Monitoring Coho Salmon Smolt Outmigration Survival in Lake Washington

Muckleshoot Indian Tribe, Fisheries Division
Auburn, Washington

December 27, 2016

Muckleshoot Indian Tribe 2016. Monitoring Coho Salmon Smolt Outmigration Survival in Lake Washington. Prepared by the Muckleshoot Indian Tribe Fisheries Division, December 2016 Auburn, Washington.

Contents

List of Tables

List of Figures

Introduction

Mortality during the early life history of salmonids has been extensively studied (Bradford 1995; Beamish et al. 2000). Though most of the research has been directed at the early marine phase (Melnychuk et al. 2013; Moore et al. 2012; Moore et al. 2015), mortality and productivity due to habitat alterations has been identified as problematic during freshwater rearing (Petrosky et al. 2001; Russell 2012; Harnish et al. 2014). Recent Passive Integrated Transponder (PIT) tagging studies have shown a declining trend in survival for both hatchery and natural origin Chinook salmon (*Oncorhynchus tshawytscha*) in the Lake Washington Basin (Kiyohara 2016).

It is widely believed that loss of freshwater habitat is largely responsible for the imperilment of many salmonid populations (Nehlsen et al. 1991; Lackey et al. 2006; Bisson et al. 2009). The Lake Washington/Sammamish Basin is highly urbanized and modified. The Lake Washington Ship Canal (LWSC) is the most thermally stressed water body in western Washington and is projected to be further exacerbated under future warming scenarios (Climate Impacts Group 2009). Excessive water temperatures can reduce growth rates and increase direct mortality (Marine and Cech 2004). Overwater structures, bank alterations, and thermal conditions have been identified as a high priority concern for salmonids in the Lake Washington Basin (Northwest Indian Fisheries Commission 2016). Docks and piers extensively line the perimeters of much of the basin, and an estimated 82% of the shoreline has been bulkheaded. Migrating Chinook smolts have been observed to avoid these structures, moving into deeper water where they may become more vulnerable to predation (Celedonia et al. 2006; Tabor et al. 2011). A reduction in overwater structures and replacement of armoured shorelines with “green shoreline” designs has been identified as a priority for restoration in the basin (Shared Strategy Development Committee & NMFS 2007).

Altered habitat and thermal regimes in the Lake Washington basin have led to a proliferation of native and introduced predators. Piscivorous fishes have greatly contributed to the decline of native fishes throughout the region (Scott et al. 1986; Minckley and Deacon 1991; Gunckel et al. 2002). For example, smallmouth bass (*Micropterus dolomieu*) was introduced to the Lake Washington Basin over 100 years ago. Although smallmouth bass are known to consume juvenile salmonids, their abundance had been relatively low and thus did not represent a substantial problem for salmonid production (Pflug and Pauley 1983; Fayram and Sibley 2000; Tabor et al. 2012, Bonar, et al. 2004). However, anecdotal evidence over the past decade suggests the smallmouth bass population has grown and, based on bass tournament results, Lake Washington and Lake Sammamish are consistently among the top tier of Washington lakes and reservoirs for bass fishing (Baker 2014). Walleye (*Sander vitreus*) have recently been introduced to the basin. Though little is known about the potential effect walleye may have on juvenile salmonids in lakes Washington and Sammamish, walleye in the Columbia River basin are known to consume predominately fish, many of which are juvenile salmonids (Poe et al. 1991; Counihan et al. 2012).Predation and declining habitat suitability are the two leading hypothesized mechanisms responsible for the lower observed return rate for hatchery coho salmon (*Oncorhynchus kisutch*) in the Lake Washington basin (4.6%) than observed in the Green River basin (9.5%) (RMIS 2015; data from BY 2000-2002). Coho smolts released at the Issaquah Creek Hatchery must migrate through Issaquah Creek, Lake Sammamish, the

Sammamish River, Lake Washington, and the LWSC before reaching the Hiram H. Chittenden Locks for passage seaward.

This study focused on coho salmon. Due to their large size at smolting, coho are more easily tagged and monitored. The primary objective was to assess the effect of releasing coho salmon smolts at two alternative release sites to bypass portions of the emigration route in the Lake Washington Basin. We identify whether differences exist in the relative loss of coho smolts released at the two alternative release sites with a control group released at the Issaquah Creek Hatchery. We evaluate emigration timing associated with the alternative release locations compared with the traditional on-station releases. In addition, the study examines adult return rates to further evaluate the impact of bypassing portions of the Lake Washington basin.

Methods

All methods and procedures used for this study were documented in an EPA-approved Quality Assurance Project Plan (Muckleshoot Indian Tribe 2015). The following information is a summary.

Coho Tagging and Releases

Traditionally, all coho smolts are released at the Issaquah Creek Hatchery. In the spring of 2015, two experimental release groups were transported to off-site locations. Experimental groups were released in Ballard (10 km from saltwater) and in Kenmore (27 km from saltwater) in addition to a control group released on-site at the Issaquah hatchery (61 km from saltwater) (Figure 1). Coho smolts comprising the three release groups received unique coded wire tags (CWT) used to monitor the influence release location has on mortality and outmigration.

Prior to release, a subsample of coho from each of the three release groups were fitted with acoustic transmitters (VEMCO, Bedford, Nova Scotia, Canada). Approximately 200 coho from each group were moved to indoor raceways at the Issaquah Hatchery and held without food for 24 hours prior to surgical implantation. Coho from each group were anesthetized (MS-222), measured (fork length, mm; weight, g), and fitted with an acoustic transmitter (Liedtke et al. 2012). Based upon the length and weight of each coho, we implanted one of three acoustic tags (V72, V74, or V8) ensuring that the tag size did not exceed fish size to tag size ratios (Chittenden et al. 2008). We continued to hold and evaluate the tagged coho for 3 days post-surgery in indoor raceways to verify successful instrumentation before returning them to outdoor raceways with the remainder of the release group.

The traditional coho smolt volitional releases from Issaquah hatchery began at 8:00 AM on May 10, 2015 and continued for 12 days, at which time all remaining coho in the hatchery raceways were forced out into Issaquah Creek. The experimental release groups were loaded into 1,000 gallon tanks and transported to the alternative release locations. Transport to the Ballard release location occurred on May 11 and 12, 2015 and transport to the Kenmore release location occurred on May 12, 2015. Transport of all coho smolts followed standard procedures (Piper et al. 1992).

Coho Outmigration Monitoring

Prior to release, 39 stationary receivers (VEMCO VR2W) were installed in the Lake Washington basin and 5 additional receivers below the Hiram M. Chittenden locks (Figure 1). In general, lake receivers were deployed approximately 150 meters from shore; a distance we have found maximizes detection probabilities. The receivers were checked and downloaded weekly to minimize data loss when practicable. In addition, the National Oceanic and Atmospheric Administration deployed 19 receivers across Central Puget Sound that we were able to obtain additional data from.

We calculated the duration and fate for each tagged coho smolt to travel between major migratory sections. These migratory sections were Issaquah Creek, Lake Sammamish, Sammamish River, Lake Washington, the LWSC, Shilshole Bay, and central Puget Sound. The duration was calculated based on the first release day. Where appropriate, comparisons among groups were made with analysis of variance. All tests were considered significant at α=0.05.

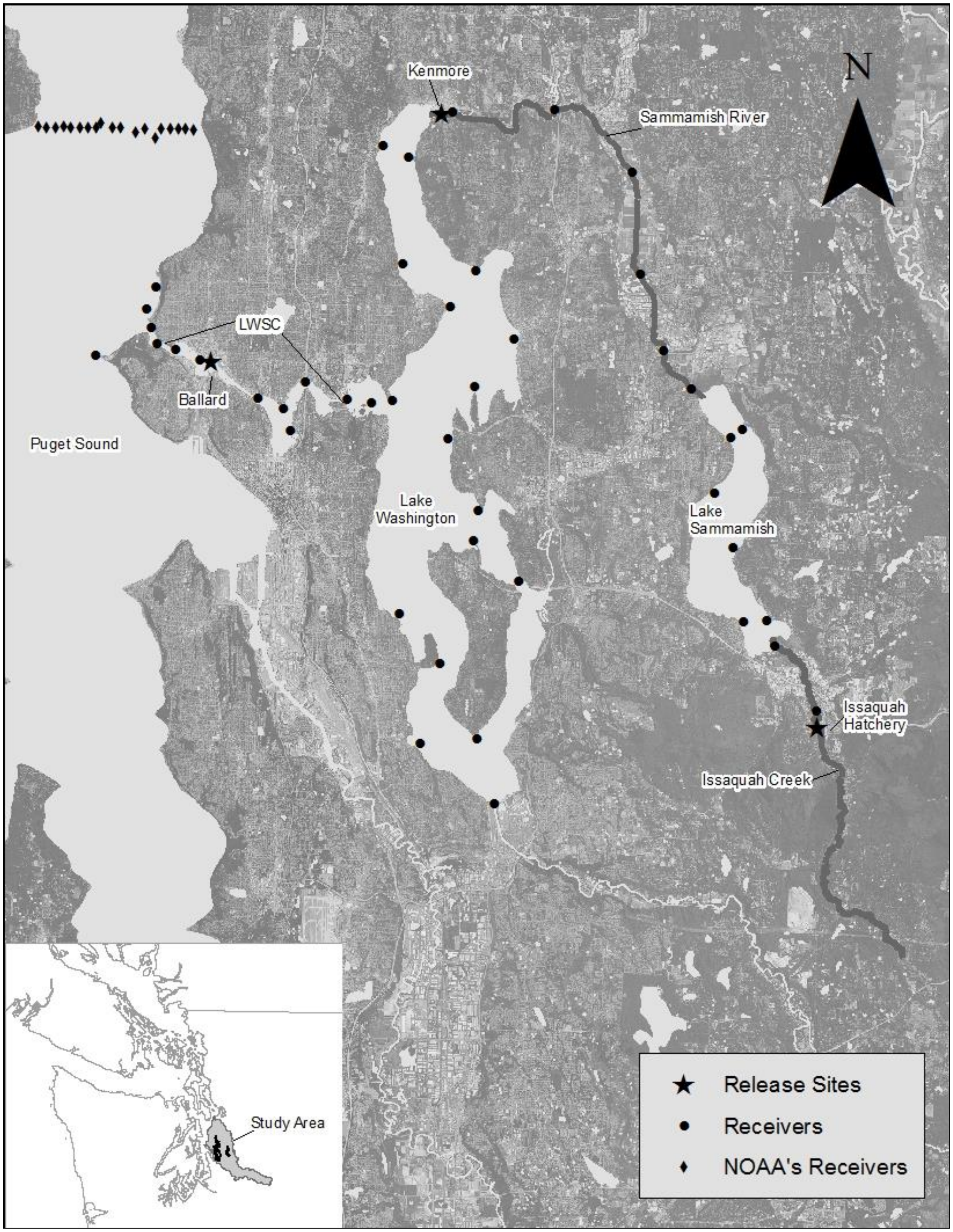

Figure 1. Map of the Lake Washington basin showing locations of smolt release sites (stars) and locations of acoustic tag receivers (circles and diamonds).

Results

Fish Tagged

A total of 148,765 coho parr were adipose fin clipped and tagged with a CWT in September 2014 at Issaquah Hatchery (Table 1). All other coho were only adipose fin clipped. Coho tagged with a CWT were split into three groups with approximately half of each group receiving one of two unique CWT codes and each group was reared in separate raceways. The CWT group destined for on-station release at Issaquah Hatchery was mixed with the adipose fin clipped coho. The total brood year 2013 coho release into the Lake Washington basin was 466,900. In addition to CWTs, 276 coho smolts were surgically implanted with acoustic transmitters during May 2015 (Table 1). After release, 1 coho was found dead in the raceway at the termination of the volitional release. Subsequent analyses for the Issaquah release group are based on 137 acoustic tagged individuals. There was no difference in weight ($F_{2, 270}$=2.086; P=0.126) or length ($F_{2, 272}$=1.681; P=0.188) among groups.

The two experimental release locations each received approximately 51,200 smolts, most of which (> 94%) were tagged with CWTs. The Issaquah release group (control) had a similar number tagged with CWTs as the experimental release groups, but the bulk of the released coho at this location were untagged coho (Table 1).

Table 1. Total number of coho smolts released, number released with coded wire tags (CWT), and number successfully released with acoustic tags.

Group	Released	CWT	Acoustic
Issaquah	364,500	49,098	137
Kenmore	51,200	50,495	69
Ballard	51,200	49,172	69

Coho Emigration Loss

Over 63% of the acoustically tagged Issaquah Creek Hatchery coho group was lost prior to entering the Lake Washington migration segment (Table 2; Figure 2). Most of this loss occurred in Lake Sammamish with relatively little loss in Issaquah Creek or Sammamish River. Loss in Lake Washington was greater than that in Lake Sammamish. Once coho entered the LWSC, loss was moderate. Loss after entering marine waters was approximately 50% to central Puget Sound.

The first experimental group released at Kenmore occurred near the end of the Sammamish River segment (Table 2; Figure 2). Less than 5% of these acoustically tagged coho were lost in this segment. Over 50% of this release group was lost in Lake Washington. Once coho from this group entered the LWSC, loss declined. Loss between Shilshole Bay and central Puget Sound was approximately 50% for the Kenmore release group.

Table 2. Apparent loss of acoustically tagged coho salmon by segment and cumulative loss (CL, %) for groups released at Issaquah Creek Hatchery, Kenmore, and Ballard.

	Issaquah			Kenmore			Ballard		
Migration segment	Enter	Exit	CL	Enter	Exit	CL	Enter	Exit	CL
Issaquah Creek	137	115	10.2	--	--	--	--	--	--
Lake Sammamish	115	58	58.3	--	--	--	--	--	--
Sammamish River	58	50	63.5	69	66	4.3	--	--	--
Lake Washington	50	16	88.3	66	32	53.6	--	--	--
LWSC	16	11	92.0	32	27	60.9	69	50	27.5
Shilshole Bay	11	5	96.4	27	14	79.7	50	24	65.2
Central Puget Sound	5	--	--	14	--	--	24	--	--

The second experimental release group occurred near the end of the LWSC segment at Ballard. Loss of these acoustically tagged coho was moderate in this segment (Table 2; Figure 2). Similar to the other release groups, loss between Shilshole Bay and central Puget Sound was approximately 50% for the Ballard release group.

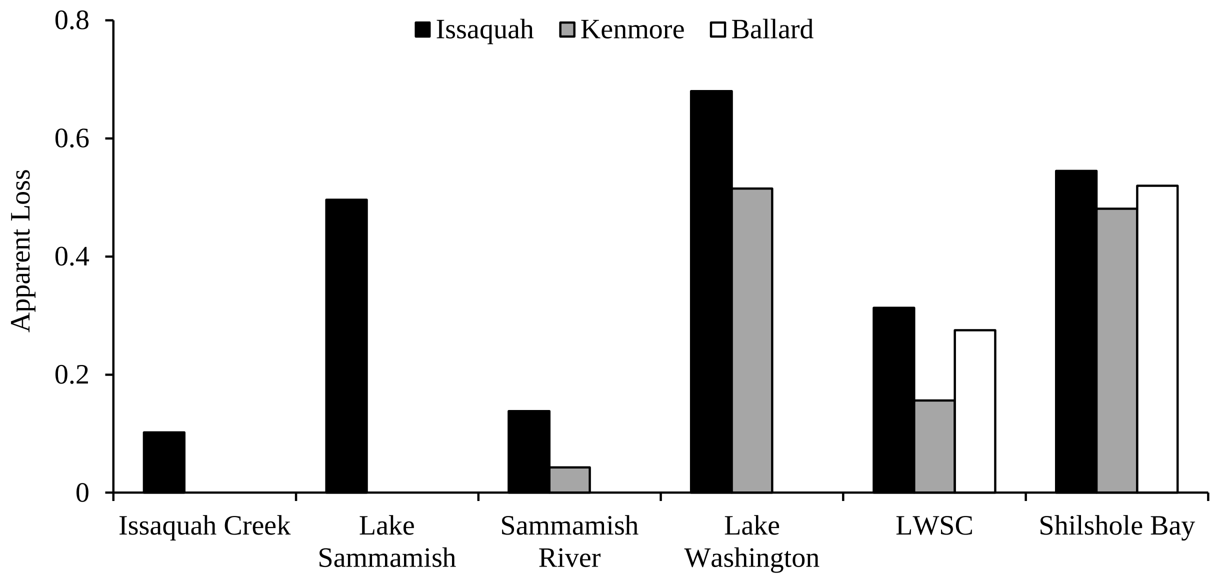

Figure 2. Apparent loss of acoustically tagged coho salmon by segment in the Lake Washington basin for three release groups.

Coho Emigration Timing

Release location significantly impacted coho emigration timing to saltwater ($F_{2, 84}$=41.99; P<0.0001; Figure 3). The Issaquah group averaged 22.9 days, the Kenmore group averaged 18.2 days and the Ballard group averaged 11.6 days to enter saltwater. Each group was significantly different (P<0.05) than other groups. In addition to duration in freshwater, the date of saltwater entry was varied among groups.

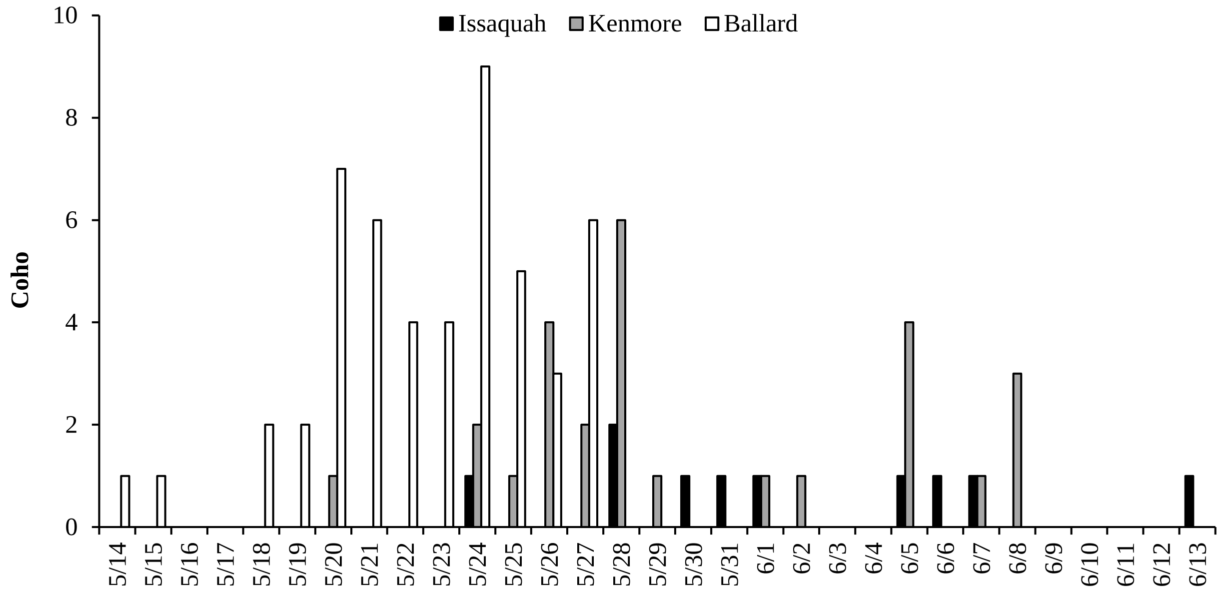

Figure 3. Saltwater entry timing for coho from each release group.

Once in saltwater, the time to reach central Puget Sound was varied among release groups. The Issaquah group took significantly longer (10.3 days) than both the Kenmore (3.1 days) and Ballard (1.9 days) groups. Timing for the Kenmore and Ballard groups were not significantly different.

Adult Coho CWT

A total of 45 CWTs were collected from adult coho at the Hiram H. Chittenden Locks (Table 3). Preliminary data indicate a significant difference in returning adults by release location (χ^2_2=16.991, P=0.0002).

Table 3. Adult coho CWT recoveries at the Hiram H. Chittenden Locks.

Release group	Recovery
Issaquah	21
Kenmore	19
Ballard	5

Discussion

Apparent coho smolt emigration mortality was significantly lower in groups released in closer proximity to Puget Sound. Hypotheses for these differences include the severely impacted habitat in the Lake Washington Basin and related impacts from predation. While this research does not identify a specific factor responsible for losses of emigrating coho, a myriad of factors are likely responsible.

The most likely reason for the survival advantage to saltwater accrued to the Ballard release group, and to a lesser degree, the Kenmore release group, is the avoidance of predation. Predation was directly observed during the volitional release at Issaquah Hatchery, where

mergansers and gulls were seen consuming smolts. Losses of smolts in Issaquah Creek downstream of the hatchery were relatively minor compared to losses in lakes Sammamish and Washington. Approximately half of the tagged smolts did not make it through Lake Sammamish and almost 60% of those remaining did not make it through Lake Washington.
Both lakes are known to have robust numbers of several piscivores including smallmouth bass, largemouth bass (*Micropterus salmoides*), cutthroat trout (*Oncorhynchus clarki*), Northern pikeminnow (*Ptychocheilus oregonensis*), and walleye. Besides introduced and native fishes, there are a number of poorly-studied but potentially important piscivorous birds, most notably double crested cormorants (*Phalacrocorax auritus*) that may prey heavily on emigrating salmonids.

Acknowledgements

Funding was provided by the Environmental Protection Agency FY 2013 EPA/PSP Noncompetitive Tribal Projects for Restoration and Protection of Puget Sound - NWIFC Cooperative Agreement #PA-00J32201-0.

References

Appleby, A.E., J.M. Tipping, and P.R. Seidel. 2004. Adult recoveries of volitionally and forced-released juvenile coho salmon. North American Journal of Aquaculture 66:137-140.

Baker, B.A. 2014. Summary report of results of bass and walleye fishing contests held in Washington 2013. Washington Department of Fish and Wildlife FPA 14-11. 51p.

Beamish, R.J., D.J. Noakes, G.A. McFarlane, W. Pinnix, R. Sweeting, and J. King. 2000. Trends in coho marine survival in relation to the regime concept. Fisheries Oceanography 9:114-119.

Bisson, P.A., J.B. Dunham, and G.H. Reeves. 2009. Freshwater ecosystems and resilience of Pacific salmon: habitat management based on natural variability. Ecology and Society 14:45.

Bonar, S.A., B.D. Bolding, M. Divens, and W. Meyer. 2004. Effects of introduced fishes on wild juvenile coho salmon using three shallow western Washington lakes. Washington Department of Fisheries and Wildlife. Olympia, WA.

Bradford, M.J. 1995. Comparative review of Pacific salmon survival rates. Canadian Journal of Fisheries and Aquatic Sciences 52:1327-1338.

Chittenden, C.M., K.G. Butterworth, K.F. Cubitt, M.C. Jacobs, A. Ladouceur, D.W. Welch, and R.S. McKinley. 2008. Maximum tag to body size ratios for an endangered coho salmon (*O. kisutch*) stock based on physiology and performance. Environmental Biology of Fishes 84:129-140.

Celedonia, M.T., R.A. Tabor, S. Sanders, D.W. Lantz, and I. Grettenberger. 2008. Movement and habitat use of juvenile Chinook salmon and two predatory fishes in Lake Washington and the Lake Washington Ship Canal: 2004-05 acoustic tracking studies. U.S. Fish and Wildlife Service, Western Washington Fish and Wildlife Office, Lacey, WA.

Climate Impacts Group. 2009. The Washington Climate Change Impacts Assessment, M. McGuire Elsner, J. Littell, and L Whitely Binder (eds). Center for Science in the Earth System, Joint Institute for the Study of the Atmosphere and Oceans, University of Washington, Seattle, Washington.

Counihan, T.D., J.M. Hardiman, D.S. Burgess, K.E. Simmons, G. Holmberg, J.A. Rogala, and R.R. Polacek. 2012. Assessing native and introduced fish predation on migrating juvenile salmon in Priest Rapids and Wanapum Reservoirs, Columbia River, Washington, 2009-11: U.S. Geological Survey Open-File Report 2012-1130, 68p.

Fayram A.H. and T.H. Sibley. 2000. Impact of predation by smallmouth bass on sockeye salmon in Lake Washington, Washington. North American Journal of Fisheries Management 20:81-89.

Furey, N.B., S.G. Hinch, A.L. Bass, C.T. Middleton, V. Minke-Martin, and A.G. Lotto. 2016. Predator swamping reduces predation risk during nocturnal migration of juvenile salmon in a high-mortality landscape. Journal of Animal Ecology 85:948-959.

Gale, W.L., C.R. Pasley, B.M. Kennedy, and K. Ostrand. 2009. Juvenile steelhead release strategies: a comparison of volitional and forced-release practices. North American Journal of Aquaculture 71:97-106.

Gunckel, S.L., A.R. Hemmingsen, and J.L. Li. 2002. Effect of bull trout and brook trout interactions on foraging habitat, feeding behavior, and growth. Transactions of the American Fisheries Society 131:1119-1130.

Harnish, R.A., R. Sharma, G.A. McMichael, R.B. Langshaw, and T.N. Pearsons. 2014. Effect of hydroelectric dam operations on the freshwater productivity of a Columbia River fall Chinook salmon population. Canadian Journal of Fisheries and Aquatic Sciences 71:602-615.

Johnson, M.S., A.R. Murdoch, and C.P.H. Moran. 2015. Adult survival of hatchery spring Chinook salmon released volitionally or forcibly as juveniles. North American Journal of Aquaculture 77:547-550.

King County Water Quality. http://green2.kingcounty.gov/hydrology/GaugeMap.aspx.

Lackey, R.T., D.H. Lach, and S.L. Duncan, editors. 2006. Salmon 2100: the future of wild Pacific salmon. American Fisheries Society, Bethesda, Maryland, USA.

Liedtke, T.L., J.W. Beeman, and L.P. Gee. 2012. A standard operating procedure for the surgical implantation of transmitters in juvenile salmonids: U.S. Geological Survey Open-File Report 2012-1267, 50p.

Kiyohara, K. 2016. Evaluation juvenile salmon production in 2015 from the Cedar River and Bear Creek. Washington Department of Fish and Wildlife, Olympia.

Mantua, N., I. Tohver, and A.F. Hamlet. 2009. Impacts of climate change on key aspects of freshwater salmon habitat in Washington state. In: Climate Impacts Group, 2009. The Washington climate change impacts assessment, M. McGuire Elsner, J. Littell, and L. Whitely Binder (eds). Center for Science in the Earth System, Joint Institute for the Study of the Atmosphere and Oceans, University of Washington, Seattle, WA. Available at: http://www.cses.washington.edu/db/pdf/wacciareport681.pdf

Marine, K.R. and J.J. Cech. 2004. Effects of high water temperature on growth, smoltification, and predator avoidance in juvenile Sacramento River Chinook salmon. North American Journal of Fisheries Management 24:198-210.

Melnychuk, M.C. V. Christensen, and C.J. Walters. 2013. Meso-scale movement and mortality patterns of juvenile coho salmon and steelhead trout migrating through a coastal fjord. Environmental Biology of Fishes 96:325-339.

Minckley, W.L. and J.E. Deacon, Eds. 1991. Battle against extinction, native fish management in the American west. University of Arizona Press, Tucson.

Moore, M., B.A. Berejikian, and E.P. Tezak. 2012. Variation in the early marine survival and behavior of natural and hatchery-reared Hood Canal steelhead. PLoS One 7(11): e49645. doi:10.1371/journal.pone.0049645.

Moore, M.E., B.A. Berejikian, F.A. Goetz, A.G. Berger, S.S. Hodgson, E.J. Connor, and T.P. Quinn. 2015. Multi-population analysis of Puget Sound steelhead survival and migration behavior. Marine Ecology Progress Series 537:217-232.

Moore, A., L.C. Russell, and E.C.E. Potter. 1990. The effects of intraperitoneally implanted dummy acoustic transmitters on the behaviour and physiology of juvenile Atlantic salmon, *Salmo salar* L. Journal of Fish Biology 37:713-721.

Muckleshoot Indian Tribe. 2015. Monitoring salmon smolt outmigration survival in Lake Washington: Quality assurance project plan. Prepared by the Muckleshoot Indian Tribe Fisheries Division, March 2015. Auburn, WA.

Nehlsen, W., J. E. Williams, and J. A. Lichatowich. 1991. Pacific salmon at the crossroads: stocks at risk from California, Oregon, Idaho and Washington. Fisheries 16:4-21.

Northwest Indian Fisheries Commission (NWIFC). 2016. 2016 state of our watersheds: a report by the treaty tribes in western Washington. Lacey, WA. 333p.

Petrosky, C.E., H. Schaller, and P. Budy. 2001. Productivity and survival rate trends in the freshwater rearing stage of Snake River Chinook salmon (*Oncorhuncus tshawytscha*). Canadian Journal of Fisheries and Aquatic Sciences 58:1196-1207.

Pflug, D. E., and Pauley, G. B. 1984. Biology of smallmouth bass (*Micropterus dolomieui*) in Lake Sammamish, Washington. Northwest Science 58:118-125.

Piper, R.G., I.B. McElwain, L.E. Orme, J.P. McCraren, L.G. Fowler, and J.R. Leonard. 1992. Fish hatchery management 5th edition. United States Department of Interior Fish and Wildlife Service, Washington, D.C.

Poe, T.M., H.C. Hansel, S.Vigg, D.E. Palmer, and L.A. Prendergast. 1991. Feeding of predacious fishes on out-migrating juvenile salmonids in the John Day Reservoir, Columbia River. Transaction of the American Fisheries Society 120:403-420.

RMIS (Regional Mark Information System). 2015. Retrieved March 2015. Available from: http://www.rmpc.org/.

Russell, I.C., M.W. Aprahamian, J. Barry, I.C. Davidson, P. Fiske, A.T. Ibbotson, R. Kennedy, J.C. Maclean, Moore, A., Otero, J., Potter, E. C. E., and Todd, C.D. 2012. The influence of the freshwater environment and the biological characteristics of Atlantic salmon smolts on their subsequent marine survival. – ICES Journal of Marine Science, doi:10.1093/icesjms/fsr208.

Scott, J.B., C.R. Steward, and Q.J. Stober. 1986. Effects of urban development on fish population dynamics in Kelsey Creek, Washington. Transactions of the American Fisheries Society 115:555-567.

Shared Strategy Development Committee and National Marine Fisheries Service (SSDC & NMFS). 2007. Puget Sound Salmon Recovery Plan for the Puget Sound Chinook Salmon (*Oncorhynchus tshawytscha*). Comprised of two documents: 1) Shared Strategy Development Committee, 2005, Puget Sound Salmon Recovery Plan, Volumes I and II, adopted by the National Marine Fisheries Service on January 19, 2007; and 2) NMFS, 2006, Final Supplement to the Shared Strategy's Puget Sound Salmon Recovery Plan.

Tabor, R.A., K.L. Fresh, R.M. Piaskowski, H.A. Gearns, and D.B. Hayes. 2011. Habitat use by juvenile Chinook Salmon in the nearshore areas of Lake Washington: effects of depth, lakeshore development, substrate, and vegetation. North American Journal of Fisheries Management 31:700-713.

Tabor, R.A., S.T. Sanders, D.W. Lantz, M.T. Celedonia, and S. Damm. 2012. Seasonal movements of smallmouth bass in the Lake Washington Ship Canal, Washington. Northwest Science 86:133-143.