015).
17. Jones, T. *et al.* Massive Mortality of a Planktivorous Seabird in Response to a Marine Heatwave. *Geophys. Res. Lett.* **45**, 3193–3202 (2018).
18. Brodeur, R.D., Daly, E.A., Sturdevant, M.V., Miller, T.W., Moss, J.H., Thiess, M.E., Trudel, M., Weitkamp, L.A., Armstrong, J., Norton, E.C. Regional Comparisons of Juvenile Salmon Feeding in Coastal Marine Waters off the West Coast of North America. in *American Fisheries Society Symposium* 57:183–203 (American Fisheries Society, 2007).
19. Brodeur, R. D. *A synthesis of the food habits and feeding ecology of salmonids in marine waters of the North Pacific.* (Fish.Res.Inst., Univ.Washington, Seattle, 1990).
20. Welch, D. W., Ishida, Y. & Nagasawa, K. Thermal limits and ocean migrations of sockeye salmon (Oncorhynchus nerka): long-term consequences of global warming. *Can. J. Fish. Aquat. Sci.* **55**, 937–948 (1998).