

2016 State of Our Watersheds Report Green-Duwamish River, White-Puyallup River and Lake Washington Basins



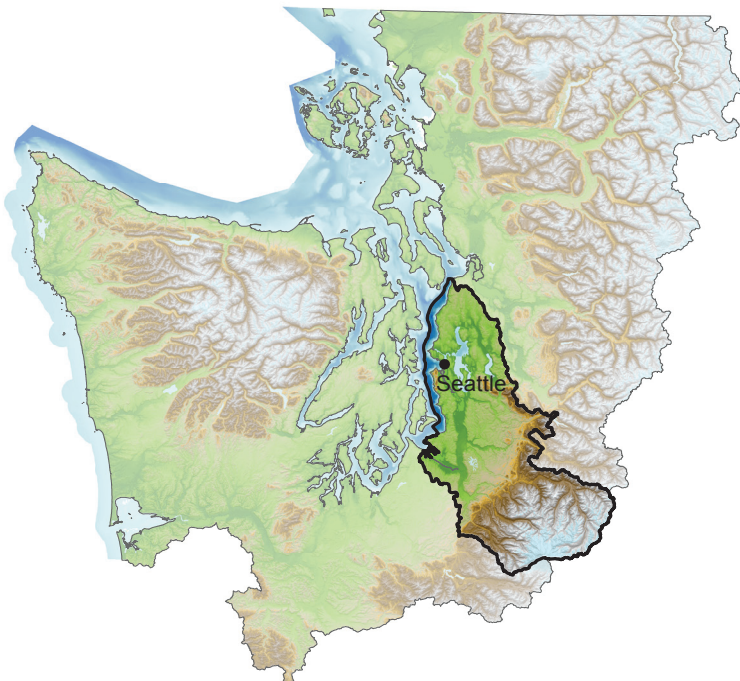
We are the salmon people. For generations, salmon have sustained our way of life. Now we must sustain the life of the salmon.

**– PHIL HAMILTON,
MUCKLESHOOT FISH COMMISSION**



Muckleshoot Indian Tribe

The Muckleshoot Indian Tribe is a federally recognized Indian tribe whose membership is composed of descendants of the Duwamish and Upper Puyallup people who inhabited Central Puget Sound for thousands of years before non-Indian settlement. The Tribe's name is derived from the native name for the prairie on which the Muckleshoot Reservation was established. Following the Reservation's establishment in 1857, the Tribe and its members came to be known as Muckleshoot, rather than by the historic tribal names of their Duwamish and Upper Puyallup ancestors. Today, the United States recognizes the Muckleshoot Tribe as a tribal successor to the Duwamish and Upper Puyallup bands from which the Tribe's membership descends. Like all native people of western Washington, Muckleshoot ancestors depended on fish, animal and plant resources and traveled widely to harvest these resources. Village groups were linked by ties of marriage, joint feasting, ceremonies, commerce and use of common territory. Downriver people intermarried with other groups along the sound, while people on the upper reaches of the drainages also intermarried with groups east of the Cascade Mountains. This network of kinship tied together ancestral Muckleshoot villages within the Duwamish watershed, extended across watersheds and the Cascade crest, giving Muckleshoot ancestors access to fishing, hunting and gathering sites throughout a broad area extending from the west side of Puget Sound across the Cascade crest.



Areas depicted do not necessarily correspond to Muckleshoot Usual & Accustomed fishing grounds and stations.

Central Puget Sound: A History of Large-Scale Habitat Loss and Degradation

The Green-Duwamish, Puyallup-White and Lake Washington basins in Central Puget Sound continue to support important salmon and steelhead runs despite dramatic habitat alteration and ecosystem decline. However, the abundance and potential production of natural-origin salmon have declined sharply. By the early 1900s, navigation and flood-control projects split apart the former 1,700-square-mile river basin that included the Green, White and Cedar rivers and lakes Washington and Sammamish and their tributaries. The White River was diverted into the Puyallup River. The Black River, the historical outlet of Lake Washington and the Cedar River, was eliminated, and a new outlet was constructed through the Chittenden Ship Canal and Locks.

The Cedar River was diverted into Lake Washington, permanently extinguishing chum and pink salmon runs unable to migrate through the lake. By the 1940s, the Duwamish estuary marsh and tidelands were filled to create Seattle's industrial port, and the Cedar, White and Green rivers were dammed. Streams, wetlands and floodplains were drained, channelized or confined, and the conversion

of forest to asphalt began.

Today, the majority of lowland areas are urbanized. Only a small fraction of marine shorelines remain in a natural condition. Now, more than 2 million people live in these basins and that number is growing.

The scarcity of properly functioning freshwater and marine habitat in Central Puget Sound basins means that hatchery fish produced from local broodstock will remain essential for salmon harvest and conservation. In these basins, the Puget Sound Chinook Recovery Plan goal of self-sustaining and harvestable salmon populations is not likely achievable in the foreseeable future. Until enough high-quality habitat is re-established so that much greater numbers of salmon can successfully complete their life cycle, the benefit of hatchery fish to population abundance will outweigh any potential genetic or ecological risks. Without support from hatchery fish, run sizes would dwindle to unfishable "museum" levels or even extinction given the severity of habitat limitations. At the same time, without sufficient habitat and water quality improvement, even hatchery fish may not be sustainable over time.



Muckleshoot Indian Tribe

A Muckleshoot tribal gillnet boat on Elliott Bay underneath the Seattle skyline at sunrise.

Habitat Decline Continues Despite Recovery Plan

Effective habitat protection and restoration efforts are necessary to sustain future salmon runs in these basins regardless of natural or hatchery origin. Local governments in WRIs 8, 9 and 10 have prepared habitat plans under the Puget Sound Chinook Recovery Plan approved by NMFS in 2005. Significant efforts are being made by the WRIA groups to implement the projects and measures identified in these plans. While some projects are completed, implementation has been limited by funding and other constraints. Even with full funding, however, the ability of these habitat plans to produce a net gain in habitat quality and quantity is uncertain given the impacts of ongoing development and population growth, the small scale of the proposed actions, and a reliance on voluntary measures and inadequate regulatory protection and impact mitigation.

The plans identify restoration projects that, while important, are generally small relative to watershed needs. In many cases, the potential to recover natural habitat processes in restoration projects is constrained by adjacent land use, recreation, flood control, water supply or other conflicts. Despite the efforts by the WRIA groups, habitat continues to be lost and degraded. A status report commissioned by NMFS to track the Puget Sound Recovery Plan implementation found that while salmon plan harvest limits had been followed, habitat for Chinook is still declining in Puget Sound.¹ The status report concluded that habitat degradation is continuing despite the adoption of the Shoreline Management Act, Growth Management Act and Forest Practices Act. Forestland conversion and impervious surface area grew by 2-3% from 2001-2004 and by another 1.3% from 2006-2011. Despite critical areas rules, riparian areas in priority watersheds in the Lake Washington-Cedar-Sammamish Watershed continued to lose forest cover and gain impervious surfaces with a 5.5% gain in rural areas and 10.6% gain inside Urban Growth Boundaries between 2005 and 2009.²

The Lake Washington-Cedar-Sammamish Chinook Salmon Conservation Plan (WRIA 8) contains habitat objectives to maintain or restore watershed processes, functional migration corridors and high-quality refuge habitats, land-use and planning recommendations, and public outreach and education.³ The plan identified 165 high-priority or “Start List” projects for implementation in the first 10 years of the plan. A current update of the “Start List” contains 200 projects.⁴ Of these, 48 (or 24%) have been completed in the first 10 years of the plan, and 66 are underway, while organizers report that 38 more are moving toward implementation.

The Green River Salmon Habitat Plan (WRIA 9) established goals to protect and restore physical, chemical and biological processes and freshwater, marine and estuarine habitats; protect and restore habitat connectivity where feasible; and protect and improve water quality and quantity conditions to support healthy salmon populations.⁵ The Puget Sound Chinook Recovery Plan 2011 Implementation Status Assessment prepared for NMFS noted that the WRIA 9 planning group has “the disadvantage of at-



Muckleshoot Tribe

Muckleshoot Fisheries Division staff capture and implant tags in adult Chinook to assess migration behaviors and pre-spawn mortality related to high summer temperatures in the Green-Duwamish River caused by a severe riparian shade deficiency along levees and banks.

tempting to achieve recovery in one of the most highly altered, diked, degraded and urbanized watersheds in Puget Sound.”⁶ As elsewhere in Central Puget Sound, restoration opportunities in WRIA 9 are challenged by high land costs, conflicting land use and site availability. The scale of the habitat plan restoration projects is generally small. For example, the projects that target estuary transition zone habitat (a high-priority action) would restore a total of fewer than 40 acres, with a long-term goal of just 173 acres. Restoring even the most basic salmon habitat needs in the lower Green River, such as an adequate riparian corridor to address lethal water temperatures, has proved to be a complex challenge given farmland preservation policies, flood control levee maintenance and construction, existing development, and other constraints and conflicts.

Pierce County serves as the lead entity for the Puyallup-White WRIA 10 Salmon Habitat Protection and Restoration Plan. Key strategies include levee setbacks, floodplain reconnection, creation of off-channel habitat, restoration of estuary and marine nearshore habitat, and protection and restoration of key tributaries, along with programmatic actions such as a Flood Hazard Reduction Plan and Shoreline Master Plan updates.⁷ While some projects have been completed, the WRIA group reports that they are not on pace to meet 10-year goals.⁸ Meanwhile, new industrial and commercial warehouse development in the lower White River floodplain is eliminating opportunities for floodplain reconnection.

Restoration Progress Slow and New Challenges Emerge

Although only one indicator of habitat conditions, a review of recovery progress and trends at the 10-year mark of the Lake Washington, Green-Duwamish and White River habitat plans indicated mixed results.

Coordination and alignment of the regulatory and programmatic efforts of jurisdictions with the goals and objectives of the recovery plans has not occurred. For example, Shoreline Master Programs governing land use and habitat protection have yet to be updated and made consistent with habitat recovery strategies.⁹

Despite its value to salmon, large woody debris placement in rivers is restricted to accommodate recreation. Progress with restoration efforts has been slow, with less than 100 acres of juvenile Chinook rearing habitat created or underway in the lower Green River and Duwamish Estuary transition zone. This represents less than 2% of the historically available floodplain rearing and intertidal marsh habitat in these areas. Few projects have been able to begin to restore characteristic natural riparian and floodplain habitat processes.

Except for the recent requirement for long-needed fish passage improvements at Mud Mountain Dam, federal agencies are still not adequately meeting their own responsibilities for salmon habitat and need to do more. Examples include:

- Continued delays in fish passage improvements at U.S. Army Corps' Howard Hanson Dam, and the Ballard Locks.
- Weak permit terms and conditions for federal actions affecting ESA Critical Habitat, such as the Corps of Engineers' in-place levee repairs under Public Law 84-99 that limit the potential for adequate riparian shade, remove scarce mature trees, and add large quantities of heavy riprap rock along miles of the Green River.

Meanwhile, as fisheries managers, we face new challenges to restore harvestable salmon runs in our watersheds. The highly modified Lake Washington system provides advantageous habitat for many non-indigenous and native fish species that prey on juvenile salmon. These include bass, cutthroat trout, northern pikeminnow – and particularly worrisome – walleye, a large and voracious salmon predator that was recently discovered, with most individu-



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A ship moves through the U.S. Army Corps of Engineers' Ballard Locks as two smolt passage flumes (foreground) provide the only safe passage to sea for juvenile salmon from the Lake Washington. Fish passage improvements are needed with new equipment and machinery to help reduce smolt mortality associated with navigation at the locks.

als in breeding condition. One study in the Columbia River basin reported that, on a per-run basis, the mortality attributed to salmon predation by non-indigenous species may be similar to mortality associated with juvenile passage through all of the eight Columbia and Snake rivers' hydropower dams.¹⁰ Preliminary results from a recent tribal study in the Lake Washington basin found that the out-migration survival rate of coho smolts was less than 10 percent. Action is needed now to remove or control walleye before this species becomes established, and to remove other increasingly populous and nonindigenous smallmouth and largemouth bass, especially from locations where salmon juveniles are most vulnerable. Support for predator control actions from state and federal agencies is essential.

Artificial nighttime lighting or light pollution along our waterways is a growing problem. Studies and experiments led by the U.S. Fish and Wildlife Service were conducted in the Lake Washington basin between 1998 and 2014. Sockeye salmon predation mortality was observed to increase as a result of artificial light levels along the lower Cedar River in Renton. Chinook salmon were generally attracted to artificially lit areas and along shadow lines in the lake and in the Lake Washington Ship Canal, along with birds and other predators. While the problem has been known for over a decade, light levels continue to increase.

Tribal biologist Jesse Nitz displays walleye caught in Lake Washington. An illegally introduced species, walleye were first discovered in the lake in 2014 with some individuals found in breeding condition. Salmon recovery may well depend on control of this invasive salmon predator as well as control of the bass and cutthroat trout that thrive in the lake system's urban shorelines and creeks.



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Review of the trend for these key environmental indicators since the 2012 State of Our Watersheds Report shows a steady loss in habitat status:

Tribal Indicator	Status	Trend Since SOW 2012 Report
Water Quality	Approximately 193 miles of stream in WRIAs 8, 9, and 10 are listed as "impaired waters" by the Washington State Department of Ecology 2012 Water Quality Assessment. An additional 42 miles in WRIAs 8 & 9 are assumed to exceed water temperature standards for fish, based on adjacent impairments or other data.	Declining
Coho Pre-Spawn Mortality	Based on NOAA and USFWS models, 269 stream miles or 56% of known coho distribution in the Green-Duwamish and Lake Washington basins are predicted to have a PSM rate of 5% or more, with 141 miles predicted to have 35%-100% PSM.	Declining
Water Wells	From 2010-2014, wells increase by 4.5% (369) in the Lake Washington and Green-Duwamish basins. The Puyallup-White basin saw a 2.6% increase (101) in wells. From 2010-2014, 26 new wells were added to the already existing 1,314 wells in the Soos Creek Basin. Summer-fall flows in Big Soos Creek show a statistically significant decline that coincides with development of municipal and private wells in the subbasin.	Declining
Water Quality - Low Flows	A total of 482 miles of streams in the Lake Washington and Green-Duwamish basins are identified as having low streamflow problems, while in the Puyallup-White basins there are 120 miles of stream with low flow concerns.	Declining
Impervious Surface	From 2006 to 2011, there was a slight increase (1.3%) in impervious surface corresponding to the economic recession. The trend is for a growing human population and more construction activity adding more impervious land cover.	Declining
Shoreline Modifications/Forage Fish Impacts	From 2005 to 2014, shoreline modifications have shown a positive trend in King County, with more armoring being removed than constructed. During this time period, 681 feet of new armoring were constructed, along with the removal of 903 feet. 2.6 miles of armoring were replaced during the same time period. An estimated 82% of Lake Washington's shoreline remains heavily modified with bulkhead and riprap.	Declining
Overwater Structures	Since 2011, Lake Washington and Lake Sammamish have seen an increase of about 60 (1%) new docks, making a total of 4,157 overwater structures.	Declining
Large Woody Debris	Wood counts in the lower Cedar and Green rivers have less than 5% of the expected key piece quantities. Watershed Analysis data on large woody debris (LWD) in the upper White River (above Mud Mountain Dam) suggests the LWD and key piece quantities is in a "poor" condition as it relates to necessary functions for salmon habitat.	Declining

The Tribe continues to work toward the protection and restoration of water quality, streamflows, nearshore, estuarine and river habitat, and to conduct research to understand the organisms and the habitats they occupy.

Looking Ahead



Muckleshoot Tribe

Muckleshoot tribal fishermen land sockeye at Rainier Beach in Seattle in 2006. No tribal or sport sockeye fisheries have been opened since 2006 on account of low abundance. High water temperatures along their migration route led to severe pre-spawn mortality in sockeye returning to the Cedar River in 2014 and 2015, negatively affecting the potential for sockeye fisheries in future years.

Salmon returns and treaty harvest opportunity continue to deteriorate in Central and South Puget Sound. The long-term outlook is challenging given degraded water quality and habitat, a rising human population, and unstable marine conditions and other effects associated with climate change. A dramatic improvement in habitat and water quality is required, along with a new, more flexible approach to salmon recovery to restore harvestable salmon and steelhead populations.

Over the next five years, the Muckleshoot Indian Tribe will work with its co-manager WDFW and others to boost salmon production and survival in our watersheds so that harvest opportunity is restored as soon as possible. A recent trib-

al study found that fewer than 10% of coho smolts released from the Issaquah Hatchery survived their freshwater migration to Puget Sound. The Lake Washington basin's miles of docks, bulkheads, rip-rap, warm water, and the many native and exotic fish predators favored by those degraded conditions are likely at fault. In the next few years, groups of hatchery fish will be released both at the hatchery and at sites closer to Puget Sound to quantify the survival benefits among release groups that bypass the hazardous shoreline. A program to remove predators at key sites in the Ship Canal and in Lake Washington will be conducted and evaluated. Target predators include introduced smallmouth and

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These salmon died because of poor fish passage at the Mud Mountain Barrier Dam on the White River. A new dam and fish trap is scheduled to finally replace the century-old barrier dam and undersized fish trap used to capture and transport fish around the 432-foot-high U.S. Army Corps of Engineers' Mud Mountain flood control dam located five miles upstream. Construction of improved fish passage is required by a NMFS 2014 Biological Opinion but awaits federal funding.



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largemouth bass, and walleye – a recently discovered criminal introduction. Finally, the greatly diminished salmon-producing potential of our watersheds means that natural salmon production alone will not support fisheries; more hatchery supplementation is essential to restore fishing opportunity for tribal members and to fulfill treaty fishing rights. The Tribe has relied on hatcheries for harvest for the past century, and more recently to conserve and rebuild salmon populations. The Tribe will work to expand production where feasible at existing hatchery facilities, develop new rearing and release strategies, and initiate other actions in order to restore treaty fishing opportunity as quickly as possible.

Habitat priorities for the next five years include establishing a riparian shade corridor along the Green River (including 20 miles through Kent and Tukwila) to address unhealthy water temperatures and comply with Washington water quality standards. To accomplish this, a new level of support from state and federal agencies will be demanded regarding permit approvals and mitigation for levee construction and repairs. Reducing lethal temperatures in the Lake Washington Ship Canal and the Sammamish River is another priority. Engineered solutions such as piping cold water from deep layers in Lakes Washington and Sammamish will be evaluated; preliminary modeling by King County shows that such an approach could effectively cool the entire Sammamish River. Contaminants entering Puget Sound from stormwater, wastewater effluent containing hormones and drugs, and other pollutant sources all reduce the survival of juvenile salmon and must be greatly reduced. Long-awaited fish passage improvements must be completed at the U.S. Army Corps' Mud Mountain and Howard Hanson dams, and at the Ballard Locks. Finally, state and tribal hatchery water supplies need to be secured against the degradation of water quality and quantity caused by the impacts of upstream development and groundwater withdrawals.

Land-use and coho population analysis has identified a linkage between pre-spawn mortality and stormwater runoff. Adult coho are highly sensitive to toxic pollutants in runoff from urban and residential landscapes, such as copper, pesticides and hydrocarbons. Based on a NOAA model, more than half of the 481 stream miles used by coho salmon in the Muckleshoot Tribe's Area of Concern are predicted to have pre-spawning mortality rates (PSM) of 5% or higher. Of these, 141 miles are predicted to have rates greater than 35%.

Healthy riparian areas require adequate vegetation and large woody debris. The watershed recovery plans call for managing riparian buffers to secure functional stream corridors. The quality

and quantity of instream wood in the Green and Cedar rivers (a tributary to Lake Washington) continue to be extremely low compared to natural conditions, due to land use and river management. The amount of existing instream wood in the Green and Cedar Rivers was estimated to be 89% to 95% less than NMFS criteria required for properly functioning conditions for salmon habitat.¹¹

The Lake Washington recovery plan recognizes the need to address degraded shorelines in both Lake Washington and Lake Sammamish. Overwater structures and bank modifications disrupt the migration and rearing of Chinook salmon. The shores of Lake Sammamish and Lake Washington are lined with 4,157 docks and piers, and an estimated 82% of Lake Washington has been bulkheaded. Of the 119 miles of marine shoreline in WRIs 8, 9 and 10, only 5% remains in a natural condition without bulkheads or riprap. Almost 60 miles of the Green-Duwamish and Lake Washington riverbanks are degraded by levees and revetments; which is 49% of the total length of the mainstem river accessible to salmon.

In addition, while many problems have been long known to limit the production of natural and hatchery-origin salmon in our watersheds, lesser known problems have been brought into focus in recent years and deserve greater attention. For example, recent studies by Roger Tabor of USFWS and others have found that artificial night lighting along our urban rivers and lake shorelines modifies the behavior of juvenile salmon and potentially exposes them to increased predation mortality.¹² Another study published in 2014 by NOAA researcher James P. Meador found that Chinook smolts migrating through contaminated estuaries including the Duwamish and Puyallup had a 45% lower average survival rate compared to Chinook moving through less contaminated estuaries. While the study was conducted using data from hatchery releases, the author noted important implications for natural-origin Chinook that spend even more time in estuaries than do hatchery-reared fish.¹³

Population growth and development will continue to challenge salmon recovery efforts. Trends indicate that we'll lose critical habitat even as restoration projects are implemented.

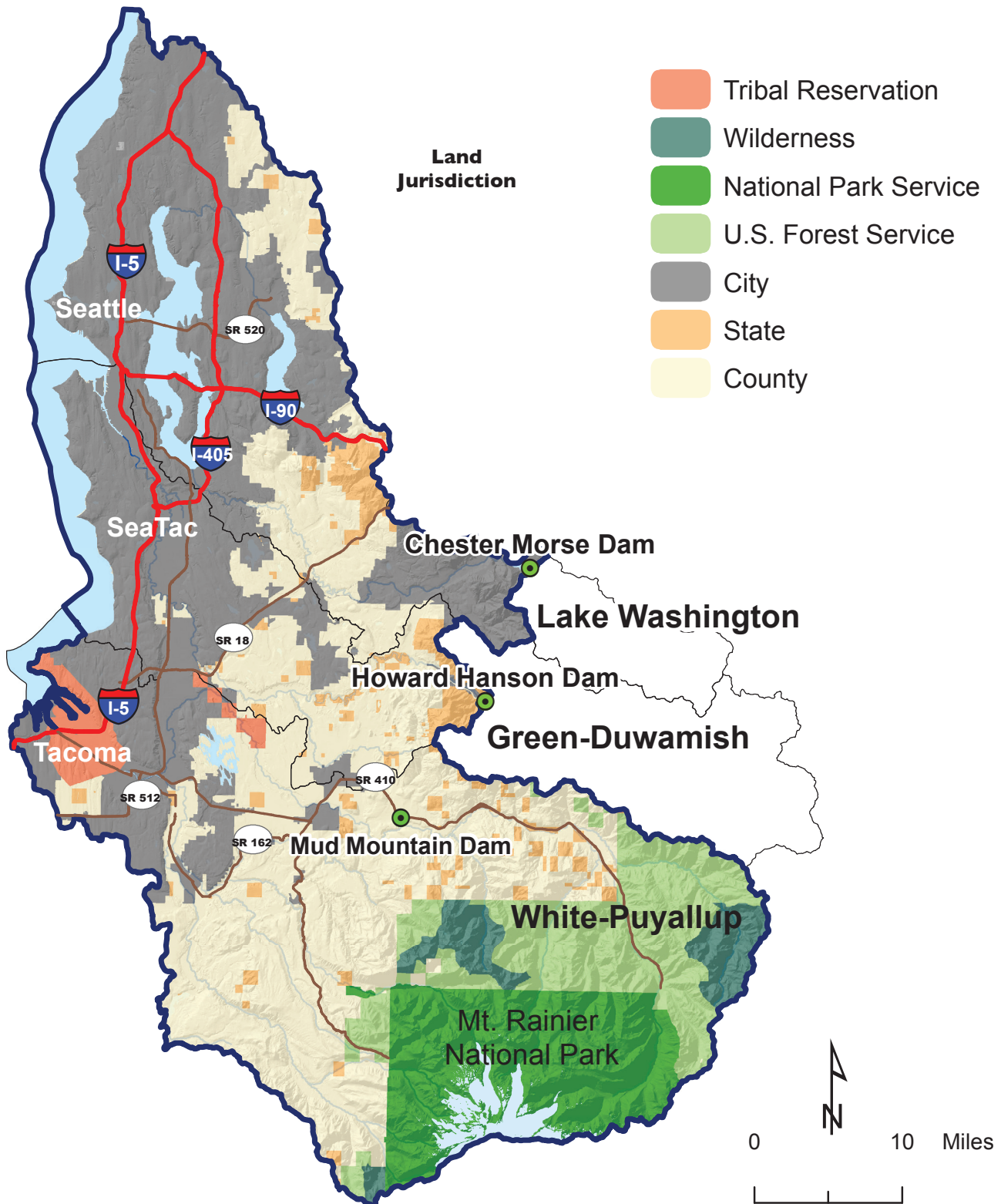
Increasing implementation of priority restoration efforts and enforcing or revising regulations that are supposed to protect salmon habitat must occur if salmon populations are to be sustained into the future. At the same time, increasing the flexibility for hatchery production and other approaches in urban basins to bypass or substitute for limiting factors must occur if fish abundance is to be restored in the near term in support of treaty harvest rights.

Muckleshoot Indian Tribe

Lake Washington, Green-Duwamish & White-Puyallup River Basins

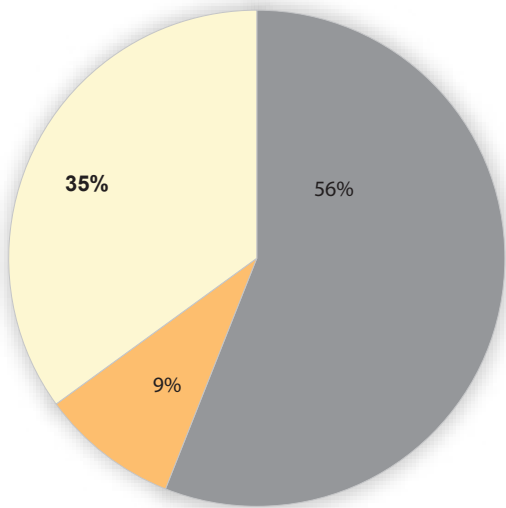
The Muckleshoot Indian Tribe's geographic Area of Focus includes all of WRIsAs 8, 9 and 10. In this chapter, the Tribe's focus is on the portions of Lake Washington (WRIA 8) and Green-Duwamish River (WRIA 9) basin that are downstream of the Chester Morse and Howard Hanson dams, and the White-Puyallup River

basin (WRIA 10) downstream of Mud Mountain Dam to highlight the status of critical low- and moderate-elevation salmon habitat. Anadromous salmonids in this area include Chinook, coho, sockeye, chum and pink salmon, and steelhead and bull trout.



Areas depicted do not necessarily correspond to Muckleshoot Usual & Accustomed fishing grounds and stations.

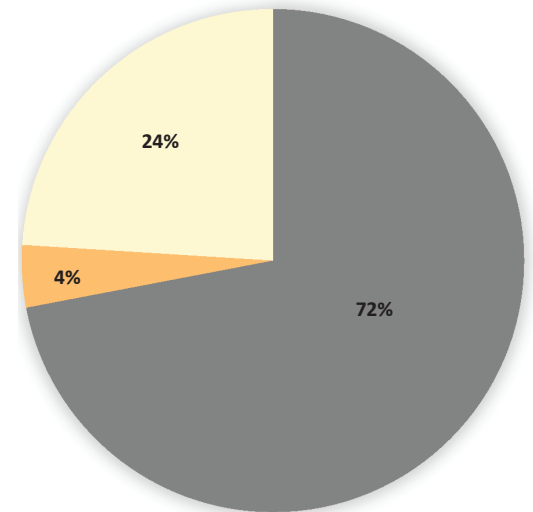
Green-Duwamish downstream of Howard Hanson Dam



- Tribal Reservation
- City
- Wilderness
- State
- National Park Service
- County
- U.S. Forest Service

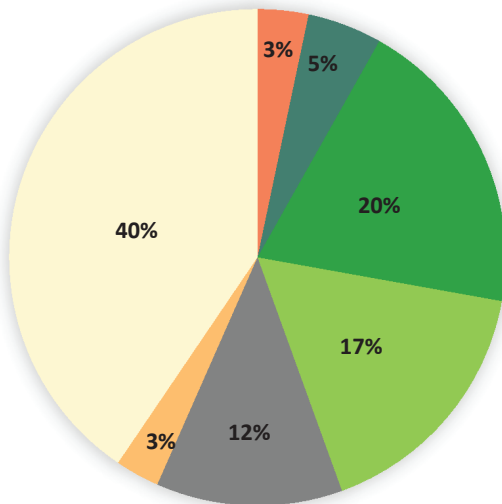
The **Green-Duwamish River** basin was historically 1,736 square miles and included the White and Cedar rivers. The Cedar and White rivers were diverted in the early 1900s, reducing the basin area to 556 square miles. The Green River flow regime is altered by flood control and storage at Howard Hanson Dam and by water withdrawals. The U.S. Army Corps' dam was constructed in the 1960s without fish-passage facilities. Approximately 98% of historic intertidal marsh and flats have been replaced with commercial and industrial development. The basin supports an estimated 596,000 people, and about 30% lies within Urban Growth Area boundaries.¹

Lake Washington downstream of Chester Morse Reservoir



The 686-square-mile **Lake Washington** basin includes the Cedar and Sammamish rivers and the lakes of Sammamish, Union and Washington. Major alterations include channelization of the Sammamish River, and the construction of the Lake Washington Ship Canal and the Ballard Locks. The basin is heavily urbanized, leading to highly modified stream hydrology and shorelines. With 25 cities and an estimated 1.5 million people, Lake Washington is the most populated basin in Puget Sound with 55% of its land area inside Urban Growth Area boundaries.²

White-Puyallup



The **White River** drains 494 square miles and originates on Mount Tacoma (Rainier) glaciers. The river flows 68 miles from its origin to its confluence with the **Puyallup River** at Sumner. Most of the upper White River is managed for timber production and has been intensively logged since 1945, leading to slope stability problems and increased sediment loads in non-glacial tributaries.³ The U.S. Army Corps' Mud Mountain Dam blocks adult fish migration and the river's flow and sediment regime are heavily altered by flood control activities at the dam. From 1911 until 2004, Puget Sound Energy diverted up to 2,000 cfs from the White River into the Lake Tapps reservoir, depleting river flows on the Muckleshoot Indian Reservation and devastating salmon and steelhead populations. A 1986 settlement with the Muckleshoot Tribe required that the diversion meet a minimum instream flow. Hydropower diversion ceased in 2004, and in 2007 an agreement was reached with the Cascade Water Alliance that further limits water diversion to Lake Tapps. The basin includes Commencement Bay, which is highly altered and contaminated with industrial discharges and urban runoff.

Land development along with hydrologic and channel modification have severely diminished the potential for natural salmon production in these basins. Much of the habitat loss and degradation is not likely to

be reversed, and new growth continues to add impacts. As a result, hatcheries continue to play a crucial role in providing salmon for tribal treaty and other harvest, and in maintaining the abundance of naturally

spawning fish. Nonetheless, habitat protection and restoration remain essential in order to sustain future salmon populations regardless of hatchery or natural origin.

Data Sources: SSHIAP 2004,⁴ USFWS 2014,⁵ USGS 2012,⁶ WADNR 2014a,⁷ WADNR 2014b,⁸ WADNR 2014c,⁹ WADOT 2013,¹⁰ WAECY 2011a,¹¹ WAECY 2013a¹²

Stormwater Runoff Implicated in Coho Pre-Spawning Mortality (PSM)

Based on NOAA’s model, 269 stream miles or 56% of known coho distribution in the Green-Duwamish and Lake Washington basins are predicted to have a PSM rate of 5% or more, with 141 miles or 29% predicted to have 35-100% PSM.

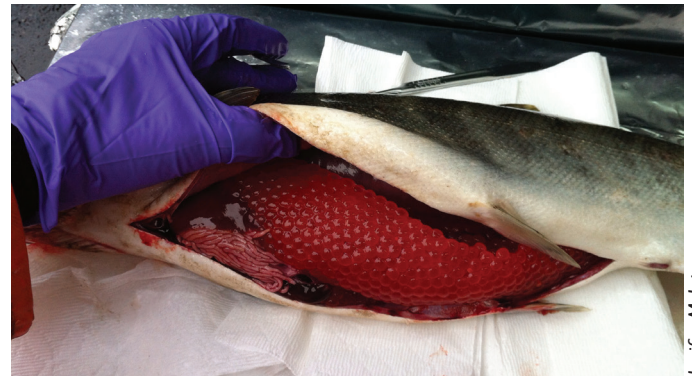
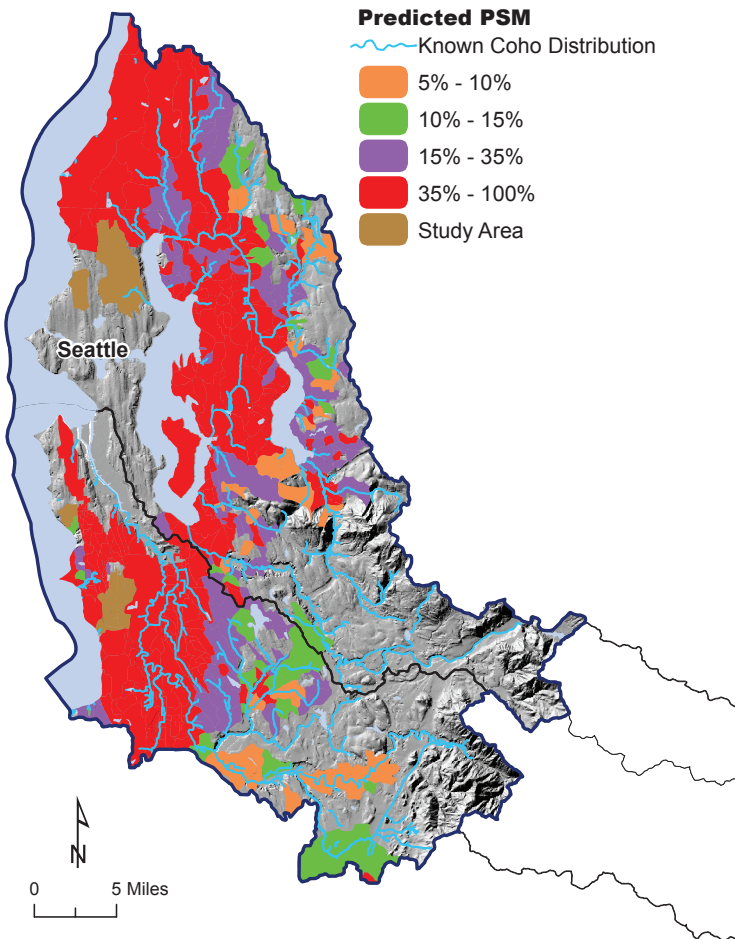
One of the Lake Washington/Cedar/Sammamish Watershed Chinook Salmon Conservation Plan objectives is the protection, maintenance and restoration of water quality and natural hydrology. In addition to adverse effects from peak and low flow changes in urban streams, coho salmon are also affected by elevated pre-spawn mortality (PSM). Scientists are still working to find out the underlying cause of death: what contaminant or mixture of contaminants in stormwater runoff is harmful to salmon. Adult coho salmon have been shown to be highly sensitive to stormwater runoff containing toxic pollutants from urban and residential land uses, such as copper, pesticides and hydrocarbons. NOAA and USFWS researchers have developed a model to predict areas of PSM in Puget Sound using spatial analyses of land-use

and coho PSM data.¹ Based on their model, 269 stream miles or 56% of known coho distribution in the Green-Duwamish and Lake Washington basins below the major dams are predicted to have a PSM rate of 5% or more, with 141 miles or 29% predicted to have 35-100% PSM. PSM rates in wild populations of coho salmon are generally less than 1%.² These researchers concluded that copper-containing stormwater from urban landscapes can cause sensory deprivation and increase predation mortality of coho juveniles. In a related experiment, deformities and low growth were observed in coho hatchlings incubated in untreated urban creek water compared to treated water from the creek.

The reduced spawning success that results from PSM has detrimental impacts on the persistence of local salmon runs. As

human populations grow and urban centers expand into less developed regions, coho salmon in currently unaffected watersheds may also be affected. Therefore, an understanding of the cause of pre-spawn mortality is essential for the protection of salmon populations today and into the future.³

Some best practices to improve water quality include techniques such as infiltration swales, low-impact development, adding green roofs, utilizing pervious pavement and establishing rain gardens.⁴ Rain gardens and swales typically filter out up to 90% of chemicals and up to 80% of sediments from polluted runoff. They also allow more water to soak into the ground, reducing not only contaminants in local waterways, but also, reducing the amount of flooding that occurs.⁵



Jenifer McIntyre

Adult coho salmon returning to Seattle-area urban streams are dying prior to spawning, as indicated by this female carcass with nearly 100% egg retention. This female returned from the ocean to spawn in Longfellow Creek (West Seattle) in the fall of 2012.



Raindog Designs

8th Ave NW Rain Gardens along the Street of Green: A rain garden is a planted area designed to filter rain water that flows from compacted or impervious areas. Rain gardens do not retain water; they only temporarily collect the water and drain within 12-48 hours.⁶

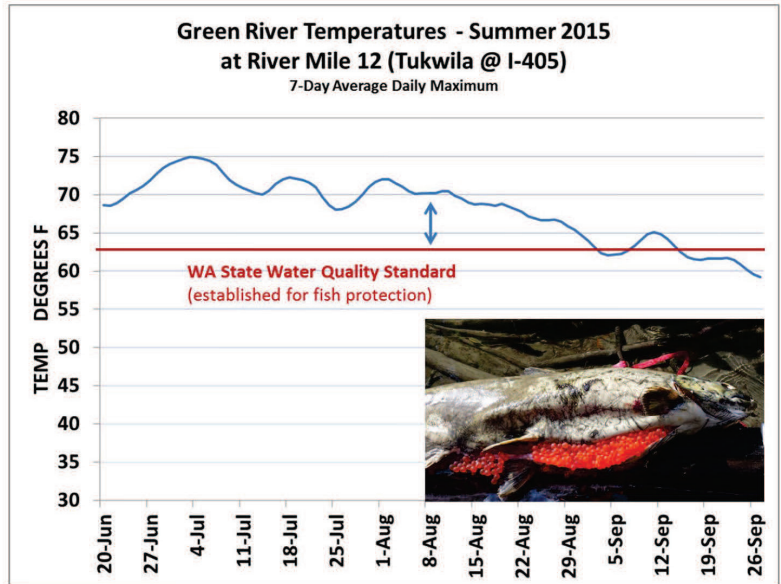
Data Sources: Scholz 2009,⁸ SSHIAP 2004,⁹ SWIFD 2014¹⁰

Water Quality Requires Corrective Actions

Approximately 193 miles of stream in WRIs 8, 9 and 10 are listed as "impaired waters" by the Washington State Department of Ecology 2012 Water Quality Assessment. An additional 42 miles in WRIs 8 and 9 are assumed to exceed water temperature standards for fish based on adjacent impairments or other data.

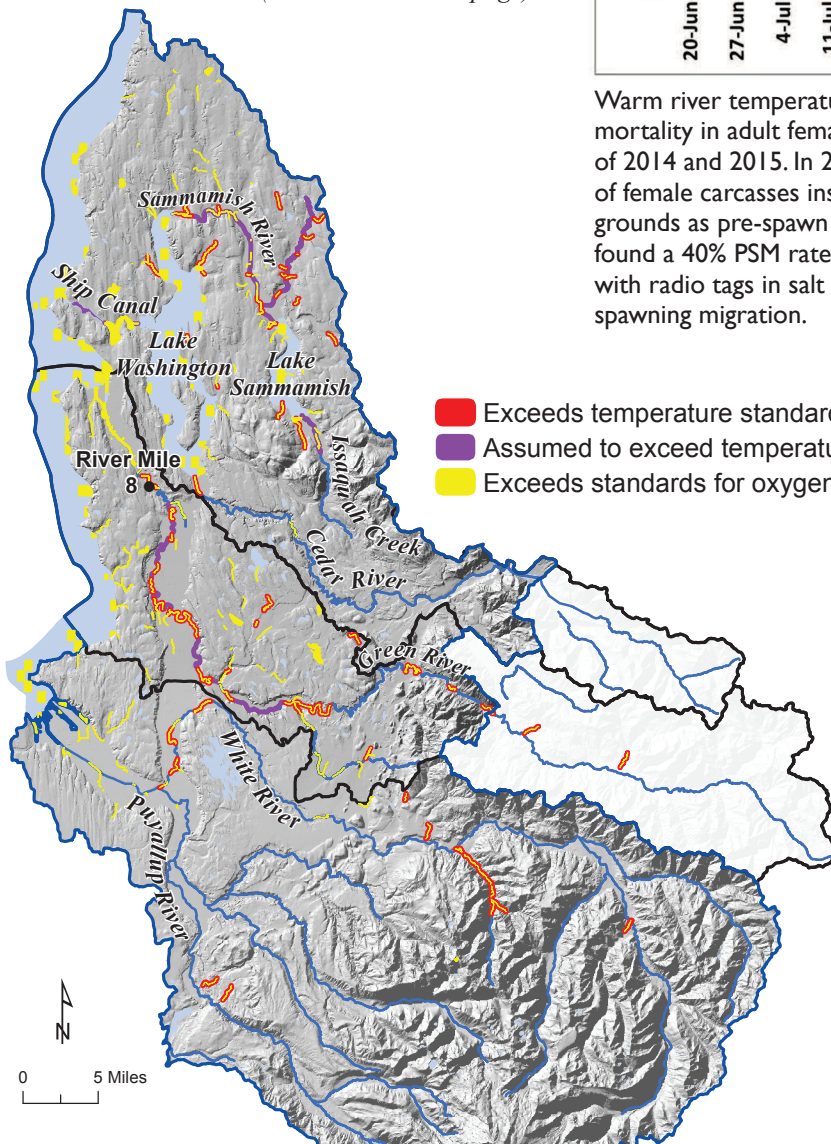
Water temperature and dissolved oxygen are known to be significant limiting factors for both juvenile and adult salmon.¹ The Lake Washington Ship Canal, the sole migration route for salmon to and from Lake Washington, routinely reaches temperatures of 21-23+ degrees Celsius by July each year. These high temperatures are believed to have contributed to disease leading to the pre-spawn mortality of approximately 40% of the Cedar River sockeye run in both 2014 and 2015. Summer temperatures in the Lower Green River typically reach 7-day average daily maximums greater than 21°C. In 2015, July river temperatures reached as high as 24 C. A major cause is poor riparian conditions. Shade levels generally range from zero to 20% of natural system potential.²

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Muckleshoot Fisheries Division

Warm river temperatures led to a high incidence of pre-spawning mortality in adult female Chinook in the Green River during the fall of 2014 and 2015. In 2015, tribal and state surveys identified 16% of female carcasses inspected on the middle Green River spawning grounds as pre-spawn mortalities (PSM). In 2014 and 2015, the tribe found a 40% PSM rate among female Chinook captured and outfitted with radio tags in salt water weeks earlier as they began their final spawning migration.

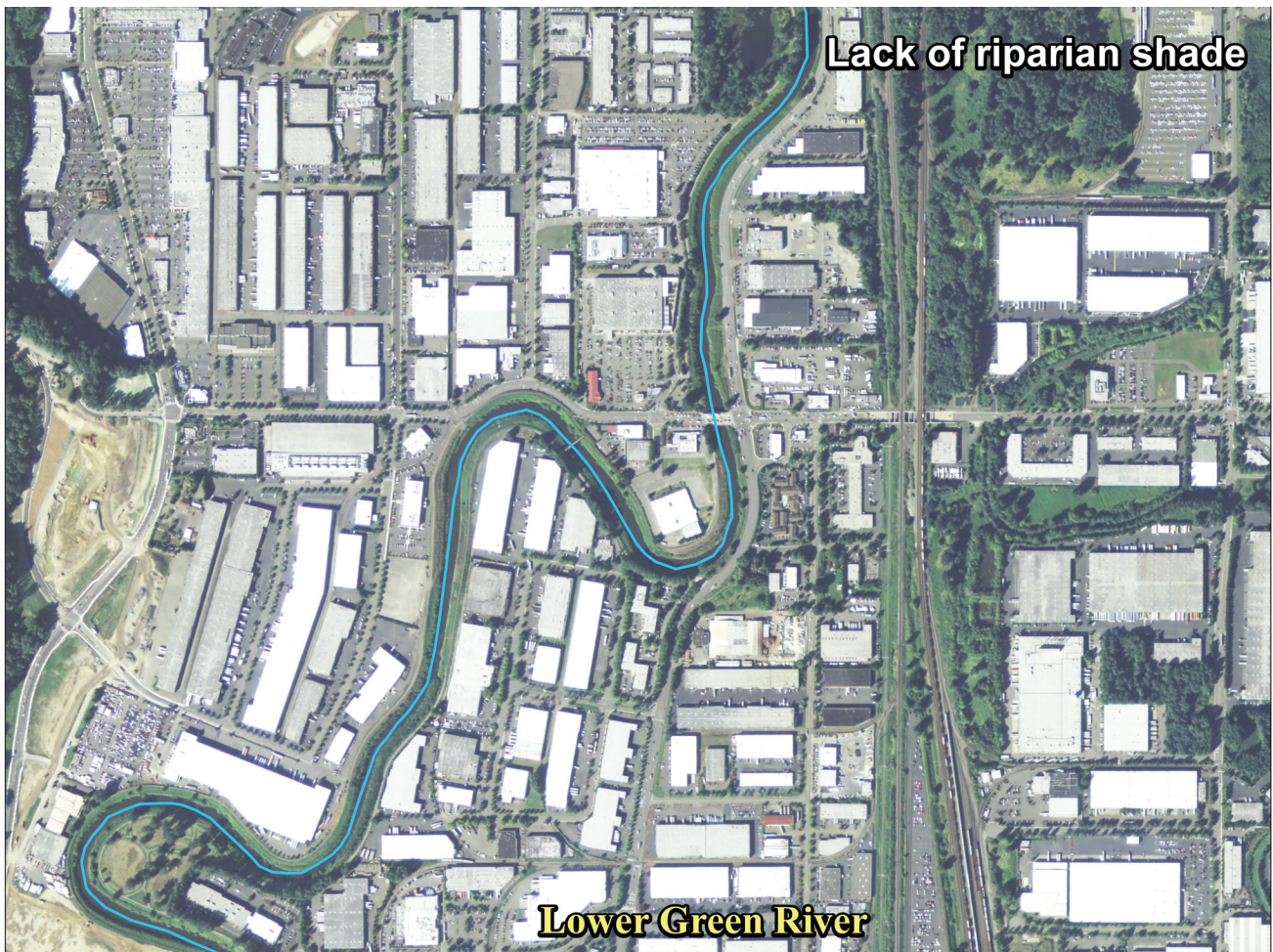


Severe infections and catastrophic outbreaks of warm water mediated bacterial and parasitic diseases causing pre-spawning mortality in migrating salmon and trout are a concern at river temperatures of 18.6 - 23°C 7DADMax.³

The Washington Department of Ecology's 2012 Water Quality Assessment identifies river reaches that exceed standards for fish.⁴ Additional areas are assumed to exceed temperature standards for fish based on proximity to impaired reaches with similar conditions or other data sets.

Areas depicted do not necessarily correspond to Muckleshoot Usual & Accustomed fishing grounds and stations.

Data Sources: NAIP 2013,⁸ SSHIAP 2004,⁹ USGS 2014,¹⁰ WAECY 2013b¹¹



The lower Green River between Auburn and Tukwila has severe shade deficits along each side of the river, elevating water temperatures to levels known to cause disease outbreaks and pre-spawning mortality in migrating salmon and trout.

(Continued from previous page)

Despite a severe shade deficiency, near-lethal water temperatures and an agreed salmon recovery strategy to “establish and enforce riparian buffers along rivers (and) streams,” more than 600 trees have been removed from the lower Green River since 2005 to comply with U.S. Army Corps’ maintenance policies for federally subsidized levees.⁵ New flood protection facilities have been constructed or repaired in locations that lack space for adequate riparian buffers. Between 2005 and 2009, riparian forests declined by 1.5% in rural areas and by 3.4% in urban growth areas in Lake Washington’s high-priority sub-basins.⁶

In late 2012, King County Flood Control District initiated a Green River System Wide Improvement Framework (SWIF) planning process to address flood control levee deficiencies in the lower Green River.⁷ The SWIF promised to be a 30-year corridor improvement plan to rebuild 16 to 25 miles of levees in a manner that would significantly restore riparian and fish habitat conditions while increasing the level of flood protection. After three years of planning, the Flood Control District decided to scale back the scope of the SWIF and instead rebuild less than 2 miles of levee without assurance of adequate riparian buffer widths in urban levee segments. In this scaled-back interim SWIF, the Flood Control District will continue federally funded levee repairs as needed. Without more effective regulatory permit conditions by NMFS and others, the interim SWIF approach is likely to perpetuate poor riparian, instream and water temperature conditions in the lower river. In 2015, the District initiated a riparian restoration grant program aptly called “Re-green the Green” to help address water temperatures using a voluntary grant approach and conservation

easements. Yet water quality modeling indicates that even the most urban leveed areas along the lower river will require 100-foot-plus buffer of tall trees with dense canopy cover to approach state temperature standards and restore a river that can sustain salmon including Chinook that migrate upstream in summer. Loss of riparian vegetation, altered streamflows, and pollution from adjacent land uses limit fish production and survival in much of the Green-Duwamish, Lake Washington and White-Puyallup basins. While some efforts by local jurisdictions have been made, more action is needed to improve water quality and avoid further degradation.

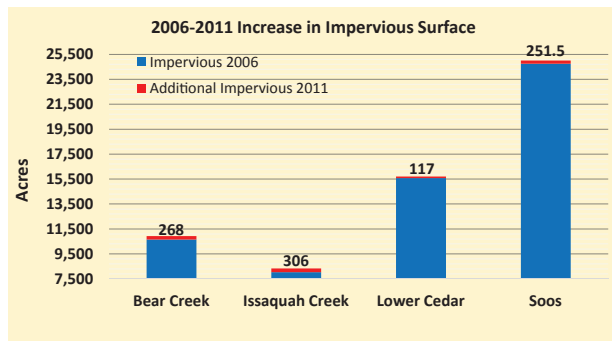
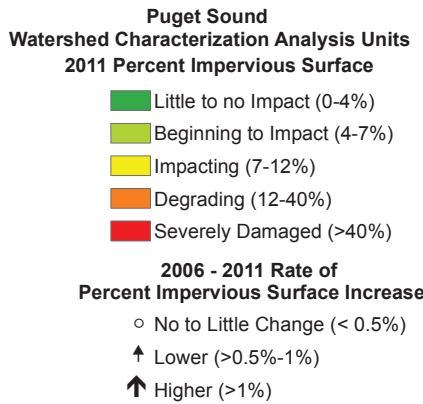
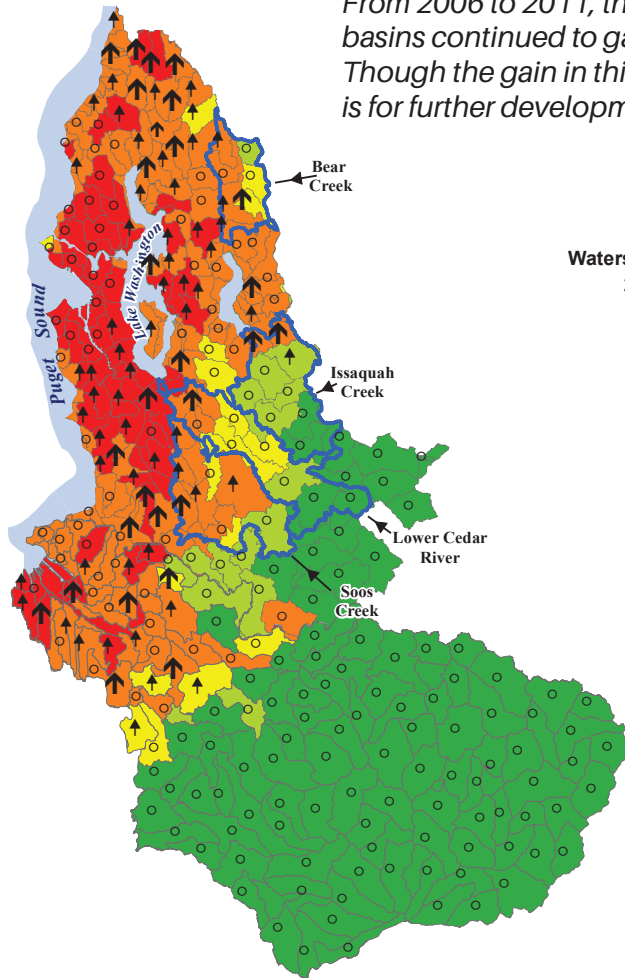
Green River Levee Project



Muckleshoot Indian Tribe

Impervious Surface Continues to Increase

From 2006 to 2011, the Lake Washington, Green-Duwamish and Puyallup-White basins continued to gain impervious surface area despite the economic recession. Though the gain in this time period was small, 1.3% of combined basin area, the trend is for further development and more impervious land cover.



Protection of existing marine and freshwater habitats is essential for salmon recovery in Puget Sound. Protection means the conservation of habitat and the functions it provides through passive actions (e.g. habitat acquisition) and the application of land-use regulatory measures. Adequate protection of salmon habitat in Puget Sound continues to be an issue in all watersheds. Our reviews noted that the continued degradation of habitat is a concern throughout the region.⁵ The Salmon Recovery Plan for WRIA 8 and 9 list Bear Creek, Issaquah Creek, the lower Cedar River and Soos Creek as Tier I streams. All of these basins had an increase in impervious surface from 2006-2011.



An example of impervious surface near a salmon-bearing stream in Soos Creek, Green-Diamond River basin.

Impervious surfaces are land areas covered with roads, parking lots, rooftops, compacted soils and other surfaces that prevent water from soaking into the ground. Impervious area in a watershed is a general predictor of biological and hydrological conditions.¹ Studies in western Washington have found that when impervious surfaces reach 10-20% of a watershed, stream stability decreases, flooding and bed scour increase, large wood decreases, gravel and water quality decrease, macro-invertebrate diversity decreases, and loss of aquatic system functioning is likely irreversible.² Impairment can begin as low as 7 to 12% imperviousness.³

The Green/Duwamish and Central Puget Sound watersheds are among the most densely populated and developed in the state, resulting in many sub-watershed areas having high amounts of impervious surface areas. The detrimental effect of stormwater runoff from impervious surfaces on salmon habitat is well documented; this nonpoint source pollution is among the least regulated. Salmonid populations are adversely affected by increased peak flows that scour out salmon redds and displace fry; increased low flows resulting from reduced infiltration and groundwater recharge; by the contaminants carried by water running across impervious surfaces; and by sedimentation and habitat simplification caused by excessive runoff. Salmon survival is critically linked to landscape cover and the management of surface water and stormwater runoff. Stormwater discharges from impervious surfaces also are the primary way in which pollutants are conveyed to the marine waters of Puget Sound.⁴

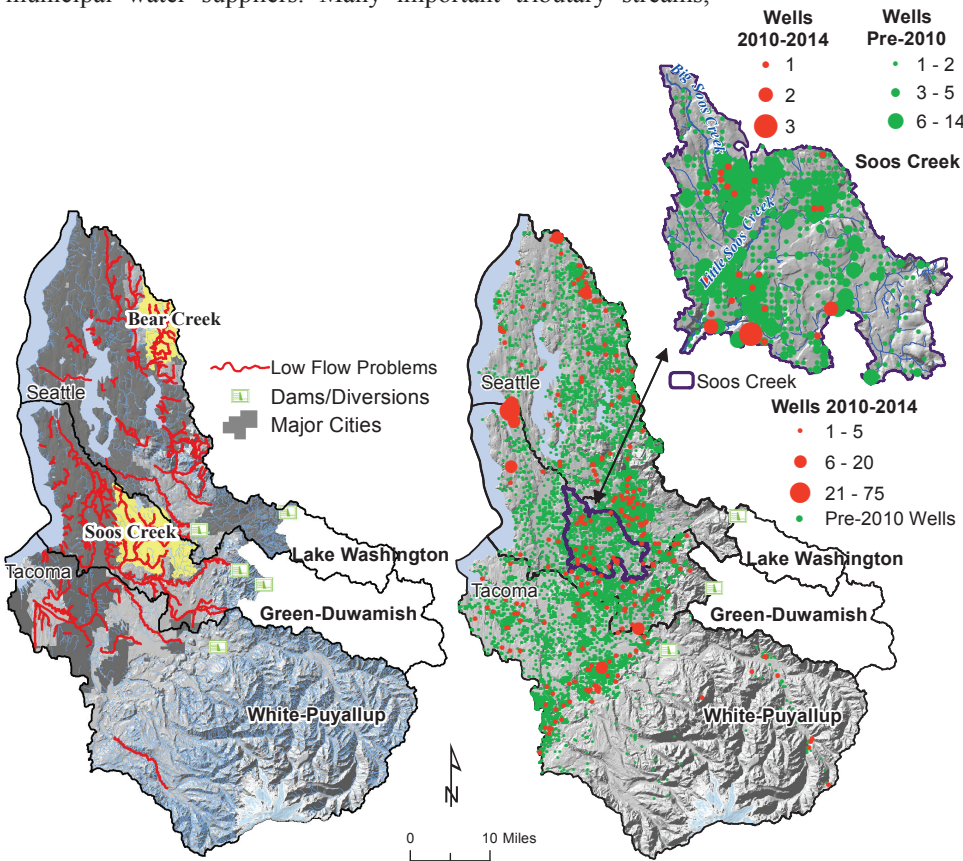
Data Sources: NAIP 2013,⁶ NLCD 2006,⁷ NLCD 2011,⁸ SSHAP 2004,⁹ USGS 2014,¹⁰ WADNR 2006,¹¹ WAECY 2000,¹² WAECY 2011a,¹³ WAECY 2011b¹⁴

Summer-Fall Flows Decreasing as Water Resource Development Continues

From 2010-2014, 369 new wells (4.5% increase) were added to the already existing 8,227 wells in the Lake Washington and Green-Duwamish basins, while the Puyallup-White basin saw an increase of 101 new wells (2.6%) to the already existing 3,881.¹ A total of 482 miles of streams in the Lake Washington and Green-Duwamish basins are identified as having low streamflow problems,² while in the Puyallup-White basin there are 120 miles of low flow concerns.

Low streamflows are one of many factors that contribute to low productivity and abundance of Chinook and other salmon. Low flows reduce the available habitat for rearing, migration and spawning, and contribute to warm water temperatures. Instream flows in the Cedar, Green and White river mainstems have been protected and restored through tribal settlement agreements with municipal water suppliers. Many important tributary streams,

however, currently lack protection and restoration and are in need of streamflow. Greater enforcement of water rights laws, a halt in the proliferation of wells, and greater use of conservation, source exchange, and aquifer recharge strategies are critically needed for salmon habitat and to protect the water rights of state and tribal fish hatcheries.

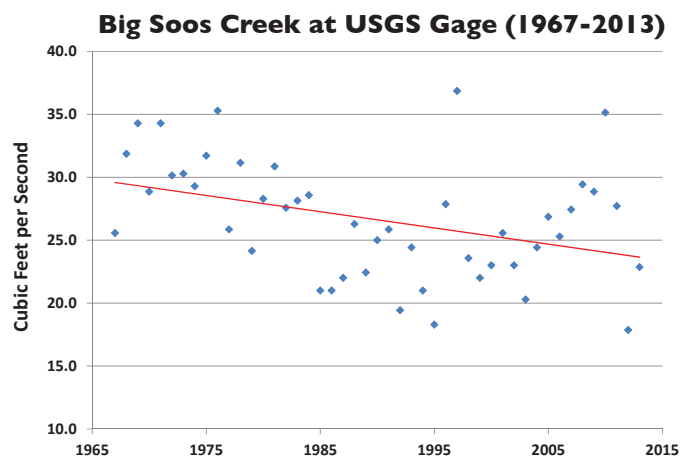


The 2005 Lake Washington and Green-Duwamish Salmon Conservation Plans call for the maintenance of adequate streamflows. Ground and surface water extractions are estimated to be 37% of the current summer low flows in the Green-Duwamish River basin.³ Summer low flows in the Bear Creek drainage have been reduced by 39%.⁴ Private and municipal well extractions in the Soos Creek sub-basin were estimated to equal 52% of the current summer low flow,⁵ reducing habitat for Chinook, coho and steelhead.

Over 8,500 wells currently exist in the Lake Washington and Green-Duwamish basins, in addition to two large municipal water diversion dams. The number of wells drilled continues to rise as land development proceeds with an increase of 369 wells from 2010-2014.

Areas depicted do not necessarily correspond to Muckleshoot Usual & Accustomed fishing grounds and stations.

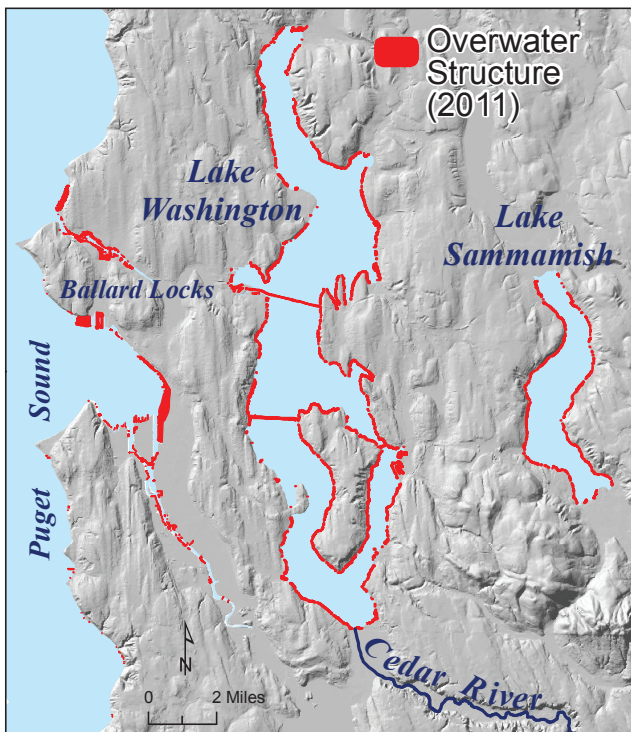
Summer-Fall flows in Big Soos Creek show a statistically significant decline that coincides with development of municipal and private wells in the sub-basin. From 2010-2014, 26 new wells were added to the already existing 1,314 in the Soos Creek Basin.



Data Sources: King Co. 2014,⁶ MIT 2014,⁷ SSHIAP 2004,⁸ USGS 2012,⁹ USGS 2014,¹⁰ WADNR 2014b,¹¹ WAECY 2000,¹² WAECY 2013a,¹³ WAECY 2015¹⁴

Overwater Structures Impact Lakeshore Habitat in Lake Washington

Since 2011, Lake Washington and Lake Sammamish have seen an increase of approximately 60 new docks,¹ adding to the 4,097 docks and piers already built. An estimated 82% of Lake Washington’s shoreline remains heavily modified with bulkhead and riprap.

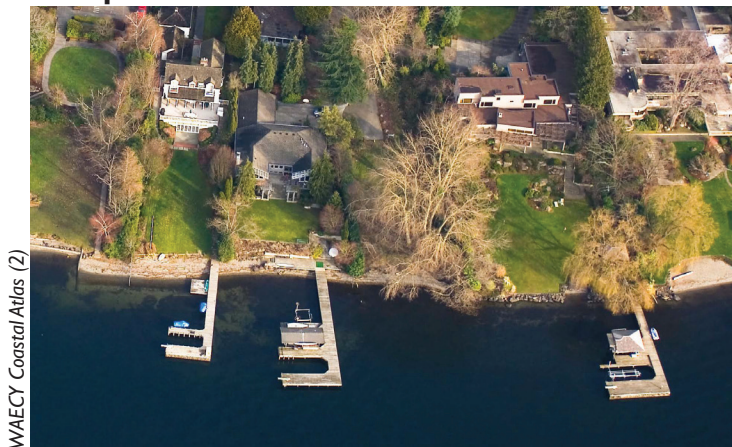


Overwater structures and bank alterations on Lake Washington and Lake Sammamish interfere with the rearing and migration of juvenile Chinook salmon. Docks, piers and bulkheads provide ideal habitat for ambush predators such as smallmouth bass and cutthroat trout, and are avoided by rearing Chinook. Extensive armoring reduces the amount of gentle sloping shorelines that small juvenile Chinook salmon use from January to May.² Migrating Chinook smolts are also observed to avoid these structures, moving into deeper water where they are more vulnerable to off-shore predators.³ The perimeter around docks and piers in Lake Washington nearly doubles the natural shoreline length to 163 miles. This longer swimming distance exposes out-migrating Chinook to increased predation, and may delay saltwater entry until midsummer when fish-passage efficiency at the Ballard Locks drops due

to warm water temperatures.

The Salmon Recovery Plan calls for a reduction in the number and coverage of overwater structures in the Lake Washington basin.⁴ According to the Habitat Work Schedule, unfortunately no docks have been removed.⁵ The overwhelming prevalence of these artificial shoreline structures means that far fewer of the juvenile salmon produced in either Lake Washington’s streams or at its two salmon hatcheries ever make it to Puget Sound. Given the lack of progress in re-naturalizing the lake shoreline, alternative approaches that can bypass lethal hazards to salmon migration are warranted, such as trucking or barging hatchery fish as on the Columbia River. The Tribe will be testing this approach over the next few years.

Examples of bank alterations and docks on Lake Washington



WAECY Coastal Atlas (2)

Data Sources: NAIP 2013,⁶ SSHIP 2004,⁷ WADNR 2007,⁸ WAECY 1994,⁹ WAECY 2011,¹⁰

Riverbank and Shoreline Modifications Limit Fish Habitat in Fresh and Marine Waters

From 2005 to 2014, marine shoreline conditions in King County have changed very little. During this time period, 903 feet of armoring was removed, while 681 feet of new armoring was constructed. 2.6 miles of armoring was replaced.¹ Meanwhile, a total of 115 miles of artificial shoreline continue to negatively affect nearshore habitat for salmon.



Salmon produced in Lake Washington, Green-Duwamish and White-Puyallup basins lack natural nearshore habitat for juvenile rearing, transitioning to salt water, and migration to the Pacific Ocean. Extensive development along marine shorelines has resulted in loss of productive marine aquatic habitat and vegetation. Bulkheads and seawalls have filled shallow water habitats, resulting in reduced rearing area, food supply and cover from predators, and has isolated the aquatic environment from natural sediment sources such as feeder bluffs that sustain beach habitats.

contrasts between light and dark areas. Juvenile salmon hesitate to swim under the waterfront piers due to the lack of light. Juvenile salmon can't see well in the dark, so to avoid swimming blindly, juveniles swim around these structures into deeper waters where they face food competition from larger fish and predation.² However, Seattle is getting a new Elliott Bay seawall, and a small part of this big job is to give migrating juvenile salmon a safer route to the sea. Construction on the new wall started in early 2014. Workers have completed the first section of the wall, including a migratory corridor for juvenile salmon that will eventually run the entire length of the downtown waterfront.

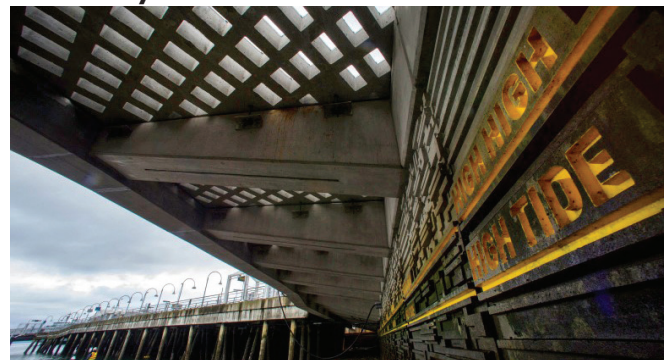
In Elliott Bay, approximately 90% of the central waterfront is covered with piers and other overwater structures, resulting in stark

Elliott Bay



WAECY Coastal Atlas

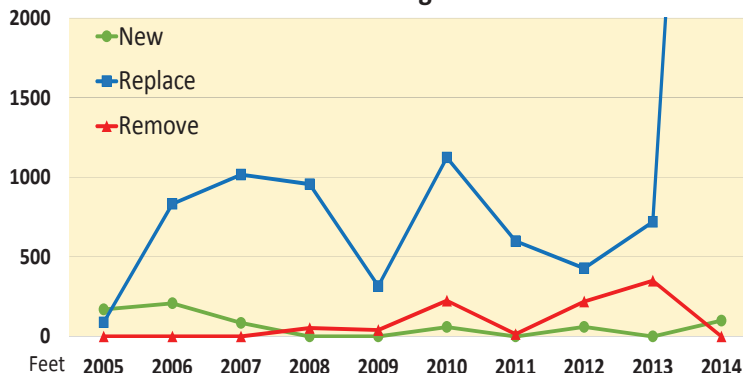
Elliott Bay Seawall



Seattle Times

The new wall's face along the Seattle waterfront is studded with grooves and shelves to promote growth of algae and invertebrates that supply food for juvenile salmon.

King County 2005-2014 HPAs
 Armoring



Data Sources: ACOE 2011,³ Carman et al 2015,⁴ King Co. 2014,⁵ PSNERP 2008,⁶ SSHIAP 2004,⁷ SSHIAP 2008,⁸ USGS 2012,⁹ USGS 2014,¹⁰ WADOT 2010,¹¹ WADOT 2013,¹² WAECY 2000¹³

Light Pollution and Salmon - A Growing Concern

Light pollution is one of the most rapidly increasing types of environmental degradation. Its levels have been growing exponentially over nocturnal lighting levels provided by starlight and moonlight.¹ Excessive outdoor artificial night lighting, or light pollution, is harmful to local ecosystems and its inhabitants. Since all living things have evolved according to a day/night cycle, it takes little light to upset nighttime cycles and alter natural rhythms. Many insects, migratory birds, sea turtles, bats, nocturnal rodents, snakes, fish, aquatic invertebrates and even plants are affected by night lighting.²

Artificial nighttime lighting can modify the behavior of various aquatic organisms, including salmonids. Affected behaviors may include foraging, predator avoidance, reproduction and migration. Often fish are attracted to artificial light and their behavior may more resemble daytime behavior than nighttime behavior. In urban areas, high-intensity artificial lights are common near rivers, lakes and streams. This lighting comes from street lights, parking lots, industrial and residential buildings, bridges and other urban structures. High-intensity artificial lighting can penetrate the entire

water column in shallow water. Thus, fish species that utilize shallow water in urban areas, such as juvenile Chinook, may be most susceptible to the effects of artificial night lighting.³

Many researchers consider light pollution to be one of the fastest growing and most pervasive forms of environmental pollution. A growing body of research suggests that light pollution can have lasting adverse effects on both human and wildlife health. Research on insects, turtles, birds, fish, reptiles and other wildlife species shows that light pollution can alter behaviors, foraging areas and breeding cycles – not just in urban centers but in rural areas as well.⁴

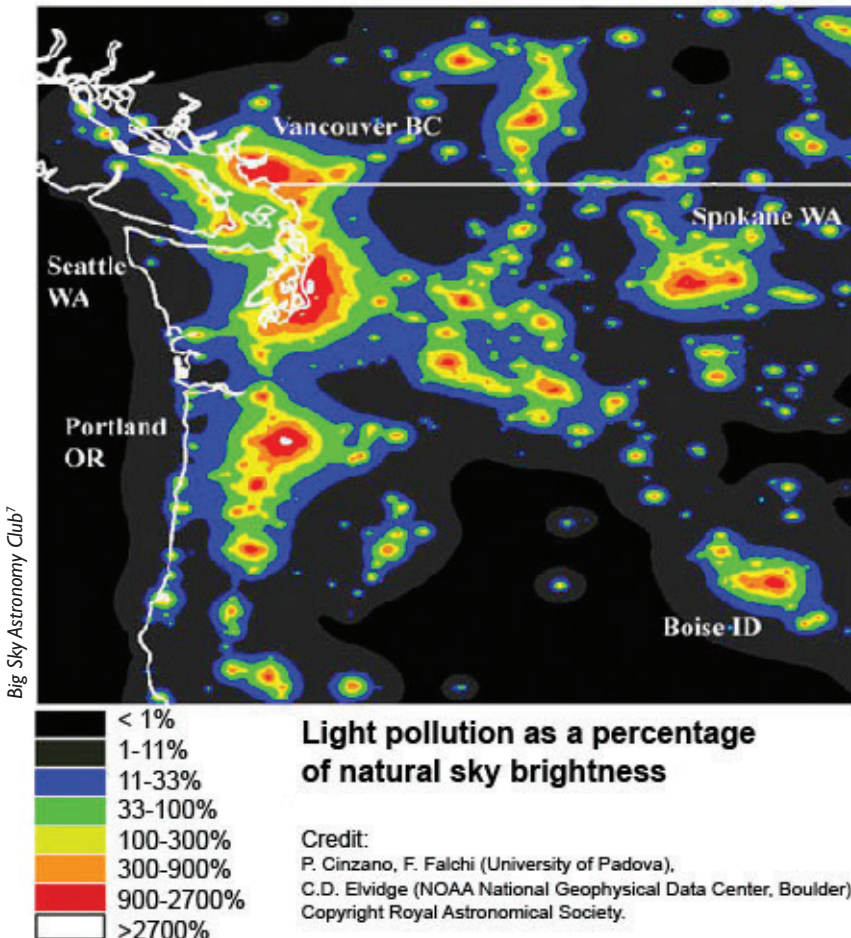
The urban regions of the Pacific Northwest are awash in nighttime illumination, much of which shines needlessly skyward. The I-5 corridor, from Vancouver, British Columbia, south to Eugene, Oregon – a stretch of over 400 miles – is a single, nearly unbroken swath of light pollution.⁵

Artificial lighting studies and experiments led by the U.S. Fish and Wildlife Service were conducted in Lake Washington (2014) and Lake Sammamish (2015), in the Lake Washington Ship Canal (2007

and 2008) in the Cedar River (2004). Fish usage “hot spots” were found in brightly lit areas and along shadow lines created by artificial lighting. Chinook salmon were generally attracted to artificially lit areas. Artificial lighting may attract juvenile salmonids and expose them to increased rates of predation from visual predators such as cutthroat trout, smallmouth bass, and northern pikeminnow. Birds such as mergansers and herons are also present, and have been observed anecdotally foraging in artificially lit areas.

Artificial nighttime lighting is extensive in urban areas and is often necessary for human safety. However, there is a need to minimize the effects from lighting by such measures as eliminating unnecessary lights near water, dimming or reducing output, re-locating or re-aiming lights, lowering lamp heights, shielding lamps or using designs that reduce the intensity of light reaching water surfaces, reducing “on” hours, or using motion sensors. Further research on different types of lighting and their effects on fish attraction and predation may yield additional benefits.⁶

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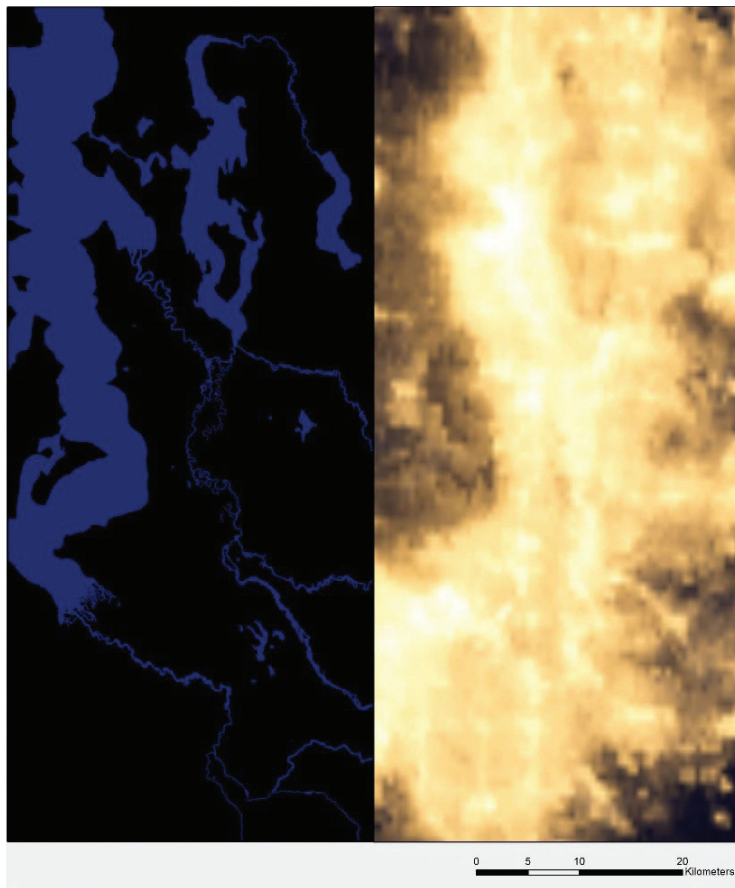
Big Sky Astronomy Club⁷

Light Pollution and Salmon – A Growing Concern

(Continued from previous page)

Simple changes in lighting design and installation yield immediate changes in the amount of light spilled into the atmosphere and, often, immediate energy savings. Between 2000-2011, a number of cities and counties passed some form of “dark sky” outdoor lighting ordinances. Examples include: Island and King counties, Redmond, Tumwater, Goldendale, Bothell and Bainbridge Island.

However, these ordinances alone are not sufficient. It is critically important that local, state and federal governments ensure that environmental assessments and permit reviews include the effects of artificial lighting on aquatic habitat, and that initiatives to retrofit and reduce artificial night lighting are undertaken especially along urban lakes and streams.



The left panel shows historical stream channels and shorelines extending from Commencement Bay and the lower White River north to the Seattle city limits and lakes Washington and Sammamish, while the right panel is a NASA 2012 satellite image of the same area at night with intense artificial lighting.



Hiimmiko / Flickr bit.ly/1Q3zXDe

This photo taken from Queen Anne Hill shows urban sky glow evident in the night sky over Seattle.

Streams Lack Large Wood and Natural Habitat Features

Wood counts in the lower Cedar and Green rivers have less than 5% of the expected key piece quantities.¹

Large woody debris (LWD) creates pools, provides hiding cover, and interacts with flowing water to produce complex stream habitats used by salmon and steelhead at all life stages. Estimates of LWD in the Green and Cedar rivers meeting NMFS size and frequency criteria are 89% to 95% below the levels necessary for “properly functioning conditions” for salmon habitat.² Comparing the wood loads in these rivers to estimated historic conditions³ and expected natural wood loads to which salmon have adapted,⁴ these rivers have a mere fraction of the wood they once contained. A study by King County of the presence and distribution of large wood in the Cedar River estimated 11,500 pieces of large wood on the Cedar River in 2010, and the vast majority

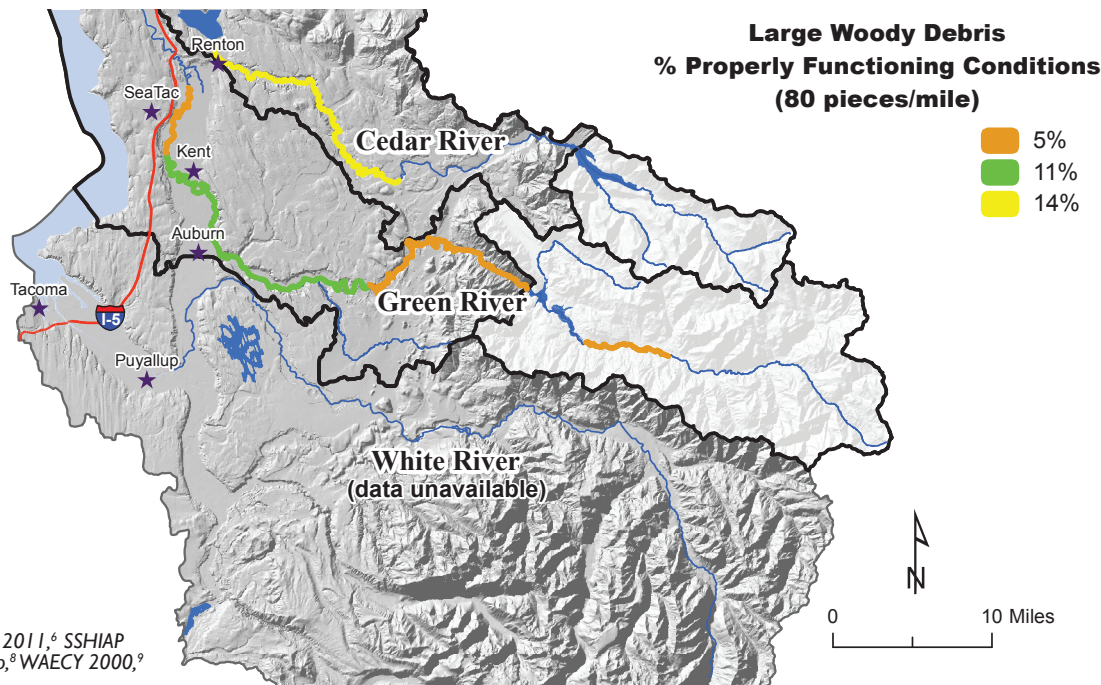
of these were categorized as small logs and branches. Only 145 key pieces (wood pieces large enough to aid in the formation of a logjam) were counted for at an average of 6.5 per river mile. Watershed Analysis data on large woody debris (LWD) in the upper White River (above Mud Mountain Dam) suggests the LWD and key piece quantities is in a poor condition as it relates to necessary functions for salmon habitat.⁵

Lake Washington, White-Puyallup and Green-Duwamish salmon habitat plans call for a focus of action to restore sources of LWD, install LWD to restore pool habitat and to protect existing LWD. However, the potential to restore large woody debris to improve salmon habitat in the Green-Duwamish and Lake Washington basins is

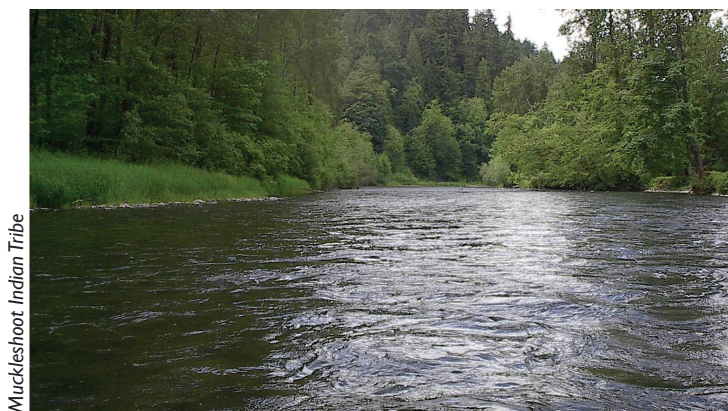
restricted by land use and also by policies that address river recreation safety. The Cedar, Green and Sammamish rivers are all designated by King County as Recreational Waterways where wood placement for restoration or mitigation purposes is restricted, and the removal, lopping or repositioning of artificially placed or naturally recruited wood deemed hazardous to boaters commonly occurs.

For more information, see: www.king-county.gov/environment/watersheds/general-information/large-wood.aspx

As a result, much of these channels are simplified and lack the necessary habitat to produce salmon naturally.



Data Sources: King Co. 2011,⁶ SSHIAP 2004,⁷ WADNR 2014b,⁸ WAECY 2000,⁹ WAECY 2011a¹⁰



Muckleshoot Indian Tribe

When large woody debris levels are low, fish habitat productivity is diminished.



Muckleshoot Indian Tribe

Riparian areas function properly when adequate vegetation, land-form and large woody debris are present.

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