Puget Sound Trends:

A Synthesis of the Drivers Shaping the Future of our Waters

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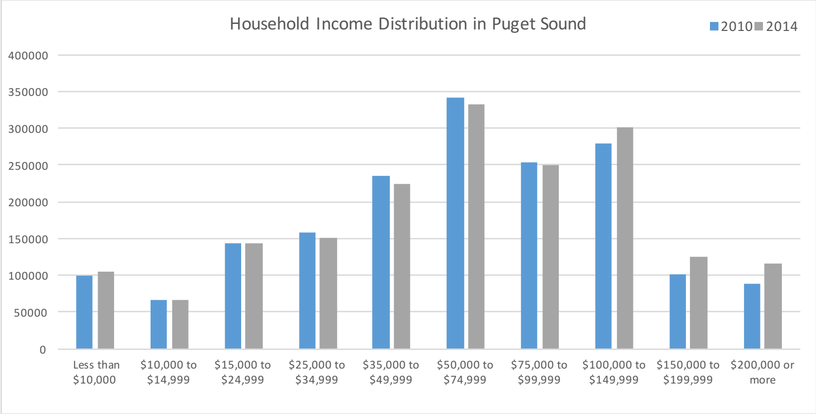
Project PI: Marina Alberti
Research Associate: Michal Russo

Economic trends, including employment, industry sectors, income and GDP, and trade/exports, function as a dominant driver in the Puget Sound, and globally. Economic trends are linked to population and housing growth, increase in municipal tax base, a corresponding growth in municipal infrastructure and service investments, as well as higher pressures on natural resources and extraction. The state is forecasted to see moderate growth over the next 5 years with personal income projected to increase by 5% between 2015 and 2021. We are expected to see a decline in the rate of growth by 2017/2018. Central Puget Sound jobs are projected to increase by 866,000 by 2040, with the majority of growth occurring in the service sector. While incomes grow, the middle class is shrinking and the disparities between the poor and the rich are growing. Trade continues to be a major component of western Washington's economy with export shipments totaling over $86 billion in 2015.

Washington State is growing richer: Overall, the state is expected to see moderate growth over the next 5 years. Washington is outperforming the nation for personal income growth (E&RFC, 2016), as it has since 1980 (OFM Trends, 2010). The national GDP is forecasted to rise by 2% by 2021. Personal income is forecasted to increase by 5% between 2015 and 2021 (E&RFC, 2016). This rate is twice the forecasted national increase (Ibid).

Threats to continued growth include slower international economic growth, the impact of a stronger dollar on exports, and a slowdown in manufacturing (Ibid). In 2015, WA ranked 13th among states for per capital income with a large portion of income growth stemmed from stock options and software industry wages (OFM, 2010).

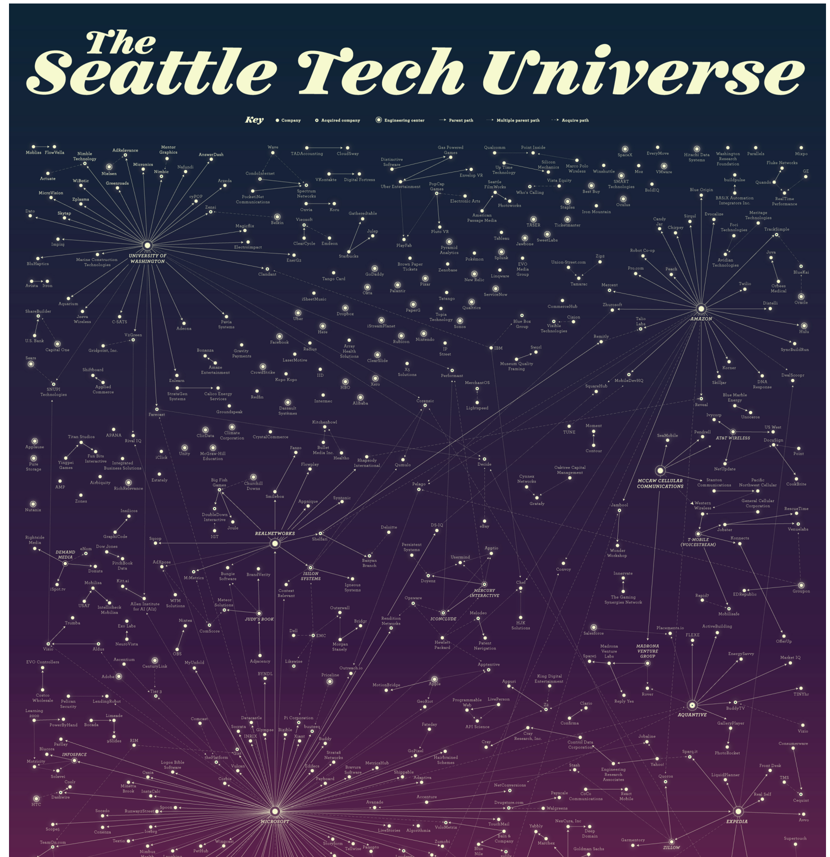


Changes in Distribution of Household Income in Puget Sound between 2010 and 2014. Census 2010 and ACS 2014.

Income Disparities are growing as the middle income disappears: In the Puget Sound, as with the rest of the U.S., middle income groups are shrinking. The median household income for the Puget Sound rose from $62,936 to $66,513 (US Census, 2010; ACS 2014). However, during that same period the percentage of households living in poverty rose from 6.8% to 8.0% (Ibid). Between 2010 and 2014 the percent of households with incomes between $25,000 and $100,000 shrank, while the number of households making under $15,000 or over $100,000 increased (Ibid). The largest margins of growth were for the 3 top income brackets, indicating that overall, the region is getting more wealthy (Ibid). These inequities threaten to reduce the region's diversity and prosperity. Seattle's Mayor, Ed Murray, is focused on addressing inequality. In Oct 2013 Proposition 1 was passed making the Seattle-Tacoma Metropolitan Area the first $15 min wage city in the nation. However, as Murray notes, wage increases alone won't fix the problem "we need to look at issues of housing and education" (Tan, 2014).

Strong and steady growth is expected, with gradual declines in the rate of growth over the next decade: Between 2010 and 2014, the number of residents (over 16 years old) in the labor force within the Puget Sound rose by 53,658 (Census 2010, ACS 2014). During the same time period, the number of individuals within that pool that are unemployed rose from 6.9% to 8.4% (Ibid). This jump in unemployment is related to the breaking of the housing market/equities/commodities bubble, which hit WA and the nation with similar force (OFM Economic Trends, 2010). The Washington Economic and Revenue Forecast Council forecasts that the unemployment rate for the State will go down steadily between 2015 and 2021 - from 5.7% to 5.1% (E&DFC, 2016). Focusing specifically within the Central Puget Sound, the PSRC forecasts a strong regional employment growth - rising from 2.06M in 2014 to 2.98M jobs by 2040 (PSRC). Tracking job growth over the last 6 years, the region has reflected a strong and steady job growth at 2.97% from 2013 to 2016 (PSRC, 2016). The region's growth is expected to slow down over the next couple of years as it heads out of the recession (Seattle Times, 2016).

The services industry continues to lead the job market: Industry estimates for the region show that professional services, educational and health care services, retail and manufacturing dominate the job market (Census 2010 & 2014). Between 2010 and 2014 the Puget Sound experienced minor increases in production, transportation and material moving



The Seattle Tech Universe Map is an update of a 2007 map aimed at depicting the genealogy of local tech companies as a solar system. Major tech companies like Microsoft, McCaw Cellular, and Boeing represented constellation surrounded by orbits of tech companies as planets that their former employees helped found. The map is widely used to depict the richness of Seattle's tech industry (WTIA, 2015).

jobs as well as the service industry (Ibid). The Puget Sound saw a decrease in natural resource, construction and maintenance occupations as well as sales and office occupations (Ibid). Construction and Professional services continue to growth, but will become less significant as the Puget Sound moves further out of the recession (Conway, 2016). Tech is a major component of the Puget Sound's employment. Boeing and Amazon directly and indirectly account for more than 40% of the jobs created in the Puget Sound region in the last five years (City of Seattle, 2016). However, this level of growth isn't expected to continue long term, with declines projected for both 2017 and 2018.

Trade is still strong and supports many jobs; ships are getting larger and the size of different ports are changing in the region: Washington's export shipments of merchandise in 2015 totaled $86.4 billion (ITA, 2016). The US currently has free trade agreements in force with 20 countries which accounted for 27% of WA's export in 2015 (Ibid). A stronger dollar is contributing to a decline in state exports (McTeer, 2015). Exports are theorized to function as a multiplier – i.e. an increase of exports not only leads to more export industry jobs, but also jobs in producing goods and services for the local economy (Conway, 2015 describing the theories of North and Tiebout). Employment multipliers, i.e. the number of jobs supported by each export job, have been increasing due to rapid gains in labor productivity and real wage rates, such that each Boeing worker today supports more jobs in the Puget Sound than s/he did 10 years ago (Conway, 2015).

Washington has 14 major ports, 8 of which (Anacortes, Bellingham, Everett, Friday Harbor, Olympia, Port Angeles, Seattle and Tacoma) are within the Puget Sound. Between 2008 and 2014 the Port at Olympia grew from conducting $1M in trade to $164M (OFM, 2015). Seattle, on the hand, while still the second largest port in the state, decreased its trade during that same period; nearly halving its trade from $40B to $21B (OFM, 2015). A major trend ports are seeing is larger vessels- "mega-ships". In 2016 the 18,000 TEU Benjamin Frankin sailed into the Puget Sound, the largest ship to ever reach the US - equal to 5 Boeing 747's placed end to end (NSA, 2016).

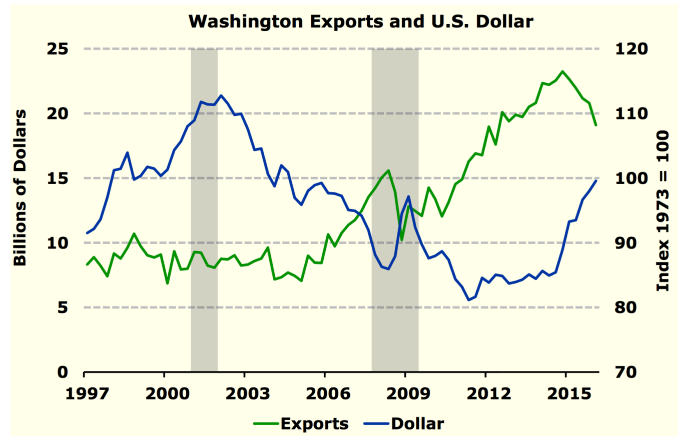


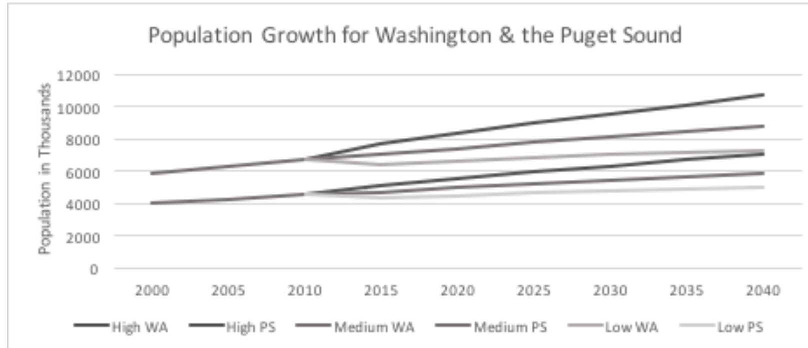
Figure 1 The Relationship between Exports and U.S. Dollar. OFM, 2015

Transportation equipment, primarily aircraft and parts, account for over 59% of Washington exports (OFM, 2015). The Washington Economic Climate Council notes that trade does not include service exports, which are difficult to track and credit. Microsoft contributes greatly to state personal income while the majority of its exports are not included in the trade data, understating the contribution of trade to the Washington economy (EFRC, 2014). While a smaller financial contributor to exports, WA remains a major exporter of food and agriculture in the US and abroad - ranked #3 nationally (OFM, 2015).

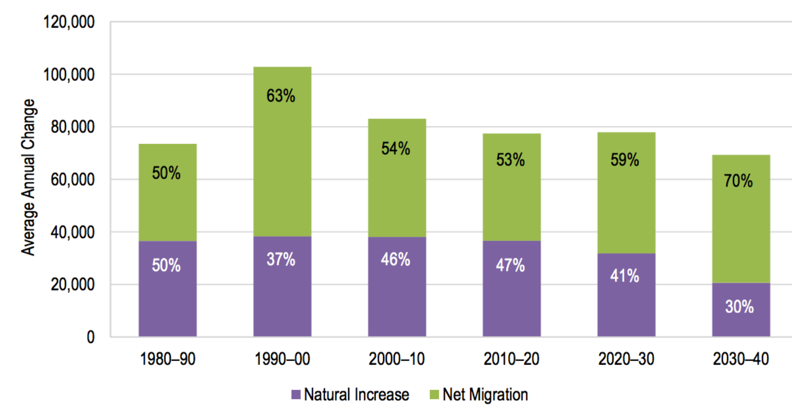
Demographic trends provide critical insight to planners and managers as they invest in services and prepare for future change. The Puget Sound represents the most heavily populated area in Washington State and is forecasted to keep growing more rapidly than the state as a whole. Growth is dominated by in-migration in response to economic opportunities. In comparison to natural increase (birth minus death rates), migration trends are harder to predict as they are heavily correlated with economic growth. Overall, state demographers forecast an aging population despite an inflow of young workers, a more diverse population with continued disparities in income and access to services, and shifting household trends that correspond with "a boomerang population" where young adults are more likely to live with their parents than alone or with a partner.

A growing population: The Puget Sound coastal shoreline counties account for 68% of the Washington State population – 4,779,172 out of 7,061,530 (Rice et al, 2015). Nearly half of these residents live in King County, the most populated county in the basin and state. The population density (people per square mile) varies considerably across Puget Sound counties, from 16.6 in Jefferson County to 913 in King County (American Community Survey 2015). Between 2010 and 2014 population in the Puget Sound was estimated to have grown by 5.8% - as compared to 5% for the state as a whole and 7.7% within King County. The increase in the population growth rate for the State is mainly due to migration as opposed to natural increase (OFM, 2016).

By 2030 the Puget Sound population is estimated to exceed 5.7 million – an 18.2% increase from 2014 estimates as compared to a 12.7% national growth rate during the same time frame (Rice et al, 2015). This rapid and extensive growth has pervasive implications on the basin – from its relationship to job growth to pressures on service provision and ecosystem functions.

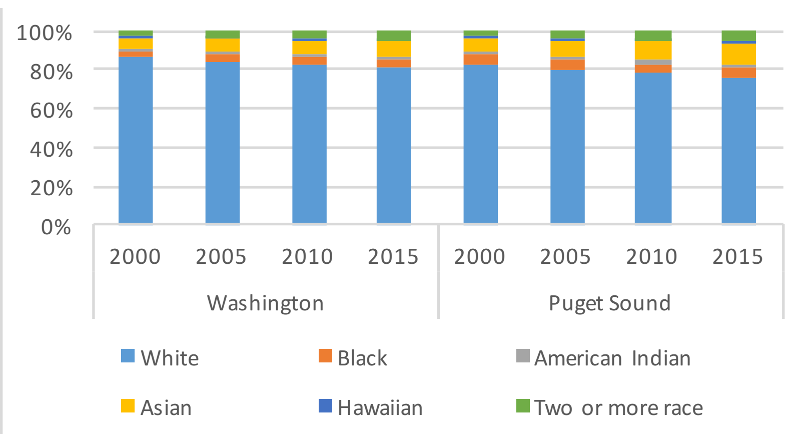


Historic and projected population growth for Washington (top lines) and the Puget Sound (2000-2040). OFM, 2016b.



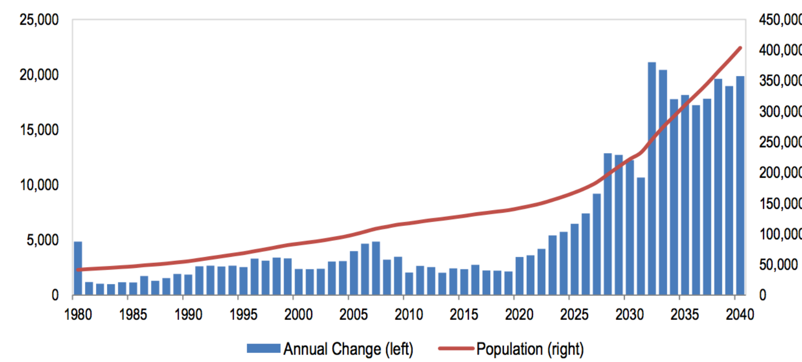
Components of population change by decade, 1980–2040. OFM, 2016b.

A more diverse population: While the Puget Sound region is predominately white (73%), the region is increasing in diversity. Nationally, it is projected that by 2050, the Hispanic share could be as high as 29%, up from 17%; the black share is projected to rise slightly to 13%, while the Asian share is projected to increase to 9% from its current 5%. Non-Hispanic whites, 63% of the current population, will decrease to half or slightly less than half of the population by 2050 (Taylor and Cohn, 2012). Seattle has higher shares of non-white population than the Puget Sound region as a whole. However, the region's trends demonstrate a faster pace of growth for non-whites than in Seattle. Persons of Hispanic/Latino ethnicity in the Puget Sound region are growing the most rapidly of any race/ethnic group within the region (322% over the last 20 years)(P&CD, 2016)



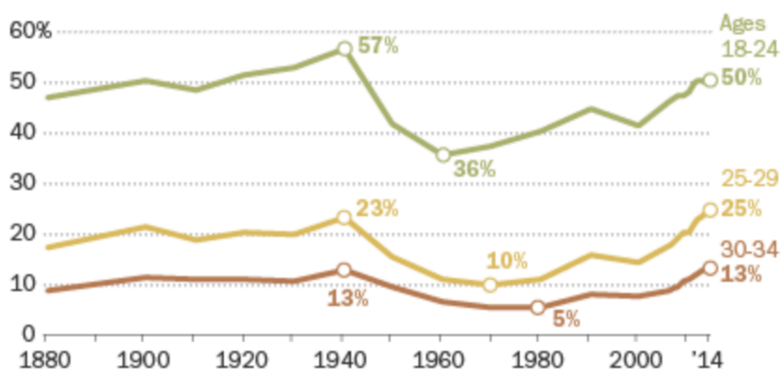
Changes in Race and Ethnicity in Washington and the Puget Sound, 2000-2015. OFM, 2015a.

An aging population with young in-migration: The Puget Sound is expected to see a "greying" population. By 2050 more than 25% of King County residents will be over 60 years old (up from ~18% in 2015), with the "oldest old" (those 80 years old and older) as the fastest growing age group (**ADS, 2016)** This trend is consistent nationally and at a state level (Census, 2010; OFM 2015). However, in urban areas the largest percentage of in-migration is for young adults, substantially skewing the age pyramid (City of Seattle, 2016). The PEW Research Center has predicted that if current national immigration trends and birth rates continue, by 2050 virtually all (93%) of the nation's working age population growth will come from immigrants and their U.S.-born children (2013).



Population characteristics ages 85 and older: OFM, 2016b

A Boomerang Population: As of 2010, Washington State was estimated to have 2.6 million households (HH), the Puget Sound basin accounted for 68% percent of those households (1.8 million HH), and the Central Puget Sound accounted for around 80% of the households in the Puget Sound (1.5 million HH). On average there is a little more than twice as many housing units as there are households (5.8 million in WA, and 5M in PS in 2010). By 2016 the Central Puget Sound added another 156,556 households (for a total of 1.6 million HHs), and the Puget Sound added another 334,747 housing units. By 2040 the Central Puget Sound is expected to add another half a million households. OFM forecasts that the number of people per housing units will continue its slow and steady decline in the region. However, according to the Pew Research Center, household trends may be beginning to reverse, in part due to multi-generational arrangements. For example, Census data reveals that in 2014, for the first time in more than 130 years, 18- to 34-year-olds in the U.S. were more likely to be living in their parents' home than with a spouse or partner in their own household (DeSiliver, 2016). Another important change is that 2010 was the first year in which same-sex marriages were counted as households by the U.S. Census (Kreider et al, 2016).



Record share of 25- to 34-year-olds living in parents' home. Desilver, 2016.

Higher educational attainment, but disparities in race and income still a major issue: In Washington State as a whole, 90.4% of residents age 25 and above were high school graduates and above in 2014. Between 2000 and 2014, WA experienced a 49.3% increase in its population with a bachelor's or higher (OFM, 2016a). Washington ranks low in four-year enrollment (43rd in the country), but high for 2-year enrollment. However, the state is ranked 10th in the percentage of its adult population with a bachelor's degree or higher. The migration to Washington of educated persons of working age to take advantage of economic opportunities in the state contributes to this high ranking (OFM, 2016a).

From 1995 to 2015, the percentage of 25- to 29-year-olds who had attained a bachelor's or higher degree increased for those who were White (from 29 to 43 percent), Black (from 15 to 21 percent), Hispanic (from 9 to 16 percent), and Asian/Pacific Islander (from 43 to 63%) (ACS, 2015).

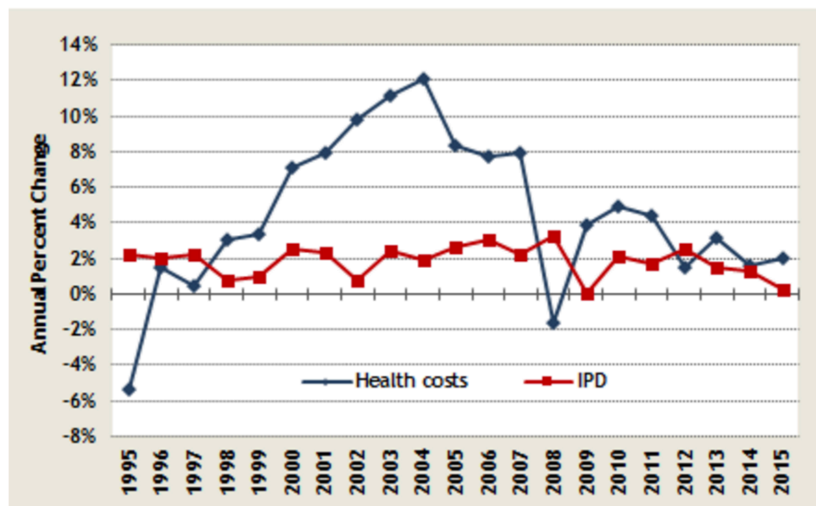
Though educational attainment is universally rising, levels vary considerably across racial and ethnic lines. Looking at 1997 data on young adults, Asian Americans have the highest high-school graduation rates at over 90 percent. For the first time in 1997, the high-school graduation rates for young blacks and whites were statistically on par at 86 and 88 percent respectively. High-school completion rates that year, however, were far lower--62 percent--for young Hispanics. Particularly troubling is that over the decade, there has been no significant change in the rate of high-school completion for young Hispanics (DOL, 2016).

Public health trends in the Puget Sound characterize changes in the ailments and environmental pathogens that pose a risk for the population at large, changes in the health status of residents, and changes in health care services and insurance coverage. Overall, Washington ranks 14 among the 50 states for total population health in the United Health Care Foundation's report, *America's Health Rankings 2013*. Despite efforts, social and economic conditions continue to be major determinants of health such that "being poor is bad for your health" (WA DOH). While mortality associated with cancer and heart disease has decreased, the state is still seeing declines associated with mental health, drug abuse, and tobacco use (Kaiser Family Foundation, 2014). While the intentional release of environmental toxins and disease vectors is increasingly regulated by state and federal government, unintentional and surprising shifts in vectors are posing new and substantial risks to the population.

Health spending is growing at an unsustainable rate: In Washington State, the governmental public health system is a decentralized model characterized by local (county) control and state-local partnerships. It consists of 35 local public health agencies or local health jurisdictions (LHJs) that work with the State Department of Health (DOH). In addition, most of Washington's 29 tribes provide public health and healthcare services to their members (DOH, 2015). Considered an 'era of health reform', Washington is investing in expanding health coverage throughout the state, increasing health systems integration, and improving health care data collection (Kaiser Family Foundation, 2014).

State spending on health services has been increasing rapidly. In 2007, the state spent an estimated $4.5 billion on health care, up from $2.7 billion in 2000. In response, Governor Inslee's Blue Ribbon Commission has proposed the goal that the rate of increase in total health care spending will be no more than the growth in personal income (OFM, 2007). Health care, including employee health insurance and medical assistance, is now over 20% of the State's general fund budget (OFM, 2015).

Between 2013 and 2014 the state's uninsured rate underwent the largest single-year decline in recent history - dropping nearly 5 percentage points from 14.0 percent in 2013 to 9.2 percent in 2014 (Yen, 2015). This dramatic change was largely due to implementation of key provisions of the Patient Protection and Affordable Care Act (ACA)(American



Spending on Health Services as Compared to Inflation in Washington State. OFM, 2015.

Community Survey 2014). The reductions in some counties were really astonishing. For example, Kitsap saw a 53.6% reduction in uninsured residents between 2013 and 2014 (Yen, 2015). The uninsured rates for the Hispanic and American Indian and Alaska Native population (AIAN) remained higher on average, with no county falling below a 10% uninsured rate. However, these groups also had the largest percentage-point declines in their uninsured rates (Yen, 2015).

Immunizations continue to be a challenge: Complete and timely immunizations support the reduction of preventable outbreaks from occurring in the Puget Sound. The state has experienced recent outbreaks of both pertussis and measles demonstrating the importance of immunization (DOH, 2015c). Overall coverage has increased since 2012. As of 2015, 55% of Washington children aged 19-36 months were vaccinated, 43% of children 4-6 years old, and 30% of children 11-12 years old. While improving, state levels still don't meet the national standard of 80% (Ibid).

Social and economic differences highlight disparities in health outcomes: Social and economic conditions continue to be major determinants of health. Income, wealth, education, employment, neighborhood conditions and social policies interact in complex ways to affect our biology, health- related behaviors, environmental exposures, and availability and use of medical services (DOH, 2015a). Health impacts associated with lower socioeconomic position (SEP) can begin before birth and build up throughout life. More simply stated, "being poor is bad for health". Despite national efforts to eliminate health disparities—including those related to low SEP—by 2010, neither Washington nor the nation have achieved this goal. In fact, disparities grew for many measures of SEP and health (Ibid).

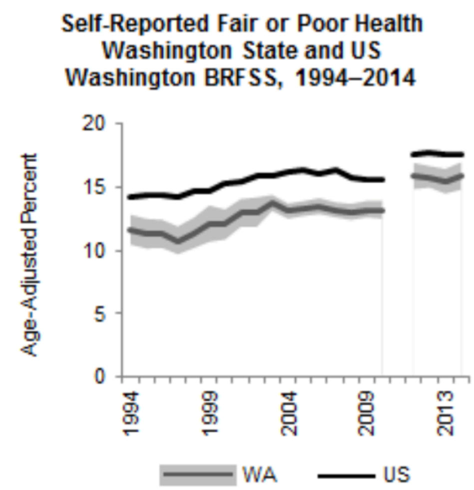
Evidence-based approaches for reducing the impact of low SEP on health include home visits, comprehensive center- based programs, full-day kindergarten, and tenant-based rental assistance programs for low-income families. In addition to these well-evaluated approaches, the Centers for Disease Control and Prevention supports initiatives to improve health among people of lower SEP by designing communities that encourage mixed land use; provide good public transportation and pedestrian and bicycle infrastructure; contain affordable housing, green space, parks and community centers; and support access to fresh fruits and vegetables (DOH, 2015a).

Behavioral Health Trends in Washington show increases in obesity, diabetes, and lack of physical activity, especially within poverty populations: As of 2014, around 16% of Washington's population self-reports fair or poor health. While these numbers are better than national levels (18%) they are higher than they were in 1994 (12%)(CDC, 2015)

A nutritious diet can reduce major risk factors for chronic disease such as obesity, high blood pressure, and high blood cholesterol. Poor nutrition has the potential to affect the growth, development, and health status of all people. Pregnant women, infants, children, and older people are especially vulnerable (DOH, 2015a). Like a nutritious diet, physical activity improves health for people of all ages. For adults, regular physical activity lowers risk of early death, coronary heart disease and stroke, high blood pressure, diabetes, and colon and breast cancers. Physical activity also prevents weight gain, helps with weight loss, reduces depression and improves cognitive functioning in older adults (DOH, 2015a)

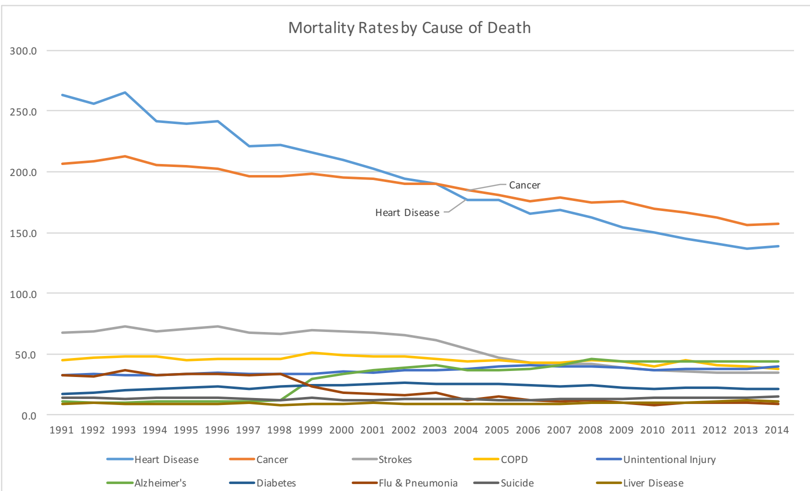
As of 2012, 69% of Washingtonians meet guidelines for moderate or vigorous physical activity. In general, counties in the Puget Sound basin were more likely to have higher percentage of residents achieving at least 60 minutes of physical activity per day, with Mason being the major exception. In 2005, about a quarter of Washington State adults reported eating fruits and vegetables five or more times each day. The Behavioral Risk Factor Surveillance System (BRFSS) found the percent of adults in Washington who ate fruits and vegetables five or more times daily remained constant from 1994 to 2005. Similarly, there was no change in the share of adults eating fruits and vegetables five or more times a day in the United States (24% in 2005).

As of 2014 about 27% of Washington adults self-reported heights and weights indicating obesity (CDC, 2015). While Washington has met the Healthy People 2020 goal of having less than 30% of the population as obese, rates have been increasing rapidly since the 1990s. In comparing the rates of obesity across Washington's counties, there doesn't seem to be a pattern between rates within or outside the Puget Sound basin. Overall, residents who are black, with Hispanic origin, or identify as American Indian and Alaska Native have higher rates of obesity than whites and Asians. Obesity is an especially significant issue with American Indian and Alaska Native as well as Native Hawaiian and Pacific Islander children ages 2-4 – with rates exceeding 30% (DOH, 2015a). Similar to obesity, rates of adults self-reported as having been diagnosed with diabetes are more prevalent in high risk subgroups including non-Hispanic blacks, Hispanics, American Indian and Alaska Natives, and Native Hawaiian and other Pacific Islanders. Prevalence is also associated with lower educational attainment levels (i.e. high school education or less (DOH, 2015a). Washington has seen an upward trend in diabetes since 1993, but rates are slowing down.



Reported Fair or Poor Health in Washington State. CDC, 2015.

Incidence of mortality is down, but tobacco, and drug-induced deaths are still a major concern: Washington's age-adjusted death rates have been falling for the past 35 years – an overall decrease of 29% (DOH, 2014). The leading causes of death in WA are cancer and heart disease. For both causes, mortality rates have been decreasing since 1991 (Ibid). For all cancers combined, age-adjusted mortality rates increased from 1980 to 1993, but since 1993, the trend has been downward. Improvements in cancer treatments, early detection, and the decline in tobacco use have likely contributed to the overall decline (DOH, 2015a). Other causes including stroke, flu and pneumonia also decreased, though at much slower paces (DO, 2014). Mortality from Alzheimer's and unintentional injury has slightly increased while liver disease and suicide deaths remained about the same (DOH 2014). Causes of death vary by age group. Accidents are among the leading causes of death for ages 1-64. Malignant neoplasms, or cancers, are especially prominent in people over 45 and suicide is prominent for ages 15-44 (OFM 2015a).



Mortality rates by cause of death, WA, 1991-2014. DOH, 2015.

Tobacco remains the leading cause of preventable disease and death in Washington, and is a significant contributor to healthcare costs. Each year, more people in Washington die from tobacco-related illnesses than from alcohol, drug use, car crashes, suicide, homicide, AIDS, and fires combined (DOH, 2010). In 2015 alone, approximately 7,930 people died as a result of tobacco use or exposure (DOH 2010).

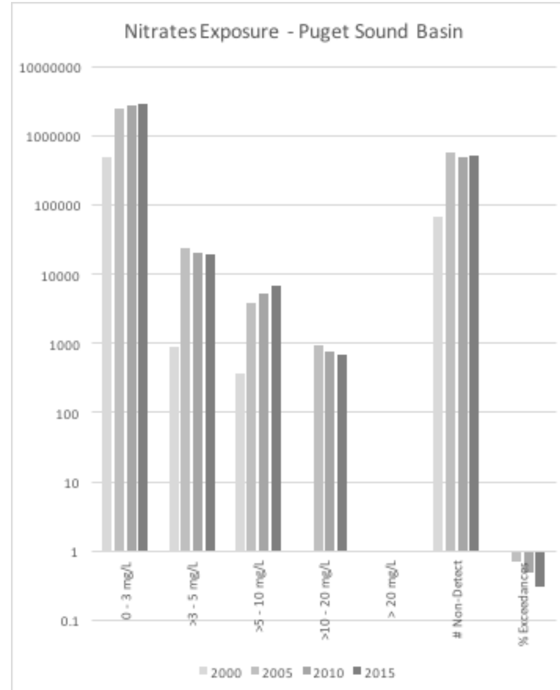
Between 2000 and 2005 the age-adjusted rate of drug-induced deaths in Washington increased by about 42%, primarily due to overdoses of prescription opioids such as methadone and oxycodone used to treat chronic pain (DOH, 2015). Between 2005 and 2011 the rate stayed relatively stable. Research indicates that school-based prevention programs, which mostly serve middle school students, generally reduce drug use. Drug-induced deaths in Washington were about 15 per 100,000 in 2011, increased from 2000–2005 and have not changed since 2005. In Washington for 2009–2011 combined, the rates of drug-induced deaths were highest among American Indian and Alaska Native residents (Ibid).

Pollutants in air, water, and on land are better monitored; arsenic, nirates, and non-agricultural pesticides are among the most substantial issues: Biomonitoring provides useful information on how much people are exposed to chemicals from the environment. Measures of breakdown products (metabolites) in human blood, urine, hair or other body tissues can tell us the amount of the chemical that gets into people from all sources combined, such as from air, soil, water, dust, and food (DOH, 2016). The WA DOH Public Health Laboratories recently conducted a biomonitoring survey, comparing state levels with national levels as reported on by the CDC (DOH, 2016). They found that urine levels of total arsenic were higher in Washington (median 11.9 µg/g creatinine) compared to U.S. levels reported by CDC (7.9 µg/g creatinine). More than 10% of participants had arsenic levels above CDC's reporting level

(50ug/L). Seafood may be the root of this arsenic, as people with higher level had reported eating shellfish, fish, kelp, or sushi in the previous three days. Median urine levels were higher for pyrethroids and lower for chlorpyrifos compared to the most recent U.S. levels from 2001 through 2002. This may be explained by the fact that chlorpyrifos was banned for home use in 2001 while home use of pyrethroids increased in usage. Median urine levels were also higher for cadmium and cobalt, and lower for cesium, lead and thallium compared to the entire U.S. (DOH, 2016).

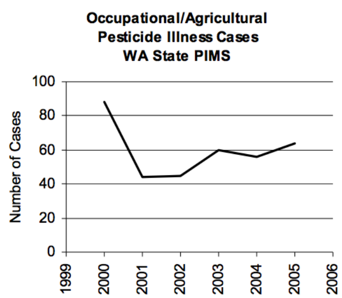
In addition to biomonitoring, Washington's DOH has long collected samples of public water systems to evaluate drinking water for public health protection. In 2014 DOH collected over 151,000 samples, 64% of which were in the Puget Sound basin. Based on those samples the state issues 97 health advisories, 56% of which were in the Puget Sound (DOH, 2013). The greatest number of advisories came from the Seattle-King County (10) and Island County (8) Systems. Overall, 60,811 residents were affected directly by these advisories as compared to 98,000 in the state (DOH, 2013). Systems most affected by these advisories included Seattle-King, Snohomish, Tacoma-Pierce, and Whatcom, reflecting higher density counties (Ibid).

Common contaminants in drinking water supplies include: nitrates, synthetic organic compounds (SOCs), volatile organic compounds (VOCs), trichloroethylene (TCE), and Haloacetic acids (HAA5). In Washington, less than 0.5% of public water systems reported nitrate levels above the federal limits of 10mg/L; SOCs, VOCs, and TCEs rarely occur in any drinking water supplies; and about 0.8% of systems tested above the maximum contaminate level of 60µg/L for HAA5 (DOH 2016b). The Washington Tracking Network maintains a database of drinking water test results by county back to 1999. In the Puget Sound, tests for nitrate exposure show a marked increase in low levels (0-3 and 5-10 mg/L) results but an overall decrease in exceedance rates (above 10mg/L) between 2005 and 2015 (WTN, 2016b).



Nitate Exposure in Drinking Water in the Puget Sound. WTN, 2016b.

The character of pesticide-related human illnesses is changing, with a decrease in agricultural cases and an increase in non-agricultural workers. In a 2000-2005 DOH investigation of pesticide incidence, out of a total of 1,762 cases, 187 cases were attributed to pesticide exposure (2007). Out of that population, most people exposed (61%) were men. Thirty-two percent of the cases occurred among agricultural workers. Within the non-agricultural sector, the greatest illness occurred in the most populous counties – including King and Pierce. The non-agricultural cases are increasing – from 2001 to 2005 cases increased fourfold (DOH, 2007).



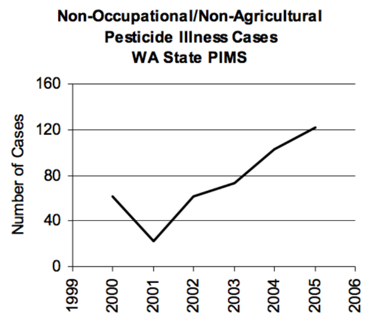
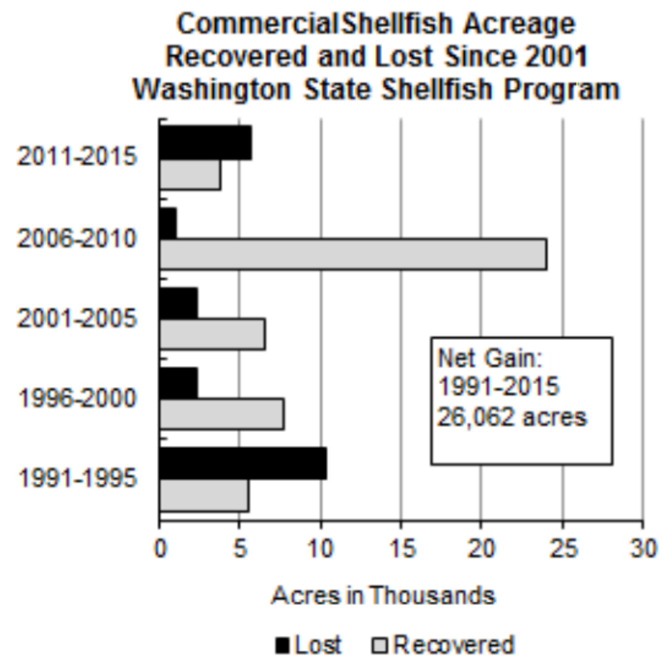


Figure Pesticide related illnesses in Washington State. DOH, 2007.

The Sound is monitored for several marine biotoxins and illnesses that stem from point and non-point source pollution and are harmful to people. The most common include: Vibrio parahaemolyticus (Vp) where the range of incidence for the past 20 years is 18-80 and traditionally increases in unusually hot and dry summers; Paralytic shellfish poison (PSP) with the highest recorded level was at 20,751mg (2002, DOH closes beaches if >80mg are found / 100g tissue); Amnesic Shellfish poison (ASP) with the highest recorded level at 295ppm (1998, DOH closes beaches if >20ppm are found in shellfish tissue; Diarrhetic shellfish poison (DSP) with the highest record at 184mg (2012, DOH closes beaches when >16mg / 100g of tissue)(DOH, 2015a). Urban areas typically have many more sources of pollution, so most approved commercial harvest areas and recreational shellfish beaches are located away from urban areas (DOH, 2015a)

In 2015, about 250,000 acres were classified as Approved or Conditionally Approved for commercial shellfish harvesting in the state while about 55,000 were classified as prohibited. (DOH, 2015a). Prohibited areas can be attributed to wastewater treatment plan, nonpoint pollution sources such as failing septic systems, and farm animal waste, marinas and other sources (wildlife waste and unknown sources). Between 2001 and 2015 about 21,700 acres have been downgraded to harvest restrictions while 47,900 acres were upgraded because



Commercial Shellfish Areas Lost and Recovered from the State. 1991-2015. DOH, 2015a.

environmental conditions improved. Most of the upgrades occurred between 2006-2010 (DOH, 2015a).

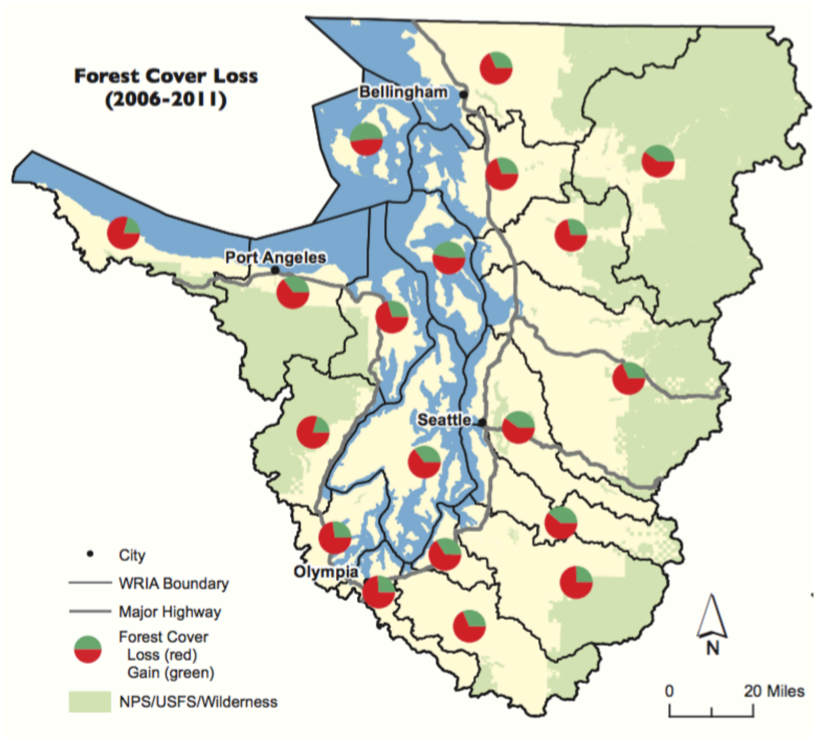
Communicable diseases are surprising scientisits:
Communicable diseases include infections that can be transmitted person to person, by direct contact with individual's discharges, or by indirect means (i.e. a vector). The most common cases reported to the state continue to be sexually transmitted conditions (DOH 2014). In general, occurrence of communicable diseases have been decreasing with improved health services. However, some environmental vectors have been spreading further than historically, rapidly increasing incidence reports. These changes have been attributed to both globalization and climate change trends (McMichael, 2013). The rapid and unprecedented spread of Zika has recently underscored the magnitude of risk associated with these outbreaks (Mercer, 2015). An additional side effect of these outbreaks is that control measures may have substantial unintended impacts on biodiversity and environmental quality. For example, recent spraying of Naled, an insecticide targeting Zika-carrying mosquitoes, Zika has resulted in the killing of millions of honeybees in Florida and South Carolina (LaMotte, 2016).

Development refers to physical and spatial alterations of the natural landscape for the purpose of human use. As human civilizations settled in the Pacific Northwest, they have altered the landscape – cutting down trees, grading hills, building roads, rerouting waterways, and constructing structures. While all species alter their landscapes, modern man has notably done so rapidly and extensively, thereby fundamentally changing the character of the Sound.

Native American tribes have lived in the region for thousands of years, however it is only around the last century – consequent to the railroad (1880s), Statehood (1889), gold rush (1897), and Boeing's role in WWII (1941) that development became a dominant force in the region. It is estimated that since Statehood, Washington has lost 90% of its old growth forest, and only 84% of the Sound remains as natural land cover today (Simenstad et al., 2011). Economic development in the Puget Sound over the past three decades, especially in metropolitan Seattle, influenced the pattern of urban expansion, particularly urban infill (Hepinstall-Cymerman et al., 2013).

Development patterns are created by micro-scale interactions between human and ecological processes which direct the functioning of ecosystems (Alberti, 2008; Pickett et al. 2008; Aberti, 1999). Once natural and agricultural lands are developed their ecosystem structure and function can become permanently impaired (Grimm et al. 2008). Development alters hydrological networks, as impervious surfaces hasten and pollute runoff, topographic changes reroute water pathways, and loss of tree cover reduces infiltration and evapotranspiration (Booth and Jackson 1997). Development has also been shown to contribute to air pollution (Novak et al, 2006), changes in micro-climate (Oke, 1967), and losses in biodiversity (Hepinstall et al 2008).

The Puget Sound continues to develop, with urban expansion and the loss of forestlands: Land cover conversion through human development is a leading cause of ecosystem decline (Georgiadis, 2015; PSP, 2014). Between 1988 and 2004 Washington saw a 25% reduction in forest lands (PSP, 2015). Within Washington, the Puget Sound is at the greatest risk of conversion. Between 2006 and 2011, 153 square miles of forest cover were lost in the Puget Sound due to timber harvesting and land conversions. While non-federal forestland was lost to development at a rate of 2,176 acres per year for the 2001-2006 period. Between 2006 and 2011 forest loss decreased to 1,196 acres per year (PSP, 2015). However, these numbers underestimate the rate of conversion in urbanizing areas and among conversion of small forested parcels which are too small to be captured by 30m NOAA satellite data used (PSP, 2015).



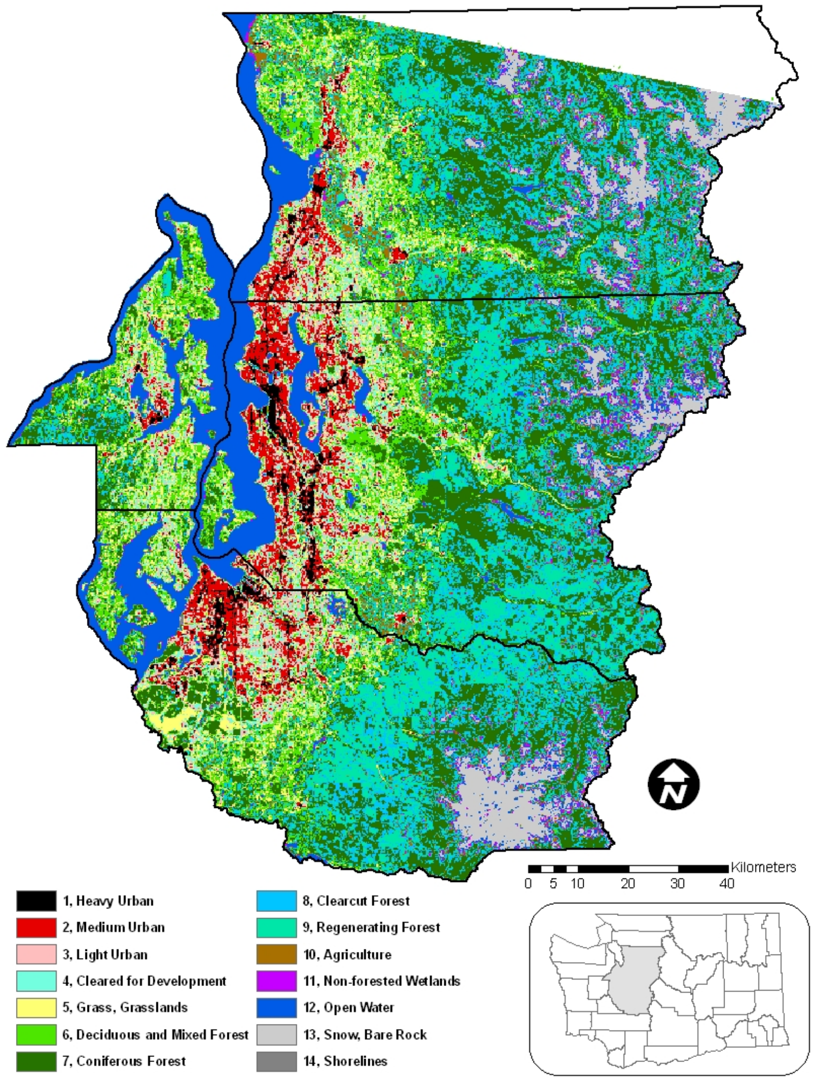
Forest Cover Loss, 2006-2011. NWIFC, 2016.

In the Central Puget Sound, each year between 1991 to 1999, urban growth produced an average increase of 0.84% in heavy urban[1] areas, and a .098% increase in mixed urban, while forests declined by 1.03% per year (Alberti, 2014).

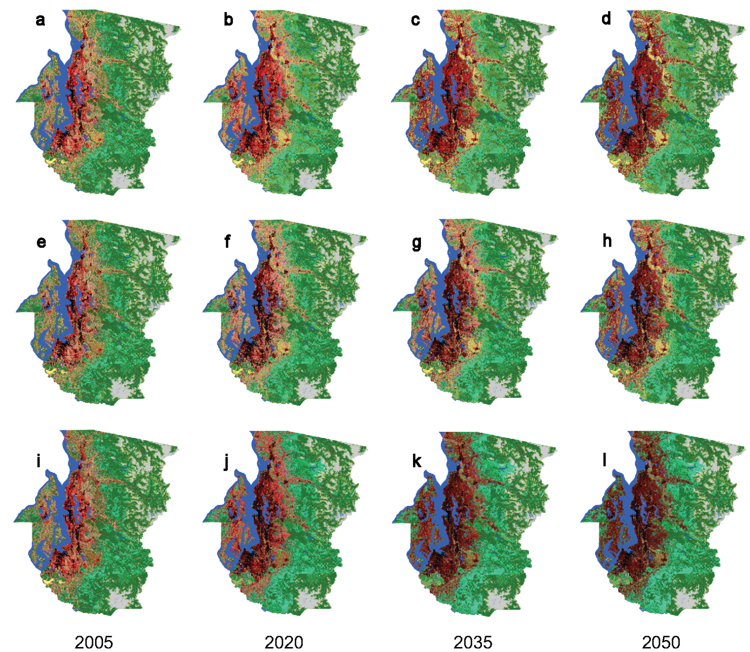
A more recent study looking at 6 counties in Puget Sound showed an 8-19% increase in urban areas between 1986 and 2007 while lowland deciduous and mixed forest cover decreased from 21 to 13%, and grass and agricultural covers decreased from 11-8% (Hepinstall-Cymerman et al, 2013).

Conversion trends are expected to continue unless further protections are put in place (NWIFC, 2016). Various land cover change models have been used to forecast future changes in land cover in the sound. A UW study estimates that nearly 1 million more acres of private forestland are currently threatened (NWIFC, 2016). The Land Cover Change Model (LCCM), which is linked to a development forecasts model, produces mosaicked patterns of urban and vegetated land covers resulting from local decisions (i.e. socioeconomic processes), development potential, and environmental and administrative/policy constraints (Marsik et al, forthcoming). According to recent model runs, an additional 7% of the Puget Sound will be converted to urban land cover by 2050 resulting in a total of around 25% urban land cover (Ibid). Between 2002-2050 mixed forests decreased in extent from 44.7% to 34.9%, and agriculture, already a minor extent, nearly disappears by 2050. By mid-century urban growth rates decreased from 0.4% growth per year in 2005 to under 0.05% per year in 2050 (Ibid).

[1] In Alberti 2014's paper, urban is defined as any 3m grid cell where more than 75% of the area is impervious. Mixed urban areas have between 15 to 75% impervious, and Low urban areas have less than a 15% impervious cover.



Land Cover in the Central Puget Sound 2007. Marsik et al, forthcoming.



Land cover simulations from LCCM every 15 years under scenarios 1991-1995 (a-d), 1995-1999 (e-h), and 1999-2002 (i-l). Marsik et al, 2016

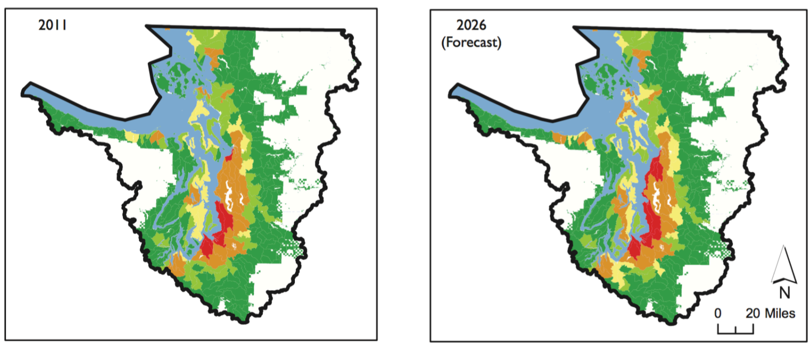
Low density growth continues outside of designated urban growth boundaries, but more slowly: In 1990, in response to rapid population growth and concerns about suburban sprawl, environmental protection, quality of life, and related issues, Washington State adopted a unique approach to manage growth (MSRC, 2016b). The Growth Management Act, or GMA, aimed to control unchecked development, provide efficient and fair access to resources for everyone, and to protect what is left of the region's natural landscape (Ibid). The Act functions by identifying and protecting critical areas and natural resource lands, designating urban growth areas, preparing comprehensive plans and implementing them through capital investments and development regulations (Ibid). In addition to policies that regulate development, economic growth and technological innovations are, and will continue to be, major drivers of the extent and type of development in the Sound. Analysts are beginning to model how changes in climate and hazards may further shape future development in the region.

There are mixed signals on whether development is effectively being funneled into UGAs. Hepinstall-Cymerman et al's analysis of growth in Central Puget sound from 1986-2007 showed that land in urban classes outside of the urban growth boundaries increased more rapidly (by both area and percentage of new urban land cover) than land within the urban growth boundaries (2013). According to this 2013 paper, the intended effect of the Growth Management Act to direct growth to within the urban growth boundaries may not have been accomplished by 2007 (2013). Between 1986 and 2002, consistent with observed trends inside the urban growth area, low and medium urban covers have been converted into high urban where while outside of the UGA grass, coniferous forest and agriculture got converted to low urban cover (Hepinstall-Cymerman et al, 2013). Historically, conversion into mixed and high urban covers occurred close to transportation corridors and urban centers. Similarly, Powell et al. (2008) observed a three-fold increase in low impervious urban cover outside of the UGA in the Snohomish WRIA basin due to urban sprawl from 1972-2006.

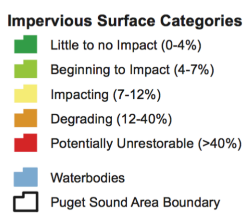
However, the PSP's vital signs report suggests that based on Washington State Department of Commerce permits for new development, growth is increasingly occurring within urban growth areas. For five central Puget Sound counties, the proportion of permits for new development within urban growth areas increased at an average. According to the Puget Sound Regional Council, 87% of regional population growth from 1995-2000 occurred within UGAs, preserving the rural landscape (PSRC, 2006). Looking out to the future, Marsik et al link a forecasted slowdown in development and loss of forestland with a growing effectiveness of the Growth Management Act (Marsik et al, forthcoming).

The basin continues to harden, negatively affecting water quality and aquatic habitat: Impervious surfaces include hard and non-pervious areas such as roads, roofs and parking lots covered by asphalt, concrete, brick, stone and rooftops. Compacted soils are also considered impervious. The increase in the proportion of area that is under impervious surface is the primary agent responsible for the hydrologic changes associated with the urbanization process (Schuster et al, 2007). Consequently, since the early 1970's impervious surfaces have been monitored as an important indicator of water quality (Putnam et al 1972). The total area covered by impervious surface (TIA) in a watershed has been shown to be positively correlated with stream temperatures, sediment transport, and pollutants in stormwater runoff (NWIFC, 2016). As TIA increases, instream biodiversity is expected to decrease (Karr and Chu, 1997). In addition to simple aggregate measures, the pattern of development (e.g. connectivity, configuration, composition and intensity) can have a marked effect on ecological conditions in urbanizing landscapes (Alberti et al 2007).

As of 2011, 7% of the Puget Sound was estimated to be covered by impervious surfaces. This number reflects an increase of 2.6% since 2006 (NWIFC, 2016). In 2011, every urban stream watershed identified in the Snohomish River Salmon Conservation plan was degraded based on impervious surface levels greater than 12%. Additionally, between 2006 and 2011, increases in impervious surface continued to spread from urban stream watersheds into the main-stem and rural stream watersheds to the east.



Forecasted in Impervious Surfaces covering the Puget Sound, 2011 and 2026.

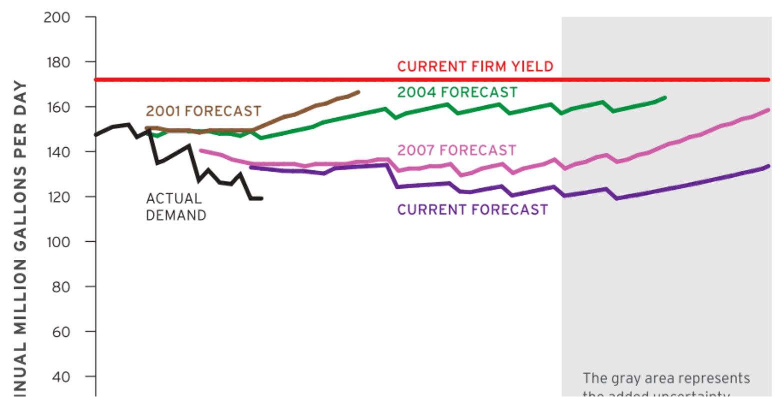


Real estate prices are growing rapidly, with no end in sight: *O*ver the last 3 years, hosing growth has strengthened in Washington. Between 2014 and 2015, housing growth strengthened by 7% adding another 32,300 housing units (OFM, 2015). While growing, these numbers are still lower than state averages from a decade ago that averaged 43,500 new units per year (Ibid). The majority of new units in 2015 are multiple family (53%) (OFM, 2015). The real estate market is strong in Washington, and especially in the Puget Sound. Housing prices continue to growth. Between 2015 and 2016 Washington saw a 9.3% increase in home values (Rosenberg, 2016). Forecasts show a 4.3% increase going out to 2017 (Housing Predictor, 2016). King County housing prices are especially high, rising 19.8% from 2015, while the number of available homes is down nearly 30% (Bhatt, 2016). As prices escalate, the demand for affordable housing grows. There is also an increasing demand for condominiums over single family homes. These trends push out demand into neighboring counties. Kitsap County, for example, has increased sales by 9% (Ibid).

Housing forecasts generally don't look more than a year or two into the future. Real estate market cycles rise and fall, largely depending on economic growth factors. While some analysts indicate that the market in the Sound is beginning to "slow down", meaning housing stocks will rise and prices will slowly drop, others indicate this shift may not happen for a few more years.

Infrastructure includes the basic physical and organizational structures and facilities (e.g., buildings, roads, and power supplies) needed for the operation of a society. Here we focus on 5 types of infrastructure – drinking water, transportation, energy, communication, waste and wastewater. Overall, technological innovations are rapidly altering the structure, efficiency, and way we use infrastructure. These changes in turn have pervasive implications on our daily lives and environmental impacts. As we look out to the future, we expect infrastructure to become more decentralized and embedded into small and mobile devices; we expect continued trends towards sustainable, or low impact solutions; and we expect changes in the climate to create novel and significant pressures on infrastructure systems.

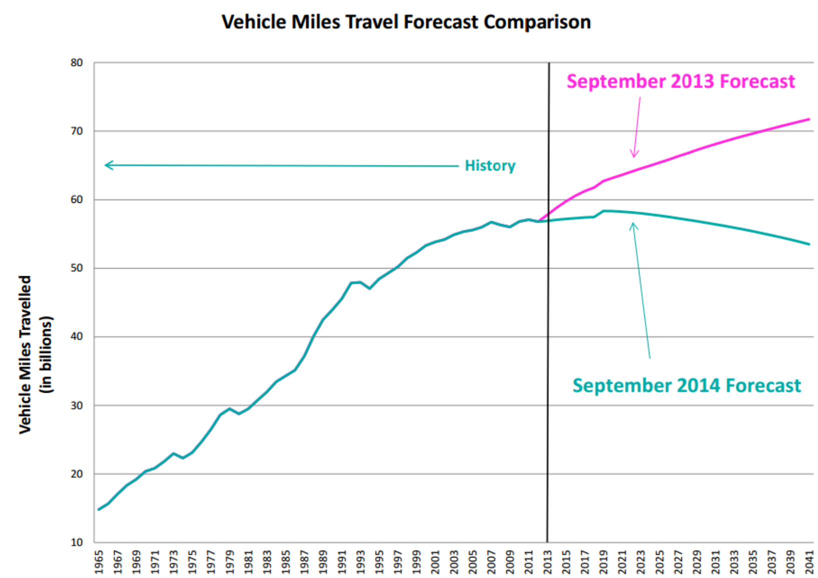
The Sound has abundant water to accommodate future growth, but reservoirs will be drawn down: The Puget Sound has abundant, clean, and readily available water resources to service its growing population (Forum, 2016). According to the USGS Water Use monitoring database, an average of 555Mgal/d were delivered to domestic, commercial, and industrial Washington users in 2010 from public supplies (USGS, 2016). Over the last decade we have seen an increase in unchecked withdrawals, mostly from exempt wells (NWIFC, 2016) and aquaculture (USGS, 2016). Since 2012, all watersheds in the Basin have seen an increase in the drilling of water wells (around 3% increase) except in Skagit County (NWIFC, 2016). Well permits are expected to be correlated with economic growth – as the economy improves, the rate of new wells permitted is expected to increase. According to USGS records, water withdrawals for aquaculture increased from under 20 Mgal/d to over 100Mgal/d between 2000 and 2010 (records are not readily available for the period before or after). Analysts expect stricter regulations around and greater accounting for water withdrawals in the future (Water Supply Forum, 2015). While in recent years, domestic use has become a more dominant user of public water (from 45% in 1985 to 70% in 2010)(USGS, 2015), water for energy production is expected to become a much more important piece of the Puget sound's water infrastructure and demand portfolio (OECD IEA, 2012). As the climate warms, high altitude snow is projected to melt earlier, increasing stream flows in the spring and decreasing natural reservoirs of snowpack traditionally used for summer supplies (Mauger, 2015). Currents models show sufficient supplies when combining a growing population, hydrological shifts, and a continued reduction in per capita demand (Forum, 2012). Part of this optimism is a result of the acquisition of Lake Tapps – one of the most significant new



City of Seattle's Current and Forecasted Water Supply trends. Note how the actual demand (black) is tracing far below the 2001 and 2004 forecasts. Even the 2007 and current projections expect more demand than we are seeing. The supply, or "firm yeild isaround 170mg.D.

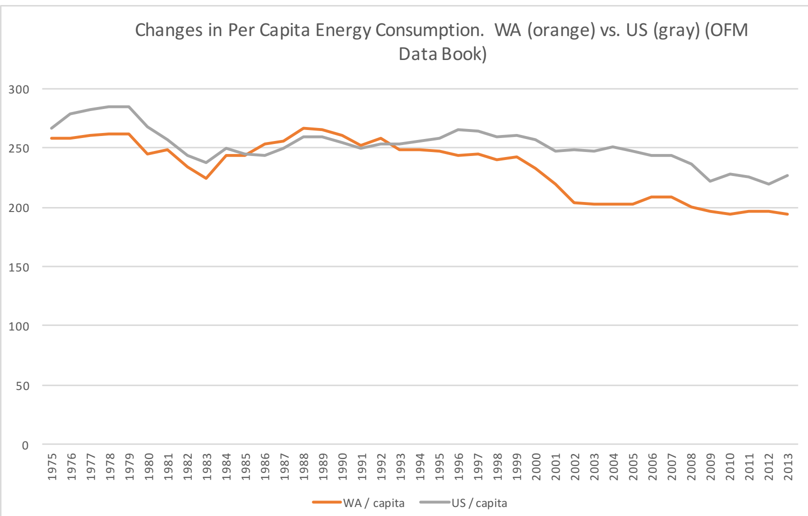
municipal water rights issued by the state in a decade (Ibid). However, reservoirs are projected to be drawn down further than ever before, and system reliability is projected to decrease by the end of the century unless new reserves are utilized (Mauger et al, 2015). If population growth occurs faster than currently forecasted, and no additional supply improvements are constructed or brought on line, the Puget Sound basin could face shortages of as much as 100 million gallons per day by 2060 (Forum, 2012).

The future of transportation may radically surprise us and change the way we move thorugh the region: Future innovations are expected to dramatically alter the way we move through the city. We are already seeing the use of smart media to more efficiently manage networks – from uber rides and highway congestion control. In the near future, we may see driverless cars and hovercrafts making what was once science fiction a reality (Bogost, 2016). Meanwhile, the Puget Sound has been seeing a greater reliance on public transportation, tele-commuting, and high occupancy lanes (Williams-Derry, 2014) which may in part be contributing to improvements in mean travel times (Woolsey, 2009; Census, 2010). While travel demands are projected to increase (1.5 million more people in the Central Puget Sound by 2040, supporting about 1.2 million new jobs)(PSRC, 2012), analysts are observing a surprising trend towards declining vehicle miles traveled (Sightline). OFM projects state VMTs peaking around 55B, as opposed to rising as traditional models forecasted (OFM, 2016b). Lastly, funding sources for travel are becoming increasingly inadequate to meet goals as state fuel tax revenues are not rising as rapidly (PSRC, 2012). Revenues are projected to be largely used to cover debts as opposed to new projects (Ibid). The historical practice of "building our way out of congestion" will need to change, with the biggest priority being maintaining the existing system.



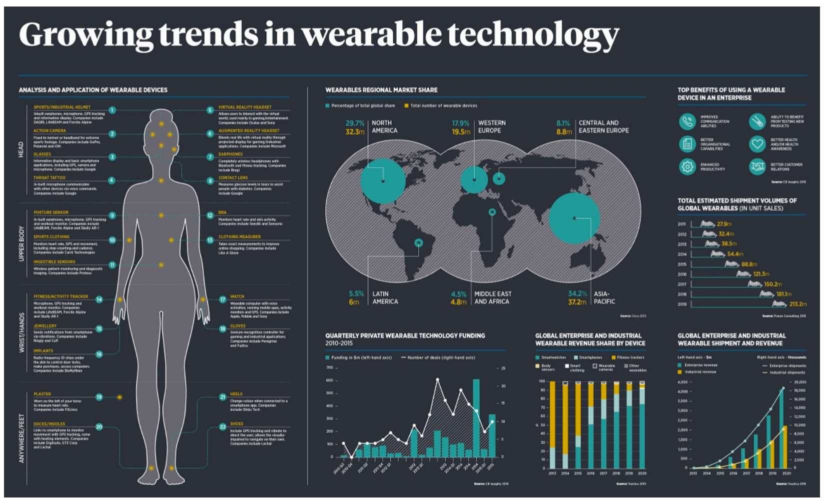
WSDOT's Vehicle Miles Travel 2013 and 2014 Forecast Comparison. Sightline, 2014.

While the dominance of hydropower will fall, decentralizing green systems will become more prevalent: Washington produces 29% of the country's hydroelectric power, which is used to power up more than 2/3 of the state's electricity (PSRC, 2010). However, hydropower has largely reached its maximum potential and no new large projects are expected to be built (Department of Commerce, 2007). Wind energy is forecasted to grow in importance, with Puget Sound Energy (PSE) already ranked as the second-largest wind power utility producer in the US (PSE, 2016). Per capita energy consumption in Washington is well below the national average and has continued to decrease since the late 1990s. The residential sector accounts for ¼ of the state's total energy, and low household usage corresponds with mild weather patterns (EIA, 2015). Transportation continues to account for the largest portion of energy, nearly doubling in usage since the 1970s. Gasoline accounts for more than half of the transportation sectors' energy use, but diesel and aviation fuel consumption is growing rapidly (PSRC, 2015). Despite the innovation of more fuel efficient vehicles, the growth in demand for less fuel efficient vehicles such as trucks and SUVs have reversed trends to reduce gasoline consumption (CTED 2008).



Per Capita Energy Consumption for Washington and the U.S. OFM, 2015.

Communication infrastructure will become more seamlessly integrated into our daily lives, making us more connected while invading our privacy: The next communication revolution is expected to be "always on, always broadband communication" (Sterkenberg, 2012). Washington State has one of the nation's fastest internet connection speed (Chokshi, 2015), the Puget Sound is ranked 1st for digital infrastructure due to its strong broadband (EDC, 2016), and Seattle is ranked as the 3rd Most Wired City in the county (Woyki, 2010). Speeds have generally increased over the last few years and are forecasted to continue to be faster. There is a strong national push to expand broadband access into rural areas (EDC, NA). Security is potentially the foremost challenge to the future of communication. Users are slowly realizing, that they cannot blindly trust the security, the integrity and the confidentiality, of our communications (Future of Communication). In addition to hackers, identity theft, and viruses that can access personal and private information, drones, or unmanned aerial vehicles (UAVs) have become an increasingly important trend, with protecting security and privacy a top challenge (Pitchford, NA). Communication technology is expected to be increasingly integrated into our daily lives with a decreasing reliance on office-bound desktop machines (Future of Communication). Videoconferencing and virtual machines are increasingly allowing people to work from just about anywhere (Vadala, 2013). Wearable devices are expected to integrate communication more seamlessly with the environment, letting us keep track of information in a much less intrusive way. Adaptive technologies, like the interfaces used to analyze a pilot's brainwaves, can adjust to environmental changes – for example adjusting the amount and form of data in real-time to accommodate stress levels. These advancement hint at a future where not only will our messages be personalized but adapted to our circumstances measured at the granular, biological level (Sterkenberg, 2012). Experts believe it is possible we will look to create more communication tools that will advise us how to reason, and advise us how to feel. Social media is also providing users with a platform with which to address the world – access that was traditionally limited to celebrities and politicians. However, the ability to communicate or translate efficiently doesn't necessarily mean we understand each other better (Vadala, 2013). We can now communicate in a socially acceptable way without adding so much context, but we may be accelerating confusion and misunderstanding. Users aim to reduce noise while increasing context, ease of use, ease of access and the certainty that their listeners understand the message. Fragmentation may accelerate as we struggle to communicate meaningful data in glanceable forms, amidst constant competition for our time and attention



Growing Trends in wearable technology. [Raconteur, 2015.](#)

We will produce more waste, but do a better job putting it to good use: Waste generation directly correlates with economic cycles – i.e. the more we make the more we waste. However, waste prevention programs, especially in Seattle, are reducing the percentage of waste that ends up in the landfill (SPU, 2011). Seattle has one of the country's best recycling programs, with single family households recycling over 70% of their waste. In addition to recycling, Seattle is focusing on "pre-cycling" – reducing the amount of waste produced in the first place, utilizing composting, reuse, and product stewardship. Despite these advancement, between 2015 and 2016 Seattleites increased their per capita waste generation by ~2.8%. Seattle's model to estimate future waste generation (the Seattle Discards Model) forecasts a gradual increase in the generation of waste out to 2030.

Hazardous waste, from both intentional and unintentional releases continues to be a major issue in the region. While State levels of hazardous waste generation have remained stable over the last four years, Snohomish has rapidly increased its generation – from 4 to 16 thousand tons (OFM, 2015).

As sea level rises and extreme precipitation events become more frequent, it will be hard than historically to control combined sewer overflows: Wastewater refers to everything that goes down a sink or is flushed down a toilet. In rural areas wastewater usually goes into a septic filed, while in urban areas it travels through sewer pipes to a wastewater treatment plant and then out to the Sound. Currently, there are around 100

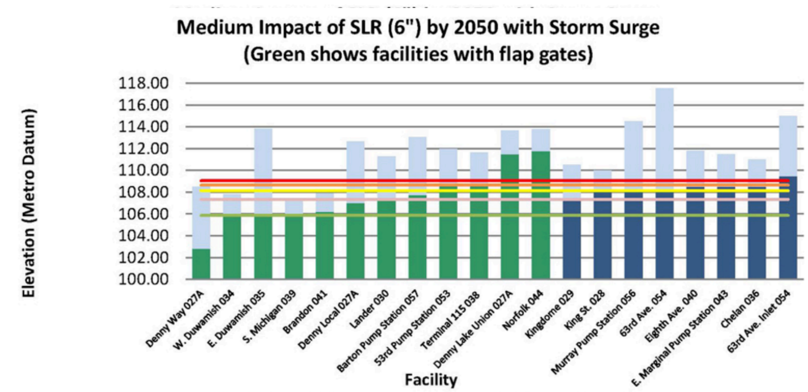
Hazardous Waste Generated by Puget Sound County (*in Tons*)						
Counties	**2010**	**2011**	**2012**	**2013**	**2014**	**Sparklines**
Clallam	1,081	35	36	80	116	
Island	196	103	79	77	84	
Jefferson	9	11	92	37	346	
King	38,968	37,687	52,855	46,278	35,921	
Kitsap	3,996	3,505	4,433	1,128	4,603	
Mason	4	6	11	45	22	
Pierce	19,853	24,233	18,267	68,720	20,509	
San Juan	0	1	0	0	0	
Skagit	3,228	9,448	2,687	2,175	3,439	
Snohomis	3,938	5,535	8,503	7,644	15,949	
Thurston	77	491	139	56	61	
Whatcom	7,717	5,396	5,913	10,996	6,126	

Hazardous Waste Generated by County. OFM , 2015b.

Wastewater Treatment Plants (WWTP) that discharge into the Sound, as well as about 300 large onsite sewage systems, and more than half a million small onsite systems. Their combined contribution of treated discharge is over 430 million gallons per day; 170M in King County alone (Milesi, 2015). The region's wastewater treatment networks and facilities face several pressures in the upcoming years, including aging infrastructure, population growth, and inundation from sea level rise. In addition, while WWTP aim to remove pollutants, including pathogens and nutrients, from wastewater, the character and quantity of contaminants presenting problems today are far more complex than those presented in the past (ECY, 2011).

Wastewater pollution is considered a major source of contamination entering the Sound (Puget Soundkeeper, 2016). A recent NOAA study estimates that over 300 lbs of harmful contaminants enter the Sound from wastewater each day (Meador et al, 2016). Combined sewer systems carry both sewage and stormwater runoff. During heavy rainfall events, the system can be overwhelmed and is designed to "overflow". Combined Sewer Overflow (CSO) events discharge untreated waste into the Sound impairing water quality (ECY). Recent extreme rainfall events have hampered efforts to reduce outfalls. In 2014, King County discharged over 1 billion gallons of untreated wastewater (King, 2015). These pressures are forecasted to increase as climate models forecast an increase in extreme rainfall events over the next century (Mauger et al, 2015).

In addition, sea level rise poses a direct a measureable threat to low-lying infrastructure in tidally influenced areas. Puget Sound levels have already increased an average of 4.24 inches



Tides above weir elevations with a 6-inch sea-level rise with and without storm surge. Philips et al, 2015.

(Phillips et al, 2015). By 2030, sea level is expected to rise an additional 6” and by 2100 an additional 13 inches. Storm surges are expected to increase tide heights even more. A King County assessment showed 20 out of 40 facilities are at risk from saltwater intrusion (Phillips et al, 2015).

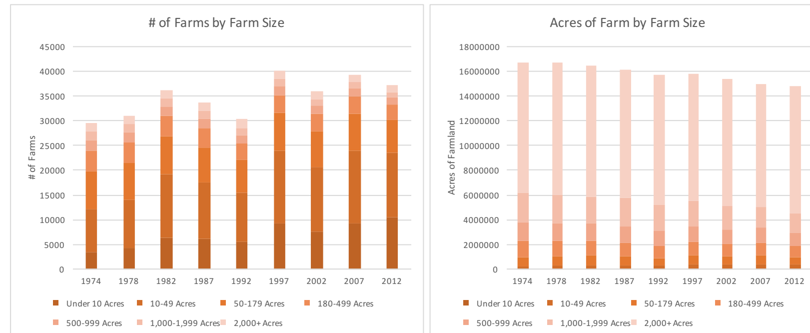
The natural and cultural **resources** of the Puget Sound have attracted people to the region for a long time. Here we focus on agriculture, forestry, fisheries, recreation and public lands, and the Pacific Northwest Tribes. Farmers, land managers, anglers, and tribal members have seen, and continue to see, multiple pressures on their livelihood – including economic incentives to develop or overharvest, shifting environmental conditions, and increasingly cumbersome regulations and restrictions. Increasingly, constraints and opportunities are borne from changes far beyond the boundary of the resource.

Agriculture > Four major trends characterize recent and future trends in farming in the Puget Sound. Foremost is an ongoing trend challenging the viability of farming in the region. While the value of commodities is growing, so too are the costs associated with owning and managing farmland. Farmers find it increasingly difficult to support farming practices, especially on smaller parcels closer to urban areas (Brockman, 2011). In addition to urban pressures, a top issue is inadequate water as a result of complying with land use regulations (MSRC, 2014). Policy restrictions, mostly associated with salmon and floodplain habitat, are seen as overly cumbersome and restrictive in the farming communities (Canty & Wiley 2005).

A second trend, which emerged around two decades ago, but is expected to continue out into the near future, is a decrease in the total area of farmland coupled with an increase in the number of farms. For the state as a whole, the largest percentage of acres is still in the large (2,000+ acre) farms, however, the proportion of small farms (under 10 acres, or 10-50 acres) is steadily increasing. This is especially true in the Puget Sound which has a larger share of smaller (1-9 and 10-49 acre) farms as compared to the east side of the state (USDA, 2007). The Puget Sound currently boasts Puget 11,501 farms totaling 580,000 acres. The rapid conversion of farmland in western Washington is associated with population increases in the Puget Sound region, with the majority of land lost in King and Snohomish Counties (USDA, 2007). The growth in smaller farms may be the result of people seeking lower land prices and the environment associated with rural areas (Clouser, 2005).

A third trend is an overall economic shift towards greenhouses in urban areas and aquaculture along the coast. Washington State produces a wide diversity of agricultural commodities (over 300, with apples, sweet cherries, pears, red raspberries and hops production ranking first in the nation)(USDA, 2007). For all but a few commodities, the value has gone up over the last few years. Within the Puget Sound, the agricultural census reports an increase in greenhouse and nursery investments, especially in the more urban counties. Along the outer coastal counties, aquaculture is increasingly important. Washington is currently the leading U.S. producer of farmed bivalves and its wild harvest shellfishery is valued at over $40 million (Washington Sea Grant, 2014). In 2012, NOAA reported that the shellfish industry injects an estimated $270 million a year into the region's economy, bringing jobs to over 3,200 people, primarily in coastal communities (NOAA 2012). The far majority of the value is found in South Puget Sound. According to WDFW, as reported by OFM, between 2005 and 2014 the value from shellfish more than doubled, while the value from salmon, sturgeon and steelhead, and other marine fish remained pretty stable, increasing slightly (2015a).

The fourth trend is towards direct marketing, organic and urban farms. Puget Sound farms are increasingly investing in small farms providing specialty and organic products marketed directly to consumers. Direct marketing is rapidly rising as a viable option in Washington state (Brockman, 2011). CSAs, or Consumer Supported Agriculture programs are seeing rapid growth in demand that is outpacing supply (Ibid). The number of farmers markets in Washington State have increased from 5,000 in 2008 to 8,144 farmers markets in 2013 (Forterra, 2015; USDA, 2013). Meanwhile, Washington State has increased its sale of organic food products by 24% between 1997 and 2001 (Brockman, 2011). Over the last decade, urban agriculture has also established itself as a growing and economically viable trend. Popular media outlets from the NYT to Huffington Post and Forbes Magazine have all featured urban agriculture in recent years. Urban agriculture boasts a variety of benefits, from food insecurity, to community development, to employment, and environmental sustainability (MSRC, 2016b). Urban agriculture is expected to maintain strong growth in the US as cities provide more incentives, more startup farmers enter the field, and consumer demand for locally grown food increases (Seedstock, 2014). Cities all over the U.S. are encouraging the growth of urban farming and enacting legislation to support it. The City of Seattle approved legislation in 2011 that allows three year leases for urban farming including uses for retail sales, allowing residents to sell the produce they grow on site (Evan, 2013). However, early studies show that the majority of urban farms aren't profitable, leading to the impression that urban farmers aren't just 'in it for the money' (Winkless, 2016).



Shift in number of farms and acres of farm by farm size. USDA, 2012.

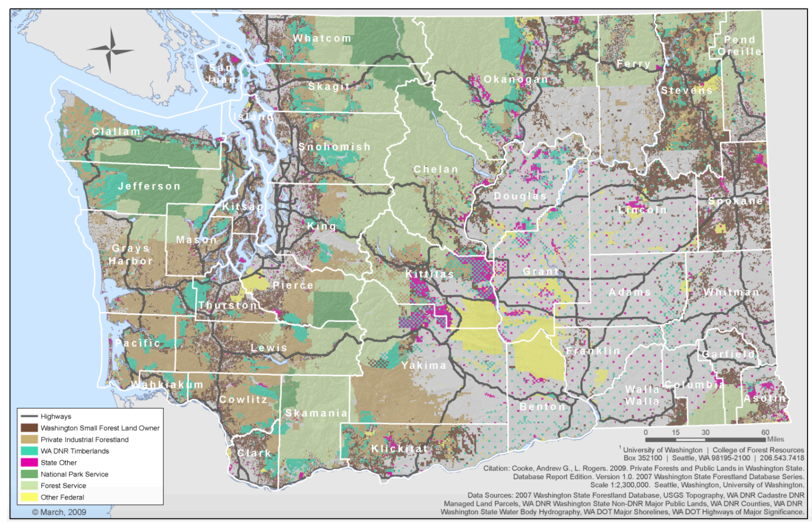
Forest bring in lower yields but higher profits, and a shift towards ecosystem services: Forestry includes both timber and non-traditional forest management uses including recreation and ecosystem services (e.g. carbon sequestration, water and soil retention, and biodiversity conservation). While Washington's timber sale volumes have decreased, investments in non-traditional uses are growing.

Washington's timber harvest volume has been declining since 1989 (USDA, 2016b). Historic timber inventories found large losses of private timberland (0.5 percent per year) to urban development in Western Washington during the 1980s and 1990s (Ibid). Timber sales have traditionally been correlated to economic growth, where upturns ignite pressures to convert forest lands to rural subdivisions and recreational homes, especially in lower elevation forests (Ibid). The landscape of ownership is also changing. Large investors are focusing on more profitable forests closer to mills and docks in western

Washington (Forterra, 2015). This leaves fewer economic forestry opportunities for slower growing forests at higher elevations and east of the Cascades. Global markets also drive regional profits (Forterra, 2015).

While large scale timber operations are declining, there is a growing value placed on small and urban forests. Nationally, tree cover on urban lands is estimated at 35 percent (USDA, 2016c). With over 60 million acres of urban lands, this represents a large but highly variable resource (Ibid). Data on these lands is scarce but improving (Ibid). Nowak et al (2000) estimated that the Puget Sound has among the nation's highest percentage of urban tree canopies, at 50-80%. Since the passage of the Salmon Recovery Act, Washington State has had an increased interest in monitoring the acreage and characteristics of private forest land ownership, including small forest land owners (SFLO)(Erikson, 2005). Analysis compiled from the Washington State Forestland Data base, 2007, shows that 215,000 small forest landowners own 5.7 million acres of forestland, half of the 11.6 million acres of private forestland in the state (Rural Technology Initiative, 2016). RTI's analysis by Watersheds shows that within the Puget Sound basin, the urban to rural transition is dominated by small forest land holdings (SFLO). Similarly, when examining ownership across the Puget Sound counties, the lowland urban fringe is dominated by these SFLOs while higher elevations are dominated by National Park Service and private industrial forestlands (RTI, 2016).

In contrast to timber sales, recreation has increased dramatically on public and private forest lands near major metropolitan areas. The use of forestland for recreation, or non-consumptive purposes has mixed impacts. On one hand there is an increased usage of lands which can increase the spread of invasive species and puts pressures on sensitive lands (Pickering, 2010). On the other hand, public uses have been correlated with higher awareness and interest and forest lands, and consequently a greater support for protection. For example, the Trust for Public Lands recently supported the protection of nearly 7,000 acres of forest land in the Puget Sound (TPL, 2016). These purchases are expected to protect productive forestlands from future development, meanwhile supporting vital intact habitat for wildlife, recreation opportunities, and maintaining the overall health and quality of the Puget Sound. A major challenge continues to be meeting the increased demand at the same time public land managers deal with dramatically reduced budgets.



Washington State Forest Land Ownership Rural Technology Initiative, 2007.

In recent years, Puget Sound's forests are increasingly looked at for their carbon storage capacity. Washington's forest are seen as a large net sink for carbon – considered among the highest in the U.S (Hutyra et al, 2008). Studies show carbon stocks in the Puget Sound to be surprisingly high, even within the heavily urbanized areas. The average live biomass stored within forested and urban land covers was 140±40 and 18±14 Mg C ha−1, respectively. The conversion of forest land to non-forest uses represents one of the greatest sources of loss of forest carbon sequestration and storage. Protection of forestlands is therefore a high priority for managing GHG emissions (Hutyra et al, 2008).

The State is currently exploring alternative incentive programs to participate in the carbon offset market. Key findings for the PNW show that longer growing rotations store more carbon, while shorter rotations increase net emissions (WEC, 2015). Meanwhile, in 2015 Microsoft partnered with the Nisqually Land Trust and the Washington Environmental Council to purchase carbon credits through the protection of a 520-acre forest near Mount Rainier (Nisqually Land Trust, 2015). The purchase aims to offset 100% of the company's worldwide emissions across all operation. The forest generates 37,000 carbon-offset credits, equivalent to taking 6,000 cars off the road. Under the program's protection the trees, taken out of industrial forestry and its short rotation cycles, will get a chance to age and "gobble carbon dioxide from the air for the next 100 years" (Seattle Times, 2015). Puget Sound's forest lands are also increasingly valued for their role in water and soil retention, and biodiversity conservation.

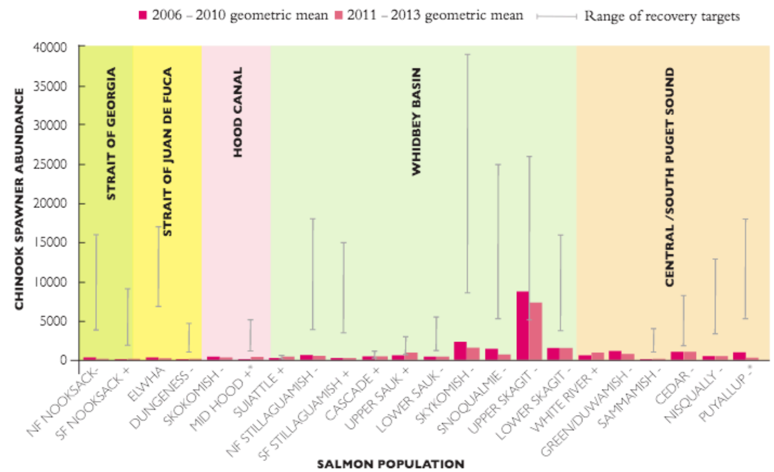
Fishing continues to be a major component of Washington's economy and culture: Fishing, as a commercial activity, cultural practice, or pastime, represents a core piece of living in the Pacific Northwest for hundreds of thousands of residents and visitors.

A 2006 WDFW report suggests that commercial and recreational fisheries not only contribute employment and personal income, but also contribute in several other significant ways to Washington's economy, as well as to its residents' quality of life. In terms of economic impacts, commercial and recreational fishing conducted in Washington fisheries directly and indirectly supported an estimated 16,374 jobs and $540 million in personal income in 2006 (WDFW, 2006). When viewed in the context of the Washington state's economy, these levels of employment and earnings account for about 0.4% of total statewide employment and about 0.2% of total statewide personal income in 2006. In 2009, WDFW reported that spending by fishers, hunters and wildlife watchers generates more than $6.7 billion annually for Washington state's economy. A large share of that come from commercial fisheries which generate an average of $3.8 billion annually by the time their catch is processed, distributed through wholesalers and sold in retail markets or served in restaurants (WDFW 2009).

Despite concerted efforts, salmon populations are still in decline, and are expected to be threatened by fishing, urbanization, and climatic changes in the future: The Puget Sound supports 253 fish species including shellfish, marine and freshwater species, as well as anadromous fish such as salmon, steelhead and surgeon. Salmon are considered the most important fish in Sound – with major economic, cultural and biodiversity implications. Despite concerted efforts and federal regulations, salmon numbers continue to decline.

The Puget Sound supports 8 species of salmon (NOAA, 2007) four of which are listed as threatened under ESA – Chinook salmon (Oncorhynchus tshawytscha), chum salmon (O. keta), bull trout (Salvelinus confluentus) and steelhead (O. mykiss). The State of Our Salmon report tracks abundance of each salmon population in the Puget Sound from 1974 to today (RCO, 2014). Abundance is considered one of four viability indicators for salmon, and the one easiest to measure. Most populations show declining number and remain far below targets set by the National Marine Fisheries Services. The Puget Sound Partnership has reported that “there is little sign of improvement in each biogeographic area” in the Sound (PSP, 2015, p41). According to NOAA’s Northwest Fisheries Science Center, between 1991 and 2009 the population abundance did not improve in nearly all Puget Sound watersheds, and actually decreased in the Stillaguamish Watershed (NWFSC, 2008).

According to the WDFW, between 1997 and 2014 commercial fishing brought in about 21 million pounds on average (2016). The trend in catch, as measured by volume, showed a slight increase up to 2014, likely due to natural variation in migration patterns (Ibid). Recreational fishing and crabbing license sales have remained steady since 1999 aside from 2-year fluctuations due to odd-year returns of pink salmon. License sales average around 189,000 to 225,000 licenses per year (Ibid). Overall trends since 1991 show an initial steep decline between 1991 and 1998, and then steady numbers between 2001 and 2013 (Ibid).



Mean Chinook Salmon spawner abundance in each population in Puget Sound, shown by geographic region (Puget Sound Partnership, 2015)

In 2016, due to very low salmon escapement forecasts, the Northwest Indian Fisheries Commission (NWIFC), proposed a “zero catch option” that would close all ocean salmon fisheries in the 2016 spring season (Associated Press, 2016). This response was due to unprecedentedly low forecasted returns. The Coho run has been described as disastrous by both state and tribal fisheries managers. According to WDFW, 2016 chinook runs are down 20-25% from 2015. NOAA estimated that Puget Sound wild Chinook salmon abundance in 2016 will fall 31% below the average of the past decade (NOAA, 2016). Coho returns are expected to be even lower (Associated Press, 2016). Only about 256,000 Coho are expected to return to Puget Sound in 2016, that’s about 60% lower than 2015, and already 2015 Coho returns were as much as 80% below their pre-season forecasts (NOAA,2016). These low numbers have challenged co-management agreements between the tribes and state managers to set catch rates that mark the beginning of the fishing season.

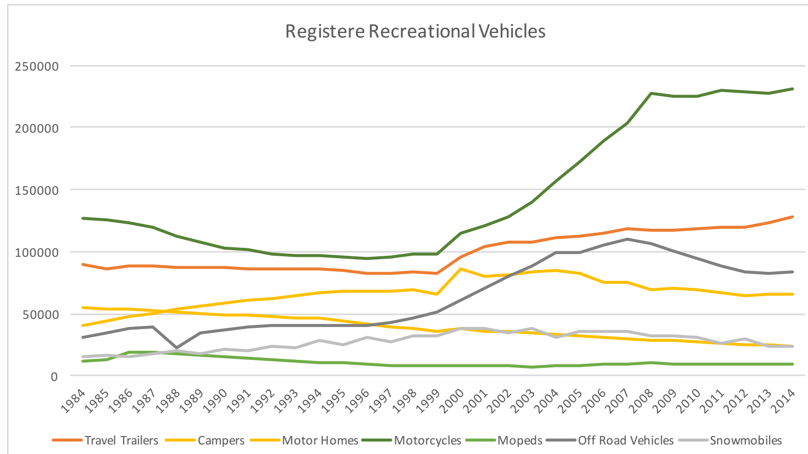
In 1974, under the Boldt Decision, the courts affirmed that, under the terms of 1854-56 treaties, certain Indian groups had retained title to 50% of the western Washington State salmon resource (Cultural Survival, 2016). Further, in 1991, Columbia River Basin salmon and steelhead were listed under the Endangered Species Act (ESA) (NW Council, 2011). The National Oceanic and Atmospheric Administration (NOAA) was put in charge of imposing restrictions on salmon fishing to ensure that fishing doesn't harm protected fish. For decades, the State, represented by the Washington Department of Fish and Wildlife (WDFW), and the Tribes, represented by the Northwest Indian Fisheries Commission (NWIFC) submit a joint fisheries proposal to NOAA in order to receive a permit that sets the catch allowance for the season. The co-management process, known as the North of Falcon process, includes a series of meetings involving representatives from federal, state, and tribal governments and commercial and recreational fishing industries to plan the season (NOAA, 2016).
This spring, for the first time, the State and Tribes could not come to an agreement over the annual catch limit. This failure resulted in the closure of commercial salmon fishing and recreational fishing from May to June. The state and tribes agreed on a catch limit, but not how to share it between them (Cauvel, 2016). There was discussion of the State and Tribes seeking federal approval for separate plans. However, on May 26th, NWIFC and WDFW did come to an agreement (Geranios, 2016). building on their tradition of cooperative co-management.

Recreational land will see more usage but less resources: Public lands cover the majority of the area in the Puget Sound (63% of land area)(DNR, 2016). Some counties are more dominated by public lands than others. For example, 75% of the land area in Clallam, San Juan, and Whatcom are public lands, and 83% of Jefferson is public (Ibid). In most Puget Sound counties, federal lands represent the majority of public lands (55%), while WDFW lands and state parks represent only a small percentage of the lands (less than 1%)(Ibid). WA DNR owns and manages over 3 million acres of public lands in the Puget Sound, the majority of which are aquatic lands in Clallam and San Juan Counties. These lands account for about 40% of the total public lands (Ibid). In addition, millions of acres of lands have been purchased and are protected by non-profits such as The Land Conservancy, Trust for Public Lands, Forterra, and Mountains to Sound Greenway Trust (1.5 million acres). Most federal and state lands continue to be managed for timber harvesting as well as non-consumptive uses. Most of the land acquisitions made in the last decade have come from non-profits who leverage contributions from private entities to protect lands.

Between 2009-2011 a change in the State's policy resulted in a majority of the state parks' financing to be shifted away, with a greater reliance on earned revenue (OFM, 2015b). Between 2007-2009 WA State Parks had $94.5M as dedicated general funds, by 2013-2015 the figure has dropped to $8.7M – less than 10% (Ibid). Instead, the agency's budget depends predominantly on revenues earned. This rapid change has resulted in a decrease in funding, leading to reductions in staffing, programs, and park operations (Forterra, 2015). This has come at a time when the demand for public lands is growing rapidly. Agencies are increasingly looking for innovative solutions to protect lands. For example, landscape scale public-private collaborative efforts have been shown to improve restoration success.

Over the past decade, the number of visitors to public lands in the Puget Sound has grown in pace with national trends. Over the last year, National Parks saw a 5% increase, and with the centennial of the National Parks Service in 2016, over 315 million are expected. Between 2004 and 2014 an additional 1 million visitors attended federal parks in Washington State (Monk, 2015). A 2015 account for Seattle and King County tracks 38 million visitors spending over $6.8B – nearly a 6% increase from 2014 (Monk, 2015). The Puget Sound Regional Council identified tourism as the largest job cluster in the central Puget Sound region, supporting 108,000 jobs (PSRC, 2008). Whatcom and Island Counties also show substantial economic value gained by tourism - $555M and $130M, respectively, in visit expenditures, and 5,870 and 2,340, respectively, jobs generated by tourism (Department of Commerce, 2008).

Lastly, public land managers are seeing a strong growth in public engagement and volunteering. Due to both constrained budgets and competing interests, public agencies and non-profits are relying more on local leaders, stakeholders, and users. Public land actions are increasingly developed with substantial input and coordination from community leaders and stakeholders. While format of engagement ranges from "listening sessions" (USDA, 2015) to "co-management", over the last decade, it has become common practice to incorporate non-technical expert, or "local knowledge" input into management decisions. Relatedly, agencies are relying on users to help support the management plan itself. The number of volunteers involved in restoration, trail building, and noxious weed removal has grown exponentially. There is also a growing reliance on "citizen science", or the use of local residents to monitor environmental conditions. Educating the public and engaging students in land stewardship activities continues to be a central component of agency programs (MTG, 2016).



Number of Registered Recreational Vehicles. 1984-2014. OFM, 2015.

Tribes are land locked, but resources are shifting: There are 12 tribes within the Puget Sound that are Federally recognized. These include Nook sack, Upper Skagit, Swinish, Lumen, Smash Tribal Headquarters, Sauk-Suiattle, Stillaqguamish, Tulip, Snoqualmie, Muckleshoot, Puyallup and Nisqually (Baker, 2015). Tribal casinos over the last 30 years many tribes have led to major economic growth and extensive investments in the members' lives and natural resources. Despite these investments, American Indians and Alaska Natives (AI/AN) of the Pacific Northwest continue to experience significant health disparities. Additionally, despite being granted federal rights for fishing, hunting, and water, tribes are finding those resources threatened by external factors - urban pollution, management practices, and climate change.

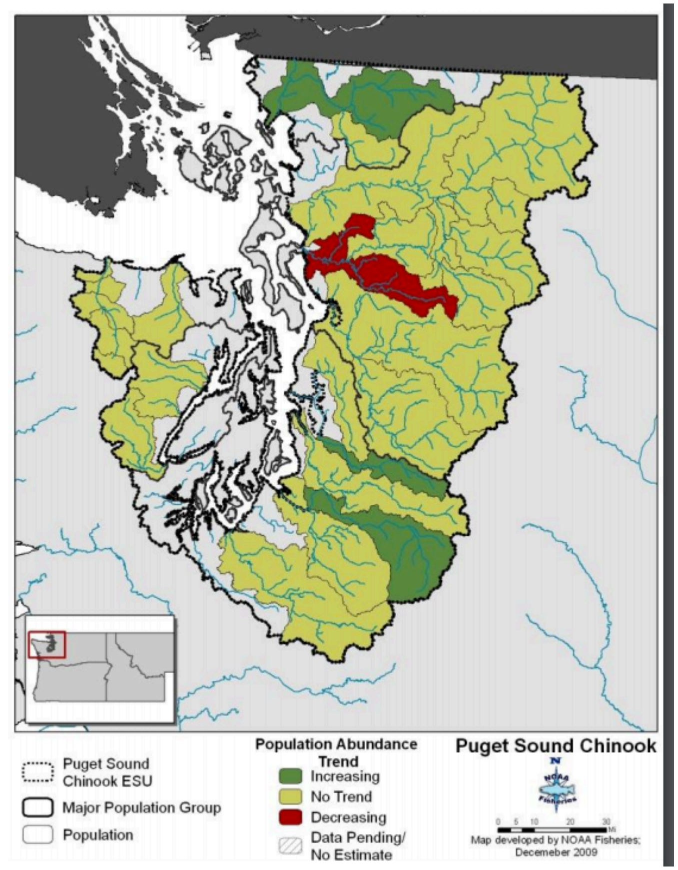
After the Supreme Court ruled in 1987 that Native American tribes, being sovereign, could not be barred from allowing gambling, casinos began popping up on reservations everywhere. Today, almost half of America's 566 Native American tribes and villages operate casinos. Between 1995 and 2012 Indian gambling revenues have skyrocketed form $5.4B to $27.9B (Economist, 2015). Tribes have used the money to build housing, schools and roads, and to fund tribal health care and scholarships. They also have distributed casino profits to individual tribal members (Economist, 2015).

While some small tribes with land close to big cities have done well a new study in the American Indian Law Journal suggests that growing tribal gaming revenues can make poverty worse. The study looks at two dozen tribes in the Pacific northwest between 2000 and 2010. During that time, casinos owned by those tribes doubled their total annual take in real terms, to $2.7 billion. Yet the tribes' mean poverty rate rose from 25% to 29% (Economist, 2015). Some critics suggest the issue lies with how profits are disbursed. According to law professor Ron Whitner, payments can be destructive as tribal members get into the trap of not working.

Recently, a new challenge is declining profits, and even losses in tribal casinos (Economist, 2105). According to the National Indian Gaming Commission while the nation's Indian gaming industry grew revenue for the fourth consecutive year in 2013, it was less than a 1 percent uptick (to $28B), the lowest jump since the recession and far below the double-digit annual increases that became common a decade ago (Stutz, 2015) In Washington, total tribal-casino revenues were up only slightly to $1.6 billion in the fiscal year ended June 30, 2009 (from $1.5B in 2008)(Washington State Gambling Commission). Once viewed as sure bets, some tribal casinos in Washington are hurting: revenues dipped as much as 30 percent at some tribal casinos in the state in 2009; the Nooksack tribe is in court with its lender; the Snoqualmie tribe is struggling to make payments on its casino debt; and the Skokomish tribe closed its casino last fall rather than keep hemorrhaging cash (Mapes, 2010).

In the Pacific Northwest, as with much of the country, a greater proportion of American Indian and Alaska Natives (AI/AN) is younger, has lower educational attainment levels, lower income levels, and higher rates of morbidity and mortality as compared to whites. A recent study by Dankochik reveals that Pacific Northwest AI/AN populations are twice as likely to die from unintentional injury, diabetes, chronic liver disease, and homicide compared to PNW non-hispanic whites (Dankovchik, 2015). According to the 2010 census, the overall life expectancy for Northwest AI/AN was 72.8. This is 6.9 years younger than non-Hispanic white Americans (NHW). Males further had a lower life expectancy (70.9 years) than females (74.6 years).

In addition to health disparities, resource challenges are especially worrisome as tribal members' rights are locked into their geographic range. Salmon, has long been the symbol and lifeblood of the Pacific Northwest tribes Tribal Fishing Resources, 2009). The cultures, intertribal interactions, fishing technologies, and very religions of the Pacific Northwest tribes are all impacted and influenced by salmon. Salmon continue to play an integral role in tribal religions, cultural and physical sustenance. They are used in religious services, they are a part of the tribes' sense of place, they are a primary food source, and the transfer of traditional values from generation to generation (Tribal Fishing Resources, 2009) For example, for the Stillaguamish Tribe, bound by treaty to fish only in their home river, poor Coho returns pose an insurmountable threat to their culture and way of life (Hansen, 2016). "They've always fed our people, they're one of the links between us and the river. They're in our songs, they're in our stories, they're in our creation." Shawn Yanity (Stillaguamish Tribe of Indians)(Tribal Fishing Resources, 2009). As captured by Billy Frank, Nisqually tribal member, Northwest Indian Fisheries Commission chairman emeritus, longtime environmental leader, fishing and tribal rights activist - "as the salmon disappear, so do our cultures and treaty right, we are at a crossroads and we are running out of time" (NWIFC, 2016).



Changes in Salmon Population Abundance. NWIFC, 2016.

The Puget Sound is expected to see substantial damages and stresses due to **climate changes**. Key forecasted changes include higher average annual temperatures and more extreme heat events, as well as drier summers with more frequent and intense rain events in the Spring and Winter (Mauger et al, 2015). These changes will have profound implications on the Sound's hydrological system. Changes depend on watershed-specific classifications, namely whether precipitation is received mostly as rain, snow, or a mixture of both. Mixed rain and snow watersheds, those watersheds near the current snowline are the most sensitive to a warming climate. They are expected to experience significant increases in winter flows and decreases in spring and summer flows (Hamlet et al, 2013). These hydrological shifts will alter streamflows, water reserves for drinking and hydropower, flood risks, as well as water quality (Dalton, 2013).

The Sound is also forecasted to see pressures from both sea level rise and ocean acidification. While some systems may benefit from changes, the overall trend is towards increased vulnerability and reduced functions (Dalton, 2013). Among the affected sectors and communities are coastal systems, agricultural lands, upland streams and forests, as well as impacts to human health and cultural resources (Dalton, 2013).

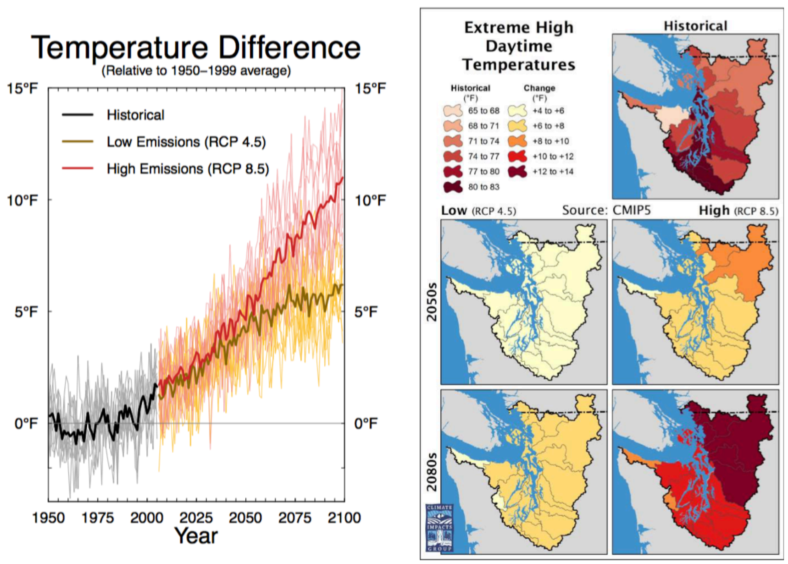
Climate Models and Uncertainty: To estimate future changes to the climate and affected systems (e.g. hydrology) scientists around the world develop and run an *ensemble*, or collection, of predictive models. Each model may be calibrated to a different region or set of adjustable parameters, but together they can better deal with uncertainties in the system. Regional modelers have developed *downscaled models* which are specifically adjusted for the unique features of the Pacific Northwest, or the Puget Sound. Modelers also run different scenarios in which they vary global greenhouse gas emissions as we do not yet know how much humankind will continue to emit in the future. In this document we refer to the regional models run under the *low* (RCP 4.0) and *high* (RCP 8.5) scenarios[1]. Future estimates, or forecasts, are generally given as a range to reflect the statistical uncertainty in the model.

A Warmer Puget Sound: The Puget Sound is forecasted to get warmer year round, with even more warming in summer. Low scenario models show an increase of +4.2°F (range: +2.9 to

[1] Climate in the Northwest's (Mauger et al, 2013) Introduction chapter has a good detailed description of regional models, scenarios and uncertainty.

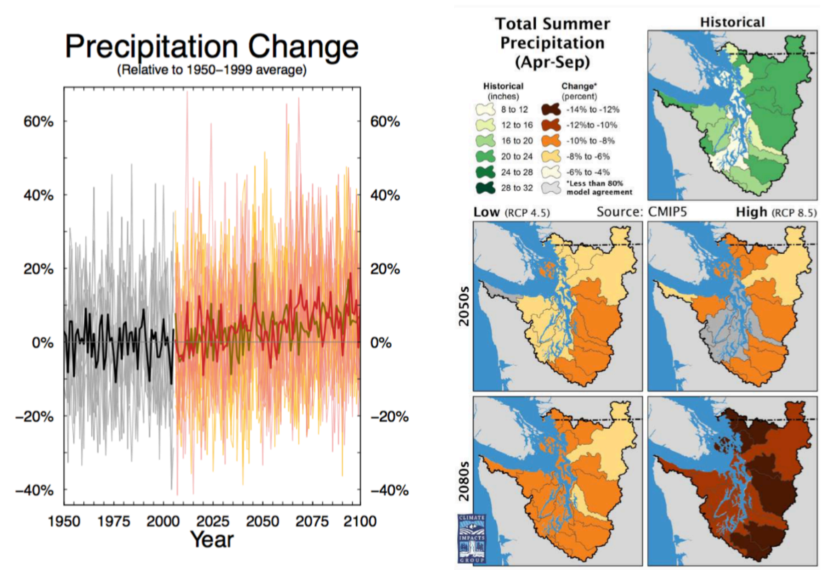
+5.4°F) by 2050[2], while higher scenario models show +5.5°F (range: +4.3 to +7.1°F). Differences in warming are much more dramatically accentuated by the end of the century (Dalton, 2013).

More extreme heat, less extreme cold: Models unanimously predict more hear extremes and less cold extremes for the Sound. For example, according to one model, the number of days a year where the average daily temperature goes above 90 °F increases by 8 days (± 7), while the number of days a year where temperature fall below freezing decrease by 35 days (± 6) (Dalton, 2013).



Changes in Temperature. Mauger et al, 2015

Summers will be a lot drier: The majority of models show annual average precipitation changing by about +3% with individual models ranging from –4.7% to +13.5% (Dalton, 2013). The biggest difference will be a 30% reduction in summer precipitation. Precipitation in the Fall, Winter and Spring is expected to increase (Dalton, 2013).



Predicted Changes in Precipitation. Mauger et al 2015.

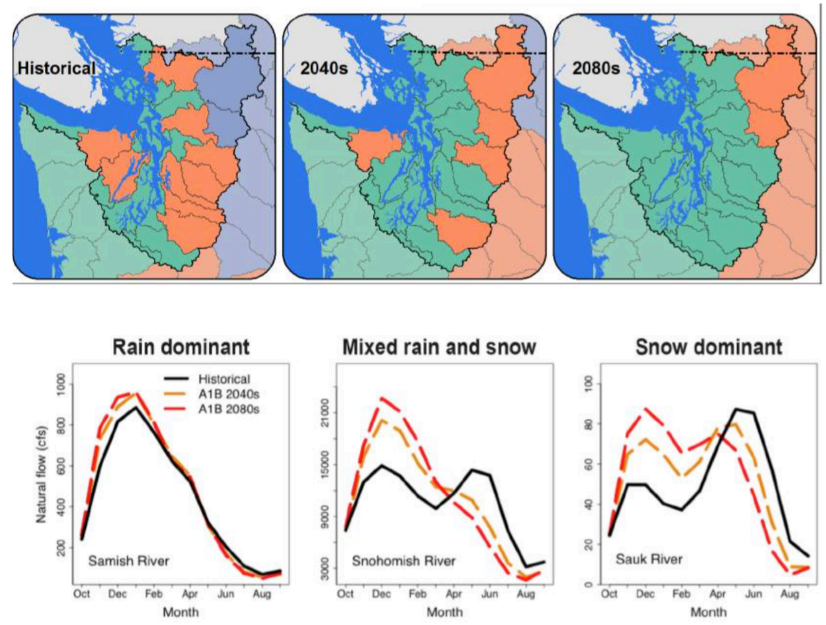
More extreme precipitation events: There is a greater level of certainty about the increase in extreme precipitation events, or

2 Global and downscaled climate models use date ranges to estimate future trends. In this report, as in Mauger et al, 2015, the year 2050 is shorthand for the 2041-2070 period.

days when it rains or snows a lot. The number of days where the Sound will experience more than an inch of precipitation is projected to increase by 13% (± 7%). The return period on a 50-year extreme event is projected to increase by 13% (-5 to +28%)(Dalton et al, 2013).

Mixed-rain and snow watersheds will become rain dominant > The impacts that changes in temperature and precipitation have on our water systems depend on each watershed's elevation. Climatologists characterize watersheds as being "rain dominants" is less than 10% of annual precipitation falls as snow; snow dominant if more than 40% of the precipitation falls as snow, and mixed rain and snow if they fall in between. Whether precipitation falls as snow or rain directly affects streamflow and snowpack – the amount of water in a water body and the amount of water that is detained higher in the watershed, as snow. As is described below, these changes have strong implications on aquatic species such as salmon, on drinking water and irrigation supplies, on water quality, and on hydropower. By mid-century there will not be any snow dominant watersheds and by the end of the century, nearly no mixed watersheds either (Hamlet et al., 2013).

Higher flows in winter, lower flows in spring and summer: As precipitation will fall more as rain, and snow will melt earlier, the seasonal timing of streamflow will change. Snow that is usually stored higher in the watershed will enter streams, increasing winter streamflows, while spring and summer flows, which have traditionally depended on that melted snow, will decrease (Mauger et al, 2015).



Top: Watershed Classifications: Rain dominant (green), Mixed rain and snow (orange) and snow dominant (blue). Mauger et al, 2015.

Bottom: Changes in Annual Hydrographs per watershed type. Mauger et al, 2015.

Lower summer water levels in reservoirs; high winter volumes: Northwest reservoir managers rely heavily on the ability of snowpack to act as additional water storage. Snowpack naturally holds back streamflows as snow in the winter, and releases the water in the spring and summer as the snow melts, and as precipitation levels are low. This has helped managers balance the need to store water for drinking, and provide sufficient space to hold water to prevent flooding in the lowlands. If most of the water comes at once, we will need much bigger (or more) reservoirs to maintain a seasonal supply of drinking and irrigation water, base flows for salmon migration, and flood protection. Researchers expect an increased demand for water as the population continues to grow. Higher demands combined with lower summer supplies will create additional pressures on water managers (Dalton et al, 2013).

Higher flood risks: More intense rain events and higher winter streamflows will raise both the frequency and magnitude of flooding in the Puget Sound region. Along the coast, sea level rise will further challenge us (Mauger and Binder, 2016). The 100-year flood event, a 1% annual flood event, is expected to increase by +18% to +55%, on average, by the 2080s in the 12 largest Puget Sound watersheds (Ibid). Developed areas in floodplains may be particularly vulnerable to the increased flood risk, depending on their flood control capacity. Over 2,800 miles of roads in Washington and Oregon coastal counties are in the 100-year floodplain (Dalton et al, 2013). Most major state highways are situated high enough that given a 2' sea level rise, they would only need to be closed temporarily in the case of a rain event (Dalton et al, 2013). However, inundation of low-lying secondary roads in coastal areas is expected to worsen, at times even cutting off access to specific communities during high tide and storm events (Ibid).

Water quality: Increasing air temperatures have been shown to result in higher instream temperatures and subsequent

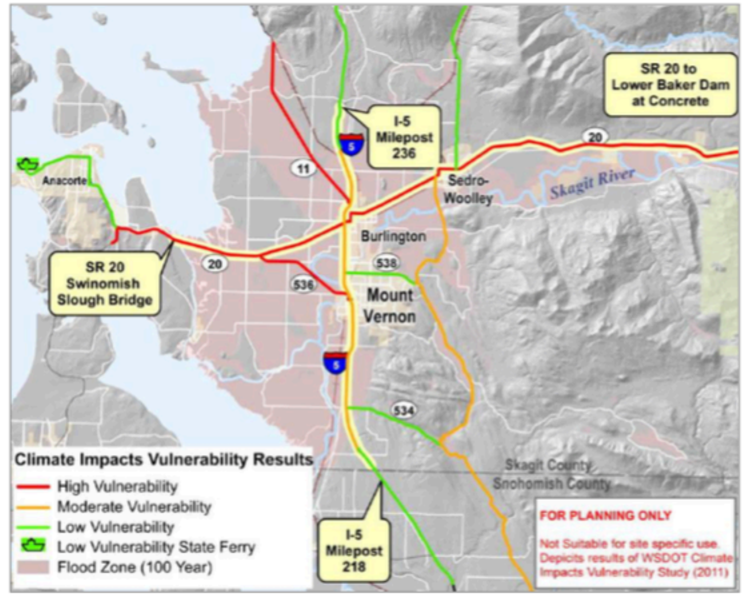
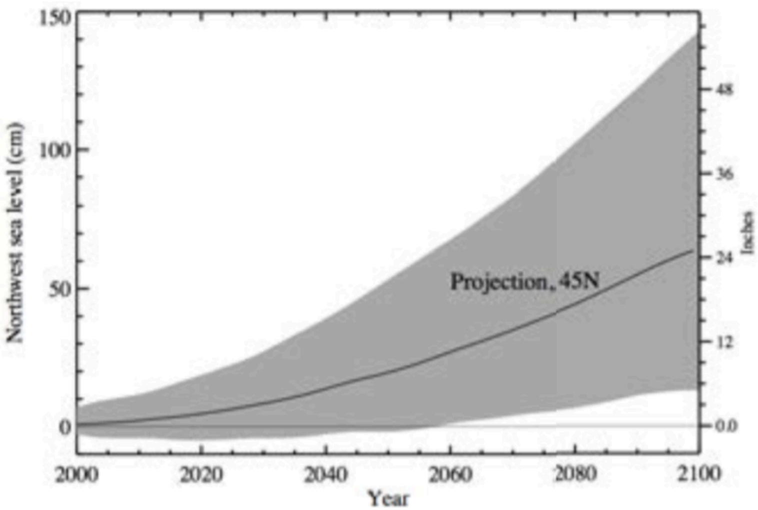


Figure 12-2. Evaluating the vulnerability of Washington State's transportation infrastructure to extreme flooding. Study area for WSDOT's Preparing Interstate and State Routes in the Skagit River Basin pilot project, funded by the Federal Highway Administration. Red lines highlight routes that are highly vulnerable to the impacts of climate change, while orange and green lines highlight routes of successively lower vulnerability. Low vulnerability classifies roads that will remain open, but may result in reduced capacity, or no impact. Moderate vulnerability classifies roads that will experience temporary closures (no more than 60 days). High vulnerability classifies roads that experience closures for more than 60 days for any one event. *Figure source: WSDOT.*[33]

decreases in dissolved oxygen levels; both of which are important factors in the health and survival of aquatic species. Meanwhile, higher peak flows and increased wildfire activity (see below) are likely to increase sediment and nutrient loads into water bodies (Dalton et al, 2013).

Sea level will rise in some places more than others: Over the last decade, the global mean sea level rose 0.12 in/year. Modelers are confident that sea level will continue to rise. Sea level along the coast is projected to rise by 4-56" by the end of the century. Local and regional factors alter the observed effect of sea level rise (SLR). Lifts in tectonic plates, as have been seen on the Olympic Peninsula counter the effects of SLR, while subsidence, as have been measured in Olympia, exaggerates the impact of SLR.



Sea Level Rise Projections. Dalton et al, 2013 based on data from NRC (2012).

Oceans will become warmer and more acidic: Ocean acidification stems from a variety of interacting factors including emissions, coastal upwelling and inputs of nutrients and organic matter. Today, the Puget Sound has some of the most acidic waters worldwide. Acidic waters have been shown to hinder the ability of some marine organisms from building shells and skeleton, thereby increasing their mortality and morbidity. Many of these organisms are essential components of ecological processes supporting coastal marine systems, fisheries and aquaculture (Dalton et al, 2013).

Ocean temperatures off the coast have been warming and are expected to continue to warm. The effect of warming is highly variable. Changes in water temperatures may cause shifts in the distribution of marine species, and increase the frequency of harmful algal blooms.

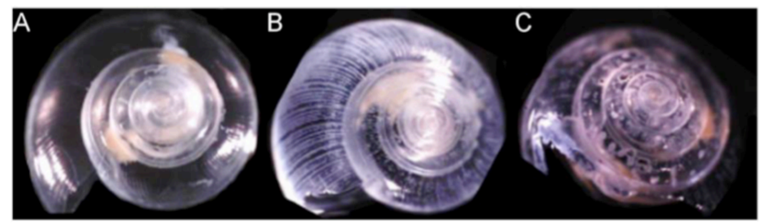
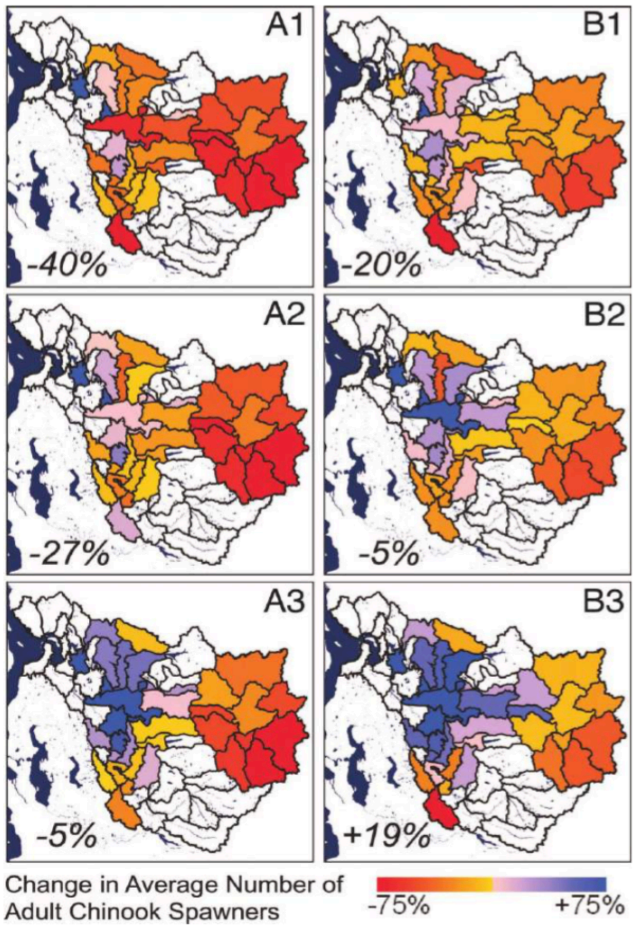


Figure 11-2. Ocean acidification is projected to reduce shell formation and increase shell dissolution in pteropods. Pictures of pteropod (sea snail) shells in aragonite saturation state levels of (A) 1.59 (current summer suface conditions), (B) 0.56 (current surface conditions during upwelling), and (C) 0.28 (projected future surface conditions during upwelling) showing corrosion and shell perforations. Pteropods are an important prey species in the Puget Sound marine food web. *Figure Source Busch et al. 2014.*[28]

Lower Hydropower capacity in the late spring and summer, but potential for higher winter production: Washington produces 40% of the country's hydropower. Hydropower facilities depend on inflows to generate power; greater flows can result in more power if the facility can handle it, while lower flows can reduce capacity. Climate-based shifts in streamflow are expected to reduce spring and summer opportunities for power generation by about 15% by 2040, while winter production may rise by about 4% (Dalton et al, 2013).

More stress on salmon and other fish: Hydrologic changes to streams may harm the spawning and migration of salmon. As streams warm, the health and extent of habitat for may aquatic species is expected to decline. Salmon, and other species that currently live in conditions near the upper range of



Changes in Average Number of Adult Chinook Spawners. Battin et al, 2007.

their tolerance for warm waters are particularly vulnerable. Higher stream temperatures may increase disease and mortality. Salmon may further be blocked from migrating upstream if water levels are too low in summer streams (Dalton et al, 2013).

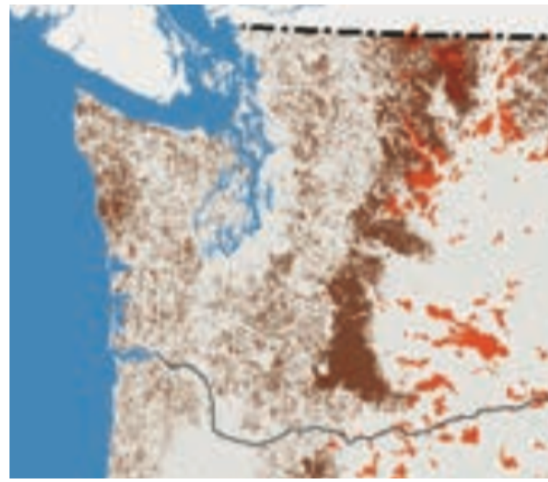
Less snow for skiing, summer water sports affects: Water sports may be impaired by dry summer conditions (boating), reduced snowpack (skiing), and lower salmon stocks (fishing). Mid-elevation ski resorts will be the most affected, shortening the ski-season, harming the skiers and the local community that has grown dependent on the tourism (Dalton et al, 2013).

Coastal marine habitats impaired: changes including sea level rise, erosion, saltwater intrusion, acidification, and warming temperatures could lead to the loss and decline of coastal marine habitats. Coastal wetlands, beaches, and tidal flats will be pushed in by sea level rise and coastal erosion. If these habitats don't have upland areas that they can migrate into, they will be heavily impacted. Saltwater intrusion will affect freshwater marshes and wetlands, which are home to many important species of shorebirds and forage fish. Acidification will further increase the vulnerability of shell forming species – with forecasts showing declines as high as 20-80%! Aquaculture, which will be directly affected by acidification, provides 72% of the commercial fishing value in Washington. Some species, like sea grasses, may actually benefit from acidification.

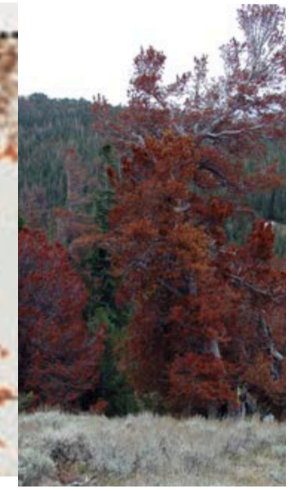
Forests species will migrate upland when possible, and will be more vulnerable to pests and diseases outbreaks: The distribution of many northwest tree species may shift with warming temperatures, largely pushing species to higher elevations. Subalpine forests will likely become extremely limited. On the other hand, tree growth may increase, as long as there are sufficient water supplies. Fire activity is expected in increase as we experience warmer and drier summers. Mountain pine beetles, Swiss needle cast, and other pest outbreaks are also expected to increase due to higher temperatures and drought stress. Outbreaks are expected to be particularly strong in high-elevation forests. The cumulative effects of climate change on disturbances and the interaction between them will dominate changes in forest landscapes over the coming decades resulting in an overall increased vulnerability in most forests (Dalton et al, 2013).

Timber losses, potentially mediated by policy: The effect of climate change on timber yields is largely uncertain. There may be increases in growth, and they may be countered by water-stress and outbreaks. Timber producers are affected by local Douglas Fir and Ponderosa Pine, two commercially important species, are becoming increasingly vulnerable to pests. Forest ecosystem services, such as flood protection or water purification, and goods, such as species habitat or forest products, add wealth to society and will be affected by climate change. However, values and extent of change are difficult to isolate and quantify.

Forest dwelling species will become more vulnerable: The forests of the Puget Sound are home to many species of fish and wildlife. As the forest changes, so will the abundance and distribution of these species. Wolverines and pika are particularly vulnerable to projected loss of alpine and sub-alpine habitat. Changes in forest habitat may impact old-growth habitat species, such as marbled murrelets and northern spotted owls. Riparian forests will be affected by warming temperatures which will affect spawning and juvenile bull trout. , and affect stream temperatures and riparian vegetation important for spawning and juvenile bull trout.



Areas of recent fire (orange) and insect disturbance (brown) in the Northwest. Mauger et al 2015.



Mountain Pine Beetle. Mauger et al 2015.

A few species, such as the northern flicker and hairy woodpecker, may thrive with more frequent fires.

Warmer winters may increase the growing season for some crops, while summer water shortages may harm others: Higher temperatures and drier summers will have variable effect on different crops. Drought stress will be a major challenge East of the Cascades. Vulnerabilities depend on agricultural sectors, cropping systems and location. Irrigation demands are expected to increase in the summertime as temperatures rise at the same time that summer water supplies are reduced. This combination may exacerbate water shortages potentially reducing yields. On the other hand, warmer winters may be favorable to winter wheat and other winter crops, and increases in atmospheric CO2 may improve yields until mid-century.

Northwest wine regions are seeing longer frost-free periods and warmer temperatures, which can adversely affect their harvest. Irrigated apple production is expected to increase by 9% by midcentury, but tree fruits are vulnerable to projected reduction in water supplies (Dalton, 2013).

Health concerns lower relative to other parts of U.S., but still troubling: When it comes to public health effects, the Pacific Northwest is expected to suffer less impacts than areas further South (where temperatures are already higher). However, local factors including heat waves, changes in infectious disease epidemiology, extreme weather including fire and flooding, air pollution, and changes in allergies may all increase risks. For example, Climate change can have a negative impact on respiratory disorders, can increase the spread of vector-borne, water-borne and fungal diseases, can lead to longer harmful algal blooms, paralytic shell fish and domoic acid poisoning.

Increased drought may result in food insecurity and wild fires which affecting human health. Changes in precipitation and streamflows may lead to an increase in landslide risk, erosion, and sediment transport in fall, winter, and spring, however the rate of these risks may actually decrease in summer.

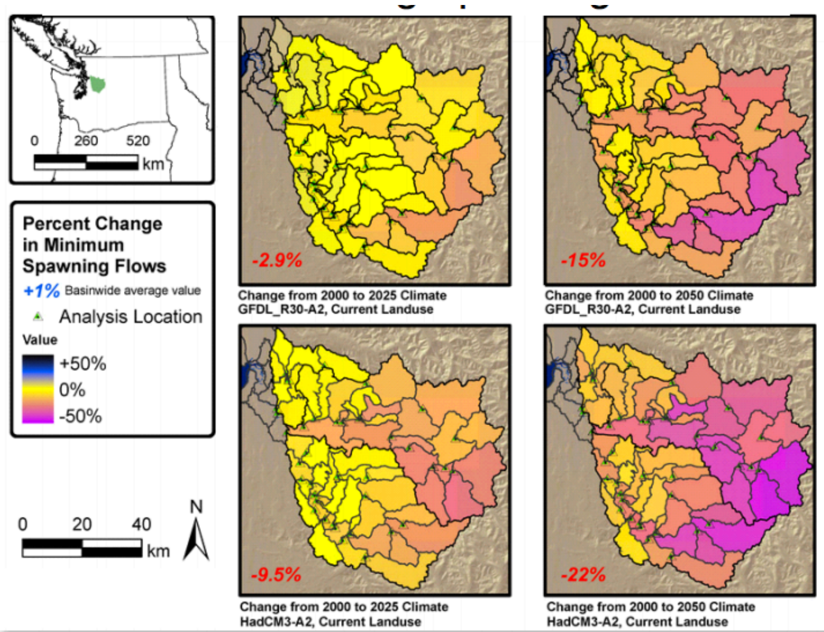
Tribes especially affected as they are tied to their homelands by law and culture: Climate change is expected to have a profound effect on tribes resources, cultures, and economics. Climate change does not recognize political or geographic boundaries. Tribal guaranteed rights for hunting, fishing, and gathering as well as water, are tied to their “usual and accustomed places”. However, climate change is shifting the distribution of those resources, potentially out of the boundaries of those rights. Climate change is expected to have a deleterious effect on salmon, which are critical to the Tribes’ culture and economy. Other species of fish and shell widely used by the tribes will be affected by acidification, hypoxia, as well as warmer air and water. Similar to other coastal communities, flood risks will increase as sea level rise, storm surge and wave heights threaten infrastructure and resources along waterways. Knowledge transfer, communication, collaboration and federal-tribal relationships have been identified as critical components of any climate plan (Dalton et al, 2013).

Ecology refers to the science of relationships between groups of living things and their environment. When examined carefully, the breathtaking beauty of the Sound's natural landscape reveals a complex and interconnected system that is critical to the support of many ecosystem functions – from water purification to biodiversity and climate regulation. Urbanization has placed pressures on these systems resulting in the alterations of essential relationships and an overall reduction in ecosystem function (Alberti, 2005). More recently, climatic changes are leading to novel pressures – from changes in streamflow to changes in migration extents (Dalton, 2013). Numerous efforts are underway to try to protect the Sound's intact natural areas. The Puget Sound Partnership, alongside the Washington Department of Ecology as well as dozens of tribes and local governments, has put together an extensive plan for how to protect and restore Puget Sound and its diversity of life (PSP, 2016). Challenges include disputes over management approaches, limited resources, continued pressures from extraction, urbanization and climate change, as well as the complexity of the system itself which often behaves in unexpected ways. In the near future, scientists expect continued degradation and the permeant loss of many habitats. However, residents, ecologists and policy makers alike hope that co-management and investments in adaptive strategies will lead to small victories and an overall slowdown in the deterioration of the Sound.

Changes in streamflow will negatively affect aquatic species: Environmental water levels affect aquatic and upland habitats. Changes in water levels may alter water quality, minimize migration patterns, and starve water limited plants and animals. Salmon are especially sensitive to changes in baseline levels of summertime streamflows as they migrate upstream. Alternatively, too much water can inundate habitats and increase pollutant loads in water bodies. Factors shaping future water levels in the basin include withdrawals, water flow regulations, and changes to the timing of precipitation and streamflow associated with climatic changes.

Instream flows are protected by the state in most but not all rivers. They are considered water rights held by the state. Instream flows are usually defined as the stream flows needed to protect and preserve instream resources and values, such as fish, wildlife and recreation. Aquifer levels also changes the amount of fresh water available to lakes, wetlands, streams and the Puget Sound nearshore, which can harm salmon at all stages of their life cycle. When more water is extracted from an aquifer than is being recharged, aquifer volume is reduced and the natural out flow from the aquifer decreases.

Withdrawals include municipal and industrial drinking water supply systems and wells, as well as agricultural irrigation. Climatic changes are expected to stress water levels at both extremes – resulting in lower summer flows (associated with decreased summer precipitation, higher temperatures, and earlier snowmelts) and higher winter flows (due to more extreme precipitation events and more rain on snow events. These changes are expected to be especially substantial in transition, or mixed watersheds, which are projected to become rain dominant watersheds by mid and late century. For example, in WRIA 7, by mid-century, higher altitude sub-watersheds are projected to see a 50% decrease in minimum flows necessary for salmon spawning (Battin et al, 2007).



Percent change in Minimum Spawning Flows. Battin et al, 2007.

Water quality is not improving despite concerted efforts: Water quality refers to the condition of water relative to the requirements of one or more biotic species and or to any human need or purpose. Quality can include the chemical, physical and biological characteristics of a water body. Under Section 303(d) of the Clean Water Act, states, are required to submit lists of impaired waters. These are waters that are too polluted or otherwise degraded to meet water quality standards (EPA, 2016). A TMDL represents a pollution "budget," including a calculation of the maximum amount of a pollutant that can occur within a waterbody. TMDL are intended to be used as a regulatory planning tool wth the aim of attaining or maintaining water quality standards. The Washington State Department of Ecology (ECY) reviews data from multiple sources to identify impairments relative to federal standards. Ecology maintains an extensive database of monitoring results for water bodies in the state with dozens of variables - from marine sediment quality to measures of specific toxics.

ECY's 2014 assessment report contains 10,175 listings for freshwaters in the Puget Sound region. Of these 1,694 listings (about 17 percent) are in Category 5 ("impaired by a pollutant or an unidentified cause"). An additional 741 listings also do not meet water quality standards but have an established cleanup plan. However, around 45% of the listings (4,583) have insufficient data to determine the water quality status. Comparing those listings whose water quality status was reported on in both 2004 and 2014 allows analysts to assess improvements. Of the 2,071 listings reviewed, only 68 (~3%) improved, mostly due to efforts to reduce fecal bacteria pollution; 236, or ~11% have degraded from non-impaired to impaired, though this may simply be due to more accurate data samples. The far majority remained impaired (PSP, 2015)

As a more synthetic account of water quality, the Annual Water Quality Index combines eight measures of water quality including dissolved oxygen, pH, temperature, and fecal coliform, nitrogen, phosphorus, suspended sediment and turbidity. Higher scores indicate better water quality. According to the Puget Sound Partnership's 2015 Vital Signs report, all 14 stations showed a decline in water quality over the past year.

TABLE 4. WATER QUALITY INDEX
2000 – 2013

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	AVERAGE
Duckabush River near Brinnon	93	95	94	90	74	94	89	85	88	96	86	89	97	95	90
Skokomish River near Potlach	95	95	94	85	70	67	92	89	89	94	86	70	88	93	86
Snohomish River at Snohomish	92	91	89	81	74	75	89	75	81	85	79	77	90	88	83
Elwha River near Port Angeles	86	88	83	76	73	74	86	67	66	81	81	76	64	61	76
Cedar River at Logan St/Renton	87	76	60	78	72	84	81	79	79	81	77	75	85	76	78
Skagit River at Marblemount	87	86	59	85	64	81	84	75	75	81	56	77	76	75	76
Skagit River near Mount Vernon	89	91	71	76	61	73	77	77	75	76	74	73	77	86	77
Nisqually River at Nisqually	40	60	79	79	69	71	74	75	91	74	83	86	86	83	75
Deschutes River at East St Bridge	62	72	70	73	61	83	88	88	83	76	74	60	84	78	75
Stillaguamish River near Silvana	81	60	44	72	55	67	71	69	75	75	71	59	81	79	69
Green River at Tukwila	82	73	66	67	75	49	72	68	60	69	63	68	75	70	68
Samish River near Burlington	86	75	32	49	34	71	67	74	59	80	63	52	78	86	65
Nooksack River at Brennan	65	68	58	57	52	54	61	51	60	69	56	55	62	61	59
Puyallup River at Meridian St	60	58	57	55	51	58	59	58	61	49	62	56	71	52	58

80 OR ABOVE | 70-79 | 40-69 | 39 OR LESS

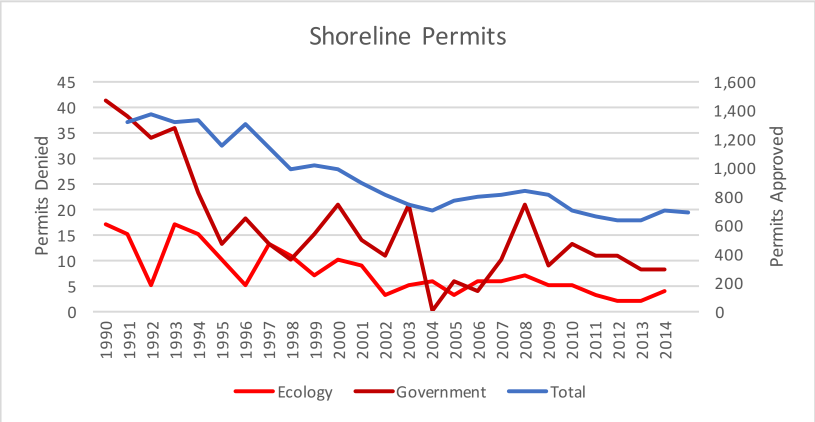
Water Quality Index. Puget Sound Partnership, 2015

Another synthetic measure is the Benthic Index of Biotic Integrity (B-IBI) which describes the biological condition of stream sites and their surrounding habitat based on the diversity and relative abundance of the benthic (bottom dwelling) macroinvertebrates living there, such as may fly larvae, stone fly larvae, caddis fly larvae, worms, beetles, snails, dragon fly larvae, and many others. Ten measures of biological condition are scored and summarized as "the B-IBI". The B-IBI scale ranges from a score of 0, indicating very poor stream condition, to 100, indicating excellent condition. A total of 398 streams were assessed for biological condition. Comparing average B-IBI scores for streams that were in excellent condition in the 2006-2009 period with the 2011-2014 period, an additional 24% lowland streams had values that declined. On the other hand, of ~100 streams that already had a fair or poor score, 30 improved and another 13 declined (Vital Signs).

In addition to direct habitat loss and point source pollution, impervious surfaces and alterations to shorelines have been shown to result in the deterioration of water quality (Alberti, 2005). High population densities lead to large amounts of impervious surfaces, such as roads and other infrastructures. From 2006 to 2011, the amount of impervious surfaces continued to increase around Puget Sound, with a common rate of increase as high as 4%. The number of road crossings also continue to negatively impact the health of aquatic life in lowland watersheds. Looking out to the near future, the projected population growth and associated land conversions will require more roads and stream crossings throughout lower portions of the watersheds. While some improvements are taking place in both forest and urban environments, it appears that development pressures thus far outweigh gains (NWFIC, 2016).

Permits for Shoreline Armoring and Dams Decline: Dams are used to generate hydroelectric energy, store water, and manage flooding. However, dams also alter the water flow of rivers and trap sediment, having a deleterious effect on deltas and embayments at the mouths of rivers and streams. Another engineering approach to manage flooding is to armor shorelines, preventing river overflows or ocean tides from reaching developed lands. Like dams, shoreline armoring also has a deleterious effect on habitat, eliminating essential riparian buffer and reducing sediment transport

Since the 1800s, the amount of artificial shoreline in the Puget Sound has increased by 3,443% (Simenstad et al., 2011). Over a quarter of the Puget Sounds' shoreline, and over 60% of the Central Puget Sound shoreline, has bulkhead or riprap along it (Simenstad et al., 2011 as noted in Rice et al, 2015). To manage this impact, Ecology now requires permits for armoring shorelines. Shoreline armoring continues to occur in Puget Sound, potentially damaging shoreline habitat. However, for the first time, results from permit data suggest that shoreline armoring is slowing down and that more armoring was removed than added in 2014 (PSP, 2015). Over the last 25 years the number of approved permits (blue) has been cut in half. It is important to note that the number of denied permits, already low, has declined dramatically in the same period. This may be because governments have become more relaxed, or



Shoreline Permits in Washington State 1990-2014. OFM, 2015b.

that developers have become more knowledgeable (OFM, 2015b).

Climate will have a deleterious effect on water quality: Climate changes are forecasted to alter water quality in both fresh and marine waters (Mauger, 2015) Observations show a clear *warming* trend, and all scenarios project continued warming during this century. Sea surface temperatures will increase as a combination of increasing air temperatures which will result in more precipitation falling as rain instead of snow, leading to more freshwater inflows into Puget Sound during winter months, and decreased freshwater inflows during summer. In addition, increasing air temperatures are expected to drive a continued increase in water temperatures. Warmer water temperatures will likely increase the frequency, severity, and season length of Harmful Algal Blooms (HABs). Ocean acidification may increase the toxicity of some HABs.

The *salinity* and *dissolved oxygen* levels of Puget Sound's waters is strongly related to surface freshwater inflows from rivers. They are also linked to human nutrient inputs. Between 1960 to 2009 dissolved oxygen levels declined by -25%. Model simulations comparing 1999-2008 and 2065-2069 dissolved oxygen levels show an overall decline by more than -0.6mg/L in Central Puget sound and Hood Canal. These changes combine the effects of both warming and nutrient inputs.

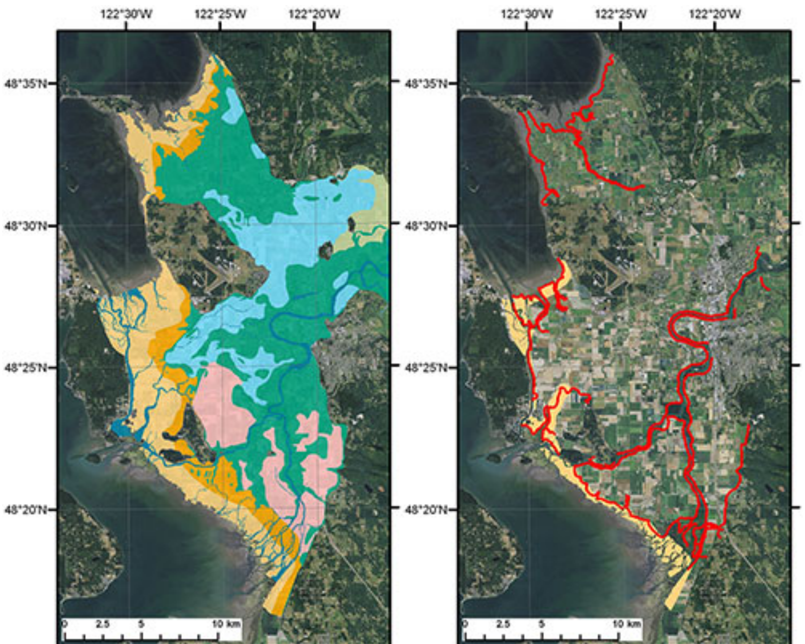
Changes in the timing and amount of river flows may affect the ability of Puget Sound's surface and deep waters to mix. *Ocean upwelling* may change, but projections are not conclusive. Short term variability in upwelling (ranging from seasons to decades) will likely be more important than long term changes related to global warming throughout the 21st century. Coastal upwelling brings nutrient-rich (nitrate, phosphate, silicate) water into the Strait of Juan de Fuca and Puget Sound. These nutrients promote phytoplankton blooms and biological productivity. Upwelled waters are also low in oxygen and high in CO2, which can stress fish and be harmful to calcifying species (e.g., shellfish). Seasonal upwelling is also a major driver of changes in salinity, oxygen, and nutrients in Puget Sound. There are no projected changes for *wind* speed or the strength of low pressure systems in the region. Wind patterns affect upwelling, mixing, and currents within Puget Sound, all of which have an influence on water quality.

The chemistry of the ocean along the Washington coast has changed due to the absorption of excess CO_2 from the atmosphere. *Ocean acidification* occurs when the pH of the ocean decreases (acidity increases) due to the uptake of CO_2 from the atmosphere. Ocean acidification is increasing (pH decreased by -0.1, a 26% in hydrogen ion concentration since ~1750) and will continue to increase (pH is projected to decline by -0.14 to -0.32, a +38 to +109% increase in hydrogen ion concentration. Increase in nutrient runoff and built structures further drive ocean acidification. The PMEL research team has estimated that ocean acidification accounts for approximately a quarter to half of the pH decrease in the deep waters of the Hood Canal sub-basin of Puget Sound relative to estimated pre-industrial (before 1800) values (Feely et al, 2010)

Wetland loss continues despite state law: Wetlands perform multiple essential functions including flood control, groundwater recharge, water filtration and purification, erosion control, wildlife habitat, recreation, research and education, and support the regional economic vitality. Approximately 2% of the state's area is covered by wetlands – which is 70% less than the 1.35 million acres that covered the state in the 1780s (ECY, 2016). Over the last 150 years, the region has suffered dramatic losses of intertidal wetlands. Of the approximately 62,000 acres of mapped historical swamp and marsh, only an estimated 14,640 acres remain (ECY, 2016).

On Dec. 12, 1989, Gov. Booth Gardner announced that half the state's wetlands were already gone, and 2,000 acres more were vanishing each year. In an effort to stop the loss he issued an order that for each wetland paved, another would need to be created to replace it - i.e. "no net wetland loss" (ECY, 2010). Both the State Water Pollution Control Act and the Shoreline Management Act, give Ecology the authority to regulate wetlands through the issuance of permits. However, twenty years later, Gardner's order has not been effective. Regulatory and political challenges to protecting wetlands include varied and contradictory regulations, failed experiments (new science), and weak or nonexistent oversight (Welch and Mapes, 2008). According to the Puget Sound Partnership's 2015 report, more than 2,000 acres of estuarine river delta wetlands have been restored over the last decade. However, these projects have thus far been insufficient to counter additional and historic loss.

Whereas historic wetland loss stemmed from agriculture and industry, and later development, increasingly the health and resilience of wetlands is shaped by management and modification of rivers and as dams and reservoirs stave tidal wetlands from sediments. As noted above, direct habitat losses still occurs, but more subtle indirect effects have grown in importance (PSP, 2015). For example, groundwater extraction for development decreases recharge in aquifers, which decreased natural flows, which then alters the freshwater inputs into lakes, wetlands and streams (NWIFC, 2016).



[Skagit River delta wetland loss](#). Aerial photograph of the Skagit River delta, in the Puget Sound area of Washington, superimposed with geographic information system (GIS) data that illustrate changes between 1850 (left) and 2010 (right). In 1850 the delta included extensive wetlands providing important habitat for salmon spawning (orange). By 2010 most of the delta had been "reclaimed" for development by a system of dikes and levees (red), greatly reducing the habitat available to salmon. Left: courtesy of Brian Collins, University of Washington. Right: Eric Grossman, USGS.

Both freshwater and tidal wetlands are projected to be affected by climate changes. *Freshwater* wetlands are threatened by declining snowpack and summer precipitation, and increasing evaporation, all of which contribute to the decline in water availability, especially at high elevations. Montane, or high altitude, wetlands are projected to be highly sensitive to climate change. The extent of montane wetlands is projected to decline due to both the reduction in winter snowpack and earlier spring melt (which are projected to increase the frequency, magnitude, and duration of wetland drying in the summer). Shifted streamflow peaks due to snowmelt may also affect floodplain wetlands. Lastly, sea level rise is projected to change the area of freshwater wetlands close to coasts – by between 0 and -29% for freshwater marshes and -33 and 3% for freshwater swamps by 2100 (relative to 1980-1999)(Mauger et al, 2015).

The extent of change in *tidal wetlands* depends on their type and the rate of sea level rise, as well as sedimentation and the availability of landward buffers into which to migrate. Sea level rise may expand the area of some tidal wetlands, while reducing the size of others. Salt marsh areas may increase by 260% (models estimate a large range, from +49% to +4300% depending on location). By 2100, the Sound may see 70 times more transitional marsh and a 240% increase in tidal flats. Meanwhile estuarine beach areas may be reduced by 79% (or as much as 96%), brackish marsh reduced by 57%, tidal swamps by 77% and tidal freshwater marshes by 4%. Sea level rise may also alter the composition of many wetlands. More than half of the Sound's brackish marshes may transition to become tidal flat, salt marshes, or transitional scrub shrub, while 2% of currently undeveloped dry land is projected to become inundated, eroded and converted to a wetland (Dalton et al. 2013).

Climatic changes will also shape the *species* and food cycles of wetlands. For example, cold-blooded species such as wetland amphibians are highly sensitive to climate. Some populations may become too dry, resulting in increased mortality, reduced growth, and other negative effects. When possible, amphibians may try to migrate north. Water losses are further projected to effect wetland habitat and cause increased desiccation stress. Climatic changes may alter food web dynamics by altering the natural relationship between relative predator and prey abundance (Mauger et al, 2015).

Wetlands are increasingly viewed in terms of their *carbon* storage potential. A recent study in the Snohomish River estuary suggests that CO_2 sequestration per hectare in these marshes (approximately 800 to 1,000 tons per hectare) exceeds that of nearby mature Pacific Northwest forests (200 to 700 tons per hectare), considered the most carbon-dense forests in the U.S. (NOAA, 2016). If these wetlands were restored before sea level rises in next 100 years, there is significant potential to double the amount of carbon sequestered in the marshes (Ibid).

River systems shaped by changes in streamflow and pollution: A century ago, dozens of rivers in the Puget Sound – from the Duwamish to the Snohomish - experienced significant alterations to make room for agriculture, industry, and hydropower (River History Project). The challenges facing the future of Puget Sound's river will likely be subtler, more indirect, and harder to control. While rivers are still affected by the loss of riparian habitat and shoreline alterations, the quality and timing of streamflows due to indirect pressures as well as water quality issues, are increasingly affecting rivers' viability. Urbanization has a more dramatic effect in the Puget Sound lowlands, while climate change dominates in higher elevations.

Riparian forests are an essential component of healthy fish habitat as they provide shade, temperature regulation, streambank stability and food supply. Despite projects to protect and revegetate riparian buffers, forests along salmon bearing streams continue to decline. Clearcuts, inadequate buffers, and poorly constructed forest roads can all degrade salmon habitat with agricultural practices largely seen as the dominant driver for these degradations (NWIFC, 2016). Land use as well as forest and river management practices have resulted in extremely decreased quantities of large dead wood and woody debris in Western Washington's riparian forests (NWIFC, 2016). Large woody debris plays an important role in channel stability, habitat diversity, and overall habitat quantity and quality. Wildlife species depend on large dead wood for nesting, roosting, or foraging (DNR, 2015). The Puget Sound area consists of 425 6^{th} level Hydrologic Units (HUCs), 303 of which are unprotected (i.e. outside the USFS, National Park System or Wilderness Area designation). The riparian forests within these unprotected HUCs is "fairing badly", with only 16.8% rated as "properly functioning" in 2011, down from 18.8% in 2006 (NWIFC, 2016).

Nearshore vulnerable to multiple stressors: Nearshore ecosystems represent the transitional area between land, freshwater, and the marine waters of Puget Sound (Simenstad et al, 2011). Their location, as a transitional zone between ecosystems makes them especially vulnerable to human impacts, and being on the waters' edge, they are often the focus of human uses that conflict with natural systems. Nearshores are vital for multiple functions including shoreline protection, nutrient cycling, recreation and habitat. Nearshore ecosystems are also considered nurseries as they are highly productive and support a great abundance and diversity of fish (Ibid).

The Sound's nearshore has been significantly impacted by human use and development over the past century. The Puget Sound Nearshore Ecosystem Restoration Project (PSNERP) has identified and quantified shoreline alterations impairing nearshore processes. Major stressors to nearshore viability include shoreline armoring, railroads and roads, marina, breakwater and jetties, overwater structures, dams, stream crossings, impervious surfaces and land cover development (Simenstad et al, 2011).

Over the past two century, the Puget Sound's shoreline has become shorter (15% reduction in length) as well as simpler, and significantly more artificial (1,062 km of natural shoreline was lost while 368 of artificial shoreline was gained) (Simenstad et al, 2011). Today, nearly half of the Sounds' shoreline has been altered by one or more stressors. Many places have experienced widespread, multiple, and compound changes. Forty percent of the shoreline of Puget Sound has been altered by one or more stressors. Armoring, the most dominant stressor in Puget Sound, is found along more than a quarter of the shoreline in the Sound (Simenstad et al, 2011). While the pace of additional shoreline armoring has declined, the uplands continue to be developed, altering land cover patterns and increasing the extent of impervious surface areas, which than alters the timing and quality of flows. Urbanization, including development and transportation systems, continues to pollute the nearshore system with nutrients and heavy metals. Fishing and aquaculture activities may have negative impacts on fish and other aquatic wildlife populations (Simenstad et al, 2011).

Climatic changes may further alter natural nearshore ecosystems. Sea level rise and more extreme coastal storm events will add increasing pressure on these vulnerable systems. Climate change may also alter circulation and flow patterns, leading to changes in the salinity gradient, a decline in water quality, and ultimately an overall impairment of habitat (Mauger et al, 2015). As coastal and riverine flooding become more severe, historic policies to limit flood protection measures with deleterious effects on the nearshore may be overturned in support of social and economic benefit, including public safety.

Natural Shoreform

Artificial Shoreform

Marine waters may see devastating changes: The waters of the Puget Sound are considered "the jewel of the Pacific Northwest" (ECY, 2016). However, the Sound is challenged by pollution, habitat degradation, pressure on water supplies and a changing climate (Ibid). While numerous agencies have as their core mission to monitor and improve the state of the sound, many of the challenges are rooted in global and historic trends that are difficult to alter regionally.

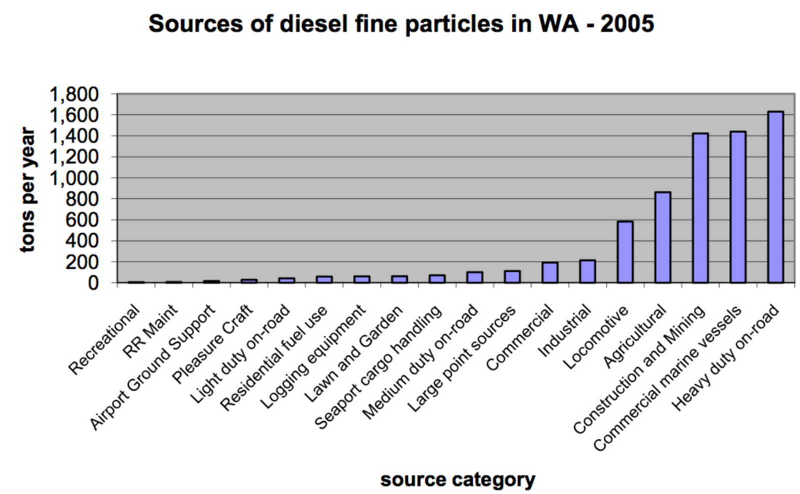
In marine ecosystems, climate is projected to result in warmer temperatures, loss of coastal habitat, ocean acidification, and changes in water quality and freshwater input with differential effects on different organisms. Some species, like salmon and shellfish, are likely to be negatively affected by these changes; other species, such as eelgrass, may benefit (Mauger, 2015). The Marine Waters Workgroup is a technical workgroup of the Puget Sound Ecosystem Monitoring Program, aimed at regional monitoring and assessment to assess progress towards the recovery of the health of the Puget Sound. Their annual investigation showed the influence of warmer water on marine species composition and distribution. Observations include a change from cold water to warm water zooplankton taxa, a shift in the migration pattern of Sockeye Salmon, and mass mortalities of juvenile Cassin's Auklets (a plankton feeding seabird) (Chandler et al, 2015).

Ocean acidification is a relatively new challenge for the Puget Sound. Ocean acidification refers to a reduction in the pH of seawater for an extended period of time due to the uptake of carbon dioxide from the atmosphere by the ocean (Washington State Blue Ribbon Panel on Ocean Acidification, 2012). Since the beginning of the Industrial Revolution the pH of surface ocean waters has fallen by 0.1 pH units, approximately a 30% increase in acidity (PSEMP , 2014). The outer coast of British Columbia has naturally high acidity which makes this region naturally vulnerable to acidification (Ianson, 2015). Because of the highly dynamic circulation, these waters also experience large variability in carbon content and pH (Ianson and Allen 2002, Haigh et al. 2015). While many aspects of climate remain uncertain, the chemistry of increasing CO_2 in the ocean is certain (Doney et al 2009). Future predictions indicate that oceans will continue to absorb carbon dioxide and become even more acidic. The current rate of acidification is nearly ten times faster than any time in the past 50 million years! Under a "business as usual" emission scenarios, by the end of this century the surface waters of the ocean could be nearly 150% more acidic (PSEMP, 2014). (Washington State Blue Ribbon Panel on Ocean Acidification, 2012).

Ocean acidification has an especially large impact on the shellfish aquaculture industry. More than 30 percent of Puget Sound's marine species are vulnerable to ocean acidification by virtue of their dependency on the mineral calcium carbonate to make shells, skeletons, and other hard body parts. Puget Sound *calcifiers* include oysters, clams, scallops, mussels, abalone, crabs, geoducks, barnacles, sea urchins, sand dollars, sea stars, and sea cucumbers. Even some seaweeds produce calcium carbonate structures (Washington State Blue Ribbon Panel on Ocean Acidification, 2012). Between 2005 and 2009 Pacific Northwest oyster fisheries experienced mass failures – billions of oyster larvae were dying at the hatcheries. The cause was the arrival of low pH seawater creating condition corrosive to shell-forming organisms like oysters (Chandler et al, 2015).

In addition to efforts to reduce emissions on a global and local level and carefully monitoring change, various Sound initiatives are aimed at minimizing the effect of ocean acidification. There are efforts to reduce local land based contributions to ocean acidification (including non-point source pollution). Other efforts aim at increase the ability of ocean communities to adapt, and engaging stakeholders to better understand and respond to changing conditions. The Puget Sound Restoration Fund, NOAA's Northwest Fisheries Science Center, and UW's Applied Physics Laboratory are leading an effort to cultivate kelp sporophytes as a potential strategy for mitigating ocean acidification. The hope is to harness seaweed, or marine macro algae to create "protective halos" in their vicinity which provides critical habitat for marine species as well as by-products such as food. Bio-fuels, and fertilizers (Puget Sound Restoration Fund, 2015).

Air quality effects are not distributed evenly across the population: pollution tends to be higher in urban areas, and disproportionately affects Washington's black, Asian, and Native Hawaiian and other Pacific Islander residents as they are more likely to live in urban areas (DOH, 2014). Local sources of air pollution such as car and diesel vehicle exhaust, non-road vehicles and equipment, wood stoves, fireplaces, outdoor burning, wildfires and industrial facilities cause most air quality problems in Washington. People living closer to these sources are likely to have higher exposure to pollutants than those who live farther away. Infants, children, the elderly, and people with lung disease, cardiovascular disease or diabetes are especially vulnerable to polluted air. Studies indicate that air pollution from PM, especially PM2.5, is associated with decreased lung development in children and with lung and cardiovascular disease in adults.



Diesel Exhaust Report. WA Department of Ecology, 2005

Air monitoring provides information on a small number of pollutants, and findings are highly accurate only at short distances from the monitors. Under the Federal Clean Air Act, the U.S. Environmental Protection Agency (EPA) sets health-based National Ambient Air Quality Standards (NAAQS) for six pollutants called criteria pollutants: carbon monoxide, lead, nitrogen dioxide (NO2), ground level ozone (ozone), particulate matter (PM) and sulfur dioxide (SO2). The most extensive monitoring in Washington is for levels of particulate matter less than 2.5 microns in diameter (***PM2.5***) and ***ozone*** because these pollutants are most likely to be present in Washington above levels known to impact health. In addition to criteria air pollutants, the EPA regulates emissions of 187 hazardous air pollutants (***HAPs***). Fine particulate air pollution can vary from year to year due to weather patterns, pollution sources, and natural events such as wildfires. Climate change is projected to worsen air pollution. The Center for Disease Control (CDC) sets 10-year national objectives for improving air quality. Their 2010 goal was to reduce the number of days the AQI-weighted (Air Quality Index) people days exceeds 100 on the AQI by 10% nationally. In Washington, there were 16,740,000 people days in 2011 that exceeded 100 on the AQI scale for PM2.5 and ozone. Washington would need to reduce this to 15,066,000 people days to achieve a 10% reduction by 2020 (CDC, 2010).

In 2006, the EPA made the standard for PM2.5 more stringent, from 65 to 35mg/m3. Subsequently, for the next three years the Tacoma-Pierce County area had not met the 24-hour standard and the area became declared as "non-attainment" in 2009. Since 2009, with the help of local authorities and the ECY, the area has met the standard. The communities of Darrington, Ellensburg, Marysville, Olympia, Yakima, Vancouver and Wenatchee all have high levels of PM2.5 and are at risk of becoming non-attainment in the next few years (DOH, 2014).

Air quality will worsen. Transportation continues to be the leading cause of air pollution; climate will increase impacts: Cars and trucks account for more than half of the air pollution from criteria pollutants in Washington State. In addition to PM2,5, cars and trucks are responsible for producing ground level ozone, a respiratory tract irritant that can cause premature aging of the lungs and aggravation and development of asthma. Ozone pollution is carried long distance by wind, and can therefore affect large areas. It is also more elevated on hot and sunny days. Climate change is expected to increase ozone levels by 16% in Spokane and 28% in King by mid-century (DOH, 2014).

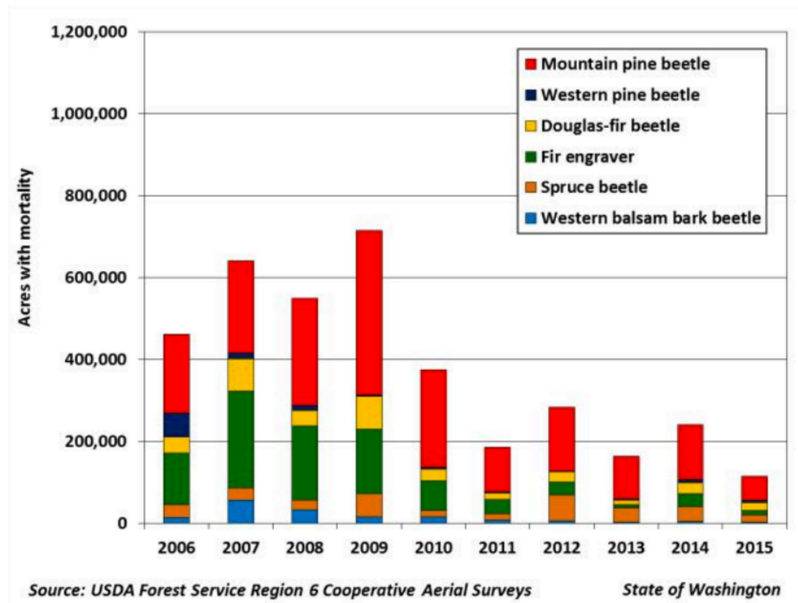
The Washington Tracking Network provides tracking data for Ozone levels. All eight counties being monitored in WA (Clallam, Clark, King, Pierce, Skagit, Spokane, Thurston and Whatcom) are currently meeting federal air quality standards for ozone. The EPA revised the eight-hour standard (the average concentration levels in an eight-hour period) for ozone in March 2008 from 84 to 75 parts per billion. Recent studies support further strengthening this standard as it may not be protective enough of public health. As a result, EPA is currently reviewing this standard and may propose to further strengthen it in 2014 (DOH, 2016b).

The EPA has developed rules to regulate various categories of industrial sources of ***HAPs***. States also have authority to regulate toxic air pollutants for new industrial plants or facilities, or when existing facilities are modified. Ecology and regional and local clean air agencies regulate approximately 400 toxic air pollutants—including most of the HAPs—by specifying the minimum air emission control technology for sources, such as factories. Ecology considers diesel exhaust, measured as diesel particulate matter (DPM), as a particularly important air pollutant in Washington and calls it a toxic air pollutant (TAP). Ecology ranked DPM as their highest priority TAP due to its potential to cause cancer and other adverse health effects.

The EPA released the most current National Air Toxics Assessment in 2011, based on 2005 data. They identified 3,100 regions (census tracts) nationally with cancer risks >100/million which include 17 tracts in King County. The data includes 177 hazardous air pollutants (HAPs), but no diesel particulate matter (DPM). Ecology conducted the same study with DPM and found an incidence of 1,000 additional cancers per million in those 17 tracts, as well as additional tracts in Pierce and King Counties. In 2007 Ecology estimated than at least 70% of cancer risk associated with toxic air pollutants stemmed from diesel exhaust. The risk level increased to 80% in 2011. Some HAPs, like Benzene are decreasing, likely due to improved vehicle emissions standards and cleaner fuels.

Forest health may decline due to pests, wildfires, and development pressures: Various factors in Washington State support stressors for managing forest health. Drought conditions coupled with higher temperatures during the growing season tends to increase tree stress and insect success. According to the US Drought Monitor, 2015 was the worst drought year out of the last 16 years for Washington (DNR, 2015). Fragmentation and increased disturbance also makes forest land more susceptible to invasive exotic and aggressive native organisms. Nonnative invasive plant species already are well established in Washington's forests. The greatest insect or disease-related changes in Washington's forests are likely to come from introduced organisms, although native pests can become a problem in response to drought, changes in stand density, or climate. Forest land is being converted to other uses throughout Washington, but particularly near urban areas in the Puget Sound (DNR, 2015).

The US Forest Service monitors tree mortality, defoliation, and folia disease on Washington's forestlands (DNR, 2015). In 2015 around 338,000 acres were designated as "affected". Importantly, 1.5 million acres in Eastern Washington were not surveyed because of recent wildfires. For those forestlands surveyed, mortality was largely attributed to bark beetles, and to a lesser degree, bear damage and root disease. Almost all defoliation recorded was caused by western spruce budworm and balsam woolly adelgid. Other disease damages stemmed from big leaf maple decline and needle casts in pines and



Ten-year Trend of Tree mortality attributed to bark beetles by annual aerial survey in Washington, 2006-2015. DNR, 2015.

western larch. The Forest Service maintains an active list and description of pests and their territory (DNR, 2015).

Forecasted climatic changes are expected to further impinge on forest health in Washington in general and the Puget Sound in particular. Vulnerability to disturbances is expected to increase in most forests. Forest diseases such as mountain pine and spruce beetle outbreaks, and Swiss needle cast are expected to increase.

Overall, climate changes are expected to exacerbate existing stressors on forest ecosystems. According to a 2013 publication by CIG, the spatial distribution of suitable climate for tree species may change considerably, making some forest types, such as subalpine forests, extremely limited (Dalton et al, 2013). Tree growth, as a response to temperature changes, will vary considerably within the region. In general, forests already limited by water availability will see decreased growth, while those currently limited by energy and temperature may see increased growth. The loss of alpine and sub-alpine forest will make wolverine and pike more vulnerable; increased fire incidence can negatively influence old growth species such as marbled murrelets and northern spotted owls, as well as raise stream temperatures for spawning and juvenile bull trout. On the other hand, the northern flicker and hairy woodpecker may thrive with more frequent fires.

Natural and technological **hazards** threaten Puget Sound's citizens and communities and can result in substantial economic hardships. Awareness and preparation for hazards can reduce impacts. Hydrologically affected hazards (e.g. floods, drought, landslides, and wildfires) are increasing, due both the increased urbanization (alterations to local flows) and climate change (alteration to seasonal flows and circulation patterns). In addition to hydrologically-affected hazards, the Puget Sound is threatened by seismic, human, and technological hazards. While the costs of damages and disaster management is rising exponentially, the number of mortalities associated with disasters continue to decline.

Climate and urbanization will increase flood risks. Due to population densities and coastal location, the Puget Sound has the highest cost of flood impacts in the State: Since 1970, every county in Washington state has received a Presidential Disaster Declaration for flooding. Counties within the Puget Sound basin are at the greatest risk for flooding in the state. Ecology and FEMA partnered to produce a watershed-based (HUC-8) risk assessment that takes into account population density, NFIP policies and claims, and % area in the floodplain (ECY, NA).

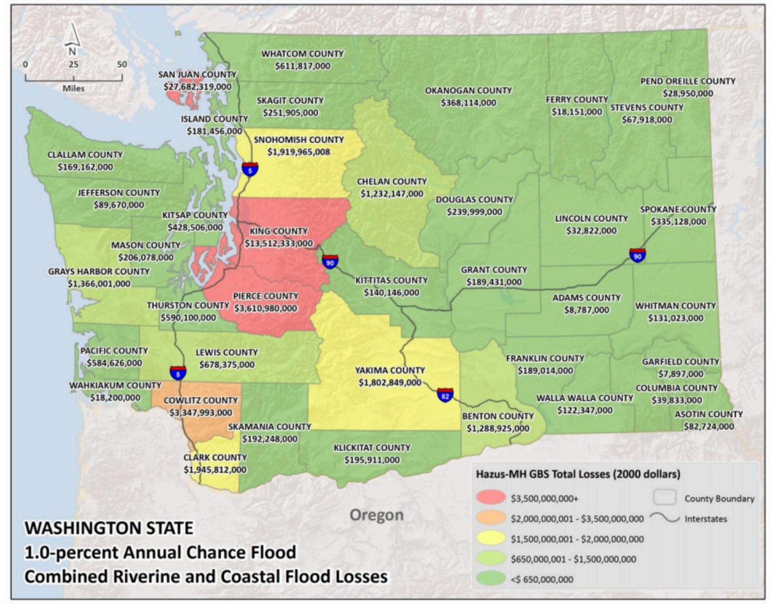
The cost of flooding in the Puget Sound has been disastrous, especially as over 28,000 structures have been built within the watershed's floodplains even after the inception of the National Flood Insurance Program (NFIP)(ECY, NA). Since 1990, the Puget Sound has experienced 16 federally declared disasters; 58 lives were lost; more than $1.4B in damages have been paid by taxpayers (Ibid). According to HAZUS models, if King County would be hit by a 1% annual chance flood today, losses would total over $13B (MIL, 2013).
Flooding in the Puget Sound can stem from overbank flooding from rivers and streams, coastal storm surge flooding, local stormwater drainage flooding (or "urban flooding"), flooding from failures of dams, reservoirs, and levees, as well as flooding from subsidence, and tsunamis (MIL, 2013). Coastal risks are further tied to riverine influences where high tides are combined with high flows from riverine systems and concentrated low pressure storms. Another unique issue in this watershed is groundwater flooding - when wet conditions persist for much more than a year (ECY, NA).

The magnitude of most floods in Washington depend on the particular combinations of intensity and duration of rainfall, pre-existing soil conditions (e.g., was the ground wet or frozen before the storm), the size of the watershed, elevation of the rain or snow level, and amount of snow pack (MIL, 2013). Climatic changes - including extreme precipitation, intense coastal storms and wind storms, and sea level rise - are expected to increase flood risk in the region. Changes in flood risk and their sensitivity to climatic change depend on the type of basin (see Climate Change). Relatively warm rain-dominant basins (>5 °C (41 °F) average in midwinter) show little systematic change. Mixed rain-snow basins show high sensitivity but no universal direction of change, with changes that range from a 30% decrease to a 30% increase in flood magnitude (Hamlet and Lettenmaier 2007). Model simulations indicate that the largest projected increases in flood magnitude and frequency are in mixed rain-snow watersheds during the winter (Mantua et al. 2010). Warmer winter temperatures and increased precipitation variability have already increased winter flood risk in these basins (Mauger et al, 2015).

Flood impacts pose risks to developed areas in floodplains including urban areas, roads, stormwater systems, and infrastructure at water crossings such as pipelines, bridges, and culverts (Dalton et al, 2013). Heavy rainfall can also saturate soils and increase risk of landslides, particularly in areas with unstable slopes or disturbed vegetation (Dalton et al, 2013). Flooding and erosion along forest road networks may damage culverts and generate increased sediment loads that can affect salmon and steelhead spawning, migration, and rearing habitat (Dalton et al, 2013). Flooding may increase the threat of communicable diseases due to standing and contaminated water, crowded evacuation centers, and lack of clean water to wash and bathe with (Watson et al. 2007).

In Washington, nationally, and globally, the cost of flooding is rising and is expected to continue to grow. Analysis by EM-DAT shows a nearly exponential growth in flood damages ($) between 1903 and 2014, and an increase in the number of occurrences as well (though this might be due to better reporting) (CRED, 2016). Recent forecast models estimate future flood costs to more than triple if climate change and development go unchecked (Hallegate, 2013). By 2030 Washington is expected to be among the 10 states most at risk for flooding (Casey, 2015). There are several strategies designed to reduce flood impacts – e.g. minimizing development in the floodplain, building hard and soft infrastructure to protect built up areas, and supporting residents through insurance programs.

Figure 8 Hazus-MH 2.1 General Building Stock Loss Estimates for the 1.0-percent Annual Chance Riverine and Coastal Flood Impacts

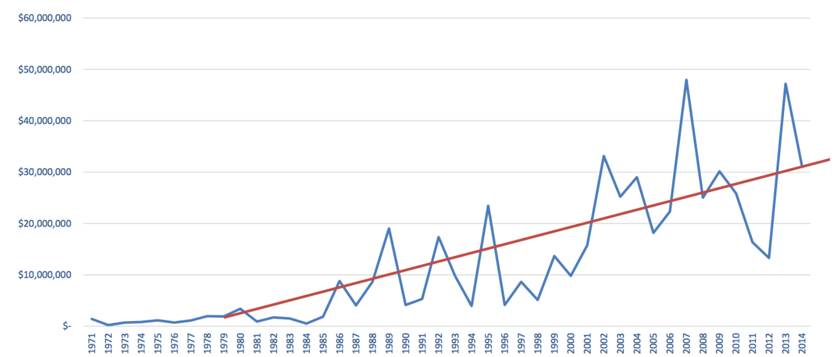


Damages associated with a 1% Annual Chance Flood per County. MIL, 2013.

Despite wetter winters, fall and spring, drier summers may lead to increased risk of drought: Unlike most disasters, droughts come on slow and last a long time. Most of the Puget Sound is categorized as having a low to moderate susceptibility, while drought risks in the Eastern part of the state are "exceptionally" high (MIL, 2012). Droughts can lead to wildfires and massive destruction of agricultural crops (MIL, 2012). Although a majority of climate models project increases in winter, spring, and fall precipitation, a majority also project decreased precipitation in the summer, which combined with temperature-driven loss of snow can lead to increased frequency of drought conditions (Dalton et al, 2013).

Landslides becoming increasingly urgent: Washington is one of the most landslide prone states in the country, with hundreds to thousands of landslides occurring each year (DNR, 2016). Washington's Department of Transportation budgets around $15 million a year for road repairs alone. In addition to road repairs, landslides result in direct and indirect costs to property and tax revenues, as well as environmental degradation, especially water quality (DNR, 2016). Three major determinants of landslide risks are populations and infrastructure at risk (the more investments, the greater the risk), the frequency and intensity of storm events, and forest stand age (where longer rotations increase stability)(DNR, 2016). As our population expands into hilly and mountainous rural forests and agricultural lands, and climate projections forecast more extreme precipitation events, understanding landslides is becoming increasingly urgent.

Costs and frequency of wildfires is growing exponentially: 2015 was the most severe wildfire season on record with over 1 million acres of forest land burned; around 3 times the record setting 2014 season (DNR, 2015). While the number of fires in the State have remained fairly constant since 1988, the total acres burnt have grown significantly. Over 100,000 acres have been lost per year in the last three years (as compared to an average of 40,000 over the last three decades). Over 350,000 acres were lost in 2014 alone - a record high (OFM, 2015). The cost of suppressing fires in Washington has grown exponentially from an average annual cost of around $2M between 1971- 1984 and is projected to continue to climb to over $35M in the last 15 years. Over the last ten years the state has experienced two record breaking seasons where nearly $50M was spent (House Environment Committee, 2015).

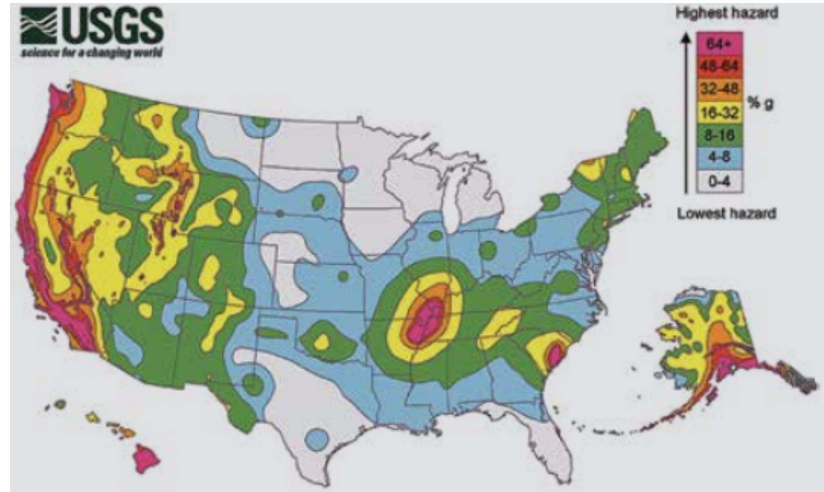


WADNR Fire Suppression Costs 1971-2014. House Environment Committee, 2015.

A Magnitude 7.0 Cascadia earthquake may be the worst disaster in US history: Washington, especially the Puget Sound basin, has a history of frequent earthquakes. More than 1,000 earthquakes occur in the state each year but only around a dozen can be felt and even fewer cause any damage. The state experienced at least 20 damaging events in the last 125 years (MIL, 2016a). The Nisqually earthquake on February 28, 2001, was the worst earthquake in recent history (MIL, 2016a). Recently there has been a lot of press about the potential of a Magnitude 9.0 (M9.0) earthquake striking the Northwest – i.e. the Big One. It is estimated that a quake of this magnitude strikes between 2-5 centuries, and it has been 316 years since the last one (Neff, 2016). A M9.0 Cascadia quake is estimated to displace nearly 1 million people, causing 14,600 deaths, and over $80B in damages (FEMA). In the event of a M9.0 quake, everything West of I-5 will be gone (FEMA, 2016). FEMA projects it would be the worst disaster the US has ever faced

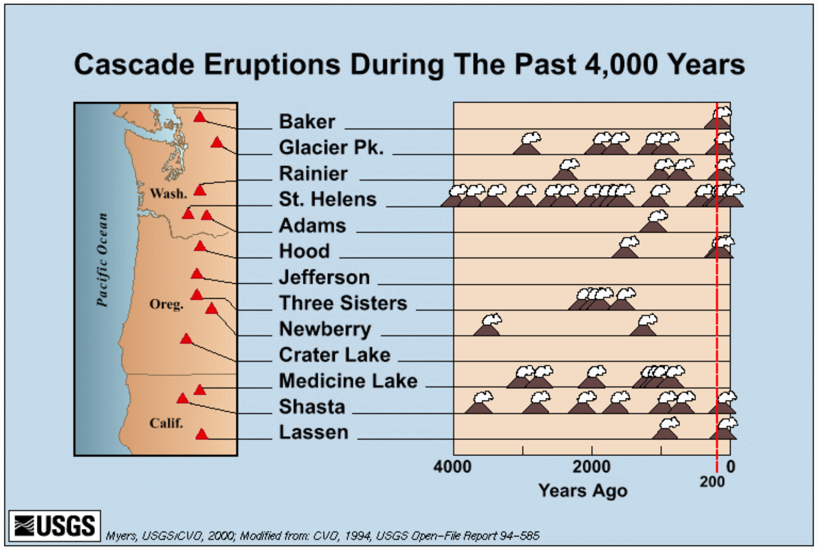
(FEMA, 2016). The area of impact will be a 13,000 square miles, including Seattle, Tacoma, Portland, Eugene, Salem, Olympia, and some seven million people. The odds of a M9.0 occurring in the next 50 years are roughly 1 in 3 (Schulz, 2015).

As the population along the coast continues to grow, the social and economic impact of a Cascadia quake has grown exponentially. Worse, critics argue that Washington does not have sufficient policies to reduce risk – for example drills and laws for schools, hospitals, and vulnerable buildings (Miles and Gouran, 2016). Earthquake warning systems, like those in place in Japan, can detect compressional waves around 90 seconds ahead of the seismic waves. These warning systems may provide enough time to perform a variety of lifesaving functions (e.g. shutting down railways and power plants, opening elevators and firehouse doors, alerting hospitals to halt surgeries, and triggering alarms so that the general public can take cover) (Ibid). However, the Pacific Northwest has no early-warning system. The far majority of infrastructure and buildings in the area are not constructed with large seismic events in mind. In the aftermath of a quake, residents will have little time to evacuate before the Tsunami hits (10-30 minutes). And while it may take months to get roads and electricity back up, researchers expect that a likely mass exodus would take many years to recover from (Ibid).



Seismic Hazard Map (Peak Ground Acceleration (PGA), 2% in 50 years). USGS 2014.

We are increasingly building in lahar valleys, increasing our vulnerability: Washington State has five major volcanoes in the Cascade Range – Mount Baker, Glacier Peak, Mount Rainier, Mount St. Helens and Mount Adams (MIL, 2016b). When Cascades volcanoes erupt high speed avalanches of hot ash and rock, lava flows, and landslides can devastate areas 10 or more miles away, while huge mudflows of volcanic ash and debris called lahars can inundate valleys more than 50 miles downstream (Ibid). Falling ash from explosive eruptions can disrupt human activities hundreds of miles downwind and drifting clouds of fine ash can cause severe damage to the engines of jet aircraft hundreds or thousands of miles away (MIL, 2016b). As the pace of development increases in proximity to these mountains, the associated risk from eruption is growing rapidly. Mount Rainier in Pierce County is one of the most hazardous volcanoes in the United States. It has produced at least four eruptions and numerous lahars in the past 4,000 years (MIL, 2016b). It is capped by more glacier ice than the rest of the Cascades volcanoes combined, and Rainier's steep slopes are under constant attack from hot, acidic volcanic gases and water. And more than 160,000 people live on the former lahars in its river valleys. These factors make this volcano especially prone to landslides and lahars (Ibid).



Cascade Eruptions During the Past 4,000 Years. USGS 2000.

Seattle and nearby cities may be the target of an attack: Terrorism damage is caused by explosions, shootings, fires, crashes, infrastructure collapses, computer failures and the release of harmful agents, be they chemical, biological or radiological ([City of Seattle, 2016).](#) Since 9/11 terrorism has been recognized as one of the top risks facing the United States (Ibid). Modern technology allows small groups to inflect high casualties. The target of terrorism depends on who is doing the targeting, their ideology, strategy, and resources. Eco-terrorism, like the attack on the UW Center of Urban Horticulture, bio-terrorism, the incidence with anthrax in the 2001, and salmonella in the 80's, or more recently cyber-terrorism, focusing on attacking electronic and communication systems all represent terrorism attacks (City of Seattle, 2016).

Seattle and the greater Puget Sound has never experienced a full-scale terrorist incident. However, according to the City of Seattle's Office of Emergency Management, there have been a series of activities that fit into the terrorist mold and could represent the first step in a pattern of escalation (Seattle Office of Emergency Management, 2016). While activity in the Puget sound has been small and sporadic, international jihadist threats have been growing nationally (Ibid).

A large scale attack is considered a low probability but plausible. Being a large, diverse and open city, Seattle has many potential targets (Seattle Office of Emergency Management, 2016). Downtown high population areas are inherently vulnerable, transportation systems are another target (Ibid). The Region's ferries are considered a potential target. The Marine Terrorism Response (MTR) project represents Washington Ports' commitment to work with the Department of Homeland Security and the Coast Guard to protect Washington's coast (Hildon, 2005). In light of increasing terrorism at home and abroad, emergency personal in the Puget Sound are preparing for the worst. City, county and state, and departments are running terror drills with first responders to practice their emergency skills (Klevin, 2012).

Aging and Disability Services (ADS). Last Viewed Sept 2016. Aging Related Population Data for King County. http://www.agingkingcounty.org/area_trends.htm

Alberti, M. 1999. Urban patterns and environmental performance: What do we know? Journal of Planning Education and Research 19(2):151-163.

Alberti, M. 2005. The effects of urban patterns on ecosystem function. International Regional Science Review. 28(2):169-192.

Alberti, Marina. 2008. Advances in Urban Ecology: Integrating Humans and Ecological Processes in Urban Ecosystems.

American Community Survey. 2015.

Associated Press May 2016. Q&A: Here's why salmon fishing is off limits in the Puget Sound. Oregon live. http://www.oregonlive.com/pacific-northwest-news/index.ssf/2016/05/qa_heres_why_salmon_fishing_of.html.

Bhatt, Sanjay. January 6, 2016. King County home prices hit new highs, inventory at new lows. Seattle Times. http://www.seattletimes.com/business/real-estate/king-county-home-prices-hit-a-new-record-in-december/

Bogost, I. May 2016. When Cars Fly: How driverless vehicles could change meetings, manufacturing, safety, and more. Atlantic. http://www.theatlantic.com/magazine/archive/2016/05/when-cars-fly/476382/

Brockman, Mike. 2011. Breaking New Ground. Puget Sound Agriculture. https://digital.lib.washington.edu/researchworks/bitstream/handle/1773/16629/Capstone_breakingnewground_brockman2011.pdf?sequence=1&isAllowed=y

Casey, M. 2015. Global cost of flooding to increase tenfold by 2030. CBS News. http://www.cbsnews.com/news/global-cost-of-flooding-to-increase-tenfold-by-2030/

Cauvel, Kimberly. May 4, 2016. Fishermen protest tribal fishery as Puget Sound closure begins. http://www.goskagit.com/news/fishermen-protest-tribal-fishery-as-puget-sound-closure-begins/article_e546bd2a-65d9-5b69-a0ac-6972940447d2.html.

CDC. 2010. Healthy People 2020. https://www.healthypeople.gov/2020/About-Healthy-People

Census. 2010. http://factfinder.census.gov/faces/nav/jsf/pages/community_facts.xhtml

Center for Disease Control (CDC). 2015. Behavioral Risk Factor Surveillance System. http://www.cdc.gov/brfss/

Center for Research on the Epidemiology of Disasters (CRED). International Disaster Database. Emergency Events Database (EM-DAT). Last Updated 19/7 2016.

Chokshi, N. June 24, 2015. Maps: The State of Broadband in the States. Internet Connection Speeds. Washington Post. https://www.washingtonpost.com/blogs/govbeat/wp/2015/06/24/the-state-of-broadband-in-the-states-in-2-maps/

City of Seattle. 2016. Population and Demographics. http://www.seattle.gov/dpd/cityplanning/populationdemographics/

City of Seattle. 2016. Proposed Budget Executive Summary. http://www.seattle.gov/financedepartment/16proposedbudget/documents/16proposedbudgetexecsummary.pdf.

City of Seattle. Terrorism. Last Accessed 2016. Emergency Management. Barb Graff, Director. http://www.seattle.gov/emergency-management/hazards-and-plans/hazards/terrorism

Clouser, Rodney L. 2005. "Issues at the Rural-Urban Fringe: The Land Use Debate-Situational Background." FE551, Florida Cooperative Extension, University of Florida, 2005.

Conway, Dick. January 2015. Economic Outlook 2015: Proving the Theory. Seattle Business Magazine. Finance.

Conway, Dick. January 2016. 2016 Economic Outlook: We're Slowing Down But don't be alarmed. Seattle Business Magazine. Finance. http://www.seattlebusinessmag.com/article/2016-economic-outlook-we%25E2%2580%2599re-slowing-down

Cultural Survival. Last Accessed 2016. The Unintended Consequences of the Boldt Decision. https://www.culturalsurvival.org/publications/cultural-survival-quarterly/united-states/unintended-consequences-boldt-decision

Dalton, M.M., P.W. Mote, and A.K. Snover [Eds.]. 2013. Climate Change in the Northwest: Implications for Our Landscapes, Waters, and Communities. Washington, DC: Island Press.

Dankovchik, et al. 2015. Disparities in Life Expectancy of Pacific Northwest American Indians and Alaska Natives: Analysis of Linkage-Corrected Life Tables. 130(1). Public Health Reports. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4245288/

Department of Commerce. 2008. Washington State Travel Impacts, 1991-2008p. Washington State Community, Trade and Economic Development Tourism Office/Dean Runyan Associates. http://www.whytourismmatters.com/regions/nwwashington/default.html

Department of Commerce. Last Accessed 2016. Leading the Way to a Cleaner Future. Department of Commerce Growing the Economy\Energy. http://www.commerce.wa.gov/growing-the-economy/energy/

Desilver, Drew. 2016. Increase in living with parents driven by those ages 25-34, non-college grads. Pew Research Center.

DNR. 2015. Forest Health Highlights in Washington – 2015. United States Department of Agriculture. Washington State Department of Natural Resources Forest Health Program. February 2016. http://file.dnr.wa.gov/publications/rp_fh_2015_forest_health_highlights.pdf

CNR. 2016. Washington Public Lands Inventory. http://publiclandsinventory.wa.gov/#Map

DOH. 2007. Health of Washington State. Pesticide Related Illness and Injury. http://www.doh.wa.gov/Portals/1/Documents/5500/EH-PP2007.pdf

DOH. 2013. Public Health Activities and Services. https://data.wa.gov/Health/Public-Health-Activities-and-Services-2013/28ar-n972 Data.gov.

DOH. 2014. Death Tables by Topic. http://www.doh.wa.gov/DataandStatisticalReports/VitalStatisticsData/Death/DeathTablesbyTopic

DOH. 2014. Outdoor (Ambient) Air Quality. http://www.doh.wa.gov/Portals/1/Documents/5500/EH-AQ2014.pdf

DOH. 2014. Washington State Communicable Disease Report 2014. http://www.doh.wa.gov/Portals/1/Documents/5100/420-004-CDAnnualReport2014.pdf

DOH. 2015a. Health of Washington State: A statewide assessment of health status, health risks, and health care services. http://www.doh.wa.gov/DataandStatisticalReports/HealthBehaviors/HealthofWashingtonStateReport/MostRecentReport

DOH. 2015c. Washington State Immunization Information System (IIS) Immunization Coverage as of December 31, 2015. Publication number 348-563 http://www.doh.wa.gov/Portals/1/Documents/Pubs/348-563-IIS-ImmunizationSlideSet.pdf

DOH. Last Accessed 2016. Biomonitoring in Washington State

DOH. Last Accessed 2016b. Drinking Water - Washington Tracking Network (WTN). http://www.doh.wa.gov/DataandStatisticalReports/EnvironmentalHealth/WashingtonTrackingNetworkWTN/DrinkingWater

DOH. Sept 2010. Burden of Tobacco in Washington State: Fact Sheet. DOH 340-164. http://www.doh.wa.gov/Portals/1/Documents/Pubs/340-164-BurdenOfTobaccoInWashingtonStateFactSheet.pdf

Doney, S.C., Fabry, V.J., Feely, R.A., and Kleypas, J.A. 2009. Ocean acidification: the other CO2 problem. Ann Rev Mar Sci 1: 169-192. doi: 10.1146/annurev.marine.010908.163834 PMID: 21141034

Economic and Revenue Forecast Council (E&RFC). June 2016. http://www.erfc.wa.gov/

Economic and Revenue Forecast Council (EFRC). December 2014. Volume XIV. Washington State Economic Climate Study. http://www.erfc.wa.gov/publications/documents/climate2014.pdf

Economist. Jan 2015. Of Slots and sloth. How cash from casinos makes Native Americans poorer. http://www.economist.com/news/united-states/21639547-how-cash-casinos-makes-native-americans-poorer-slots-and-sloth

ECY. 2016. Wetlands: Nature's Sponges, Nurseries, and Water Filters. http://www.ecy.wa.gov/programs/sea/wetlands/index.html

ECY. February 2011. Protecting Our Waters from Combined Sewer Overflows. Focus on Sewage and Stormwater. Water Quality Program. https://fortress.wa.gov/ecy/publications/publications/0010080.pdf

ECY. Last Accessed 2016. Saving the Sound. http://www.ecy.wa.gov/puget_sound/overview.html.

EDC. NA. Washington State Broadband. Western Washington Workshops Review. http://www.edcteamjefferson.com/uploads/W%20WA%20BB%20WorkshopSummary.pdf

EPA. Last updated on August 10, 2016. Implementing Clean Water Act Section 303(d): Impaired Waters and Total Maximum Daily Loads (TMDLs). https://www.epa.gov/tmdl

EPA. NA. Ground and Surface Water Quality Information. http://www.ecy.wa.gov/programs/wq/links/standards.html

Erickson, Ara. 2005. Small Forest Land Owner Parcel Identification and County GIS Data Compilation for Washington State Clallam and Jefferson Counties. Small Forest Landowner Office. Washington Department of Natural Resources. http://www.ruraltech.org/projects/wrl/sflowria/clal_jeff/

Feely, R.A., S.R. Alin, J. Newton, C.L. Sabine, M. Warner, C. Krembs, and C. Maloy, 2010. The combined effects of ocean acidification, mixing, and respiration on pH and carbonate saturation in an urbanized estuary. Estuarine, Coast, and Shelf Science, 88: 442-449.

FEMA. 2016. Cascadia Rising. Exercise Scenario Document. Cascadia Subduction Zone (CSZ) Catastrophic Earthquake and Tsunami.

Foley, J. A., G. P. Asner, M. H. Costa, M. T. Coe, R. DeFries, H. K. Gibbs, E. A. Howard, S. Olson, J. Patz, N. Ramankutty, and P. Snyder. 2007. Amazonian revealed: forest degradation and loss of ecosystem goods and services in the Amazon Basin. Frontiers in Ecology and Environment 5(1):25–32.

Forterra. 2015. 2015 Progress Report. http://forterra.org/wp-content/uploads/2015/07/Forterra-Progress-Report-2015-Web.pdf

Forum.2012. 2012 Regional Water Supply Update. http://www.watersupplyforum.org/docs/14/3449a0abbd28de4e92ed4a1adf85dcbf0a87cc9d/2012RegionalWaterSupplyUpdate.pdf

Geomorphological Research Group. http://riverhistory.ess.washington.edu/

George, Evan. 2013. The Urban Agriculture Movement: History and Current Trends. https://www.law.msu.edu/clinics/food/UrbanAgMvmnt.pdf

Georgiadis, Nick. 2015. Land cover conversion and ecosystem decline. 2015 Puget Sound Fact Book. https://www.eopugetsound.org/articles/land-cover-conversion-and-ecosystem-decline

Geranios, Nicholas. August 21, 2016. Wildfire near Spokane burns 16 homes, keeps growing. http://komonews.com/news/local/crews-battling-multiple-wildfires-in-eastern-washington

Grimm NB, Faeth SH, Golubiewski NE, Redman CL, Wu J, Bai X, Briggs JM, 2008. Global Chane and the Ecology of Cities. Science. 319 756-760.

Hallegatte, S. Green, C., Nicholls, R.J. and J.Corfee-Morlot. 2013. Future flood losses in major coastal cities. Nature Climate Change. 3: 802. doi:10.1038/nclimate1979

Hamlet, A.F. and Dennis P. Lettenmaier. 2007. Effects of 20th century warming and climate variability on flood risk in the western U.S. Water Resources Research. http://onlinelibrary.wiley.com/doi/10.1029/2006WR005099/abstract

Hamlet, A.F. et al., 2013. An overview of the Columbia Basin Climate Change Scenarios Project: Approach, methods, and summary of key results. Atmosphere-Ocean 51(4): 392-415. doi: 10.1080/07055900.2013.819555 [4] Pelto, M.S. 2010. Forecasting temperate alpine glacier survival from accumulation zone observations. The Cryosphere 4(1): 67-75.

Hansen, Terri. March 2016. Indian Country. 'Disastrous' Coho Returns Threaten Western Washington Tribes. http://indiancountrytodaymedianetwork.com/2016/03/28/disastrous-coho-returns-threaten-western-washington-tribes-163942

Hepinstall-Cymerman, J., Coe, S. & Hutyra, L.R. (2013). Urban growth patterns and growth management boundaries in the Central Puget Sound, Washington, 1986–2007. Urban Ecosystems. 16: 109. doi:10.1007/s11252-011-0206-3

Hildon, R. Chief Security Officer, Port of Seattle. July 2005. Marine Terrorism Response (MTR). http://aapa.files.cms-plus.com/SeminarPresentations/05_Security_Safety_Hilden_Rod.pdf

House Environment Committee. January 2015. Washington's Clean Energy Future. Chris Davis, Governor's Office. http://www.psrc.org/assets/12175/Gov_climate.pdf?processed=true

Ianson, D. 2015. Ocean acidification on the Pacific coast of Canada. In: Chandler, P.C., King, S.A., and Perry, R.I. (Eds.). State of the physical, biological and selected fishery resources of Pacific in 2014. Can. Tech. Rep. Fish. Aquat. Sci. 3131 (this volume).

International Trade Administration (ITA). February 2016. Washington Exports, Jobs, and Foreign Investment. Prepared by the Office of Trade and Economic analusis, US Department of Commerce. http://www.trade.gov/mas/ian/statereports/states/wa.pdf

James Battin, Matthew W. Wiley, Mary H. Ruckelshaus, Richard N. Palmer, Elizabeth Korb, Krista K. Bartz, and Hiroo Imaki. 2007. Projected impacts of climate change on salmon habitat restoration. PNAS. V104(16). www.pnas.org/cgi/content/full/ 0701685104/DC1.

Kaiser Family Foundation. Jun 2014. The Washington State Health Care Landscape. http://kff.org/health-reform/fact-sheet/the-washington-state-health-care-landscape/

Karr, J.R. and E.W. Chu. 1997. Biological monitoring and assessment: using multimetric indexes effectively. EPA 235-R97-001. University of Washington, Seattle. 149 pp.

King County. July 2015. 2014 Annual CSO and Consent Decree Report . Combined Sewer Overflow Control Program. http://your.kingcounty.gov/dnrp/library/wastewater/cso/docs/AnnualReport/2014_CSO-CD_Annual.pdf

Kleven, Alyssa. October 26, 2012. Puget Sound emergency crews to prepare for terrorist attack, earthquake. NyNorthwest.com http://mynorthwest.com/32315/puget-sound-emergency-crews-to-prepare-for-terrorist-attack-earthquake/

LaMotte, Sandee. September 2, 2016. Zika spraying kills millions of honeybees. http://www.cnn.com/2016/09/01/health/zika-spraying-honeybees/

Lucy R. Hutyra, Byungman, Yoon and Marina Alberti. 2012. Terrestrial carbon stocks across a gradient of urbanization a study of the Seattle, WA region. Global Change Biology. V17: Issue 2. DOI: 10.1111/j.1365-2486.2010.02238.x

Mantua, N., Tohver, I. & Hamlet, A. 2010. Climate change impacts on streamflow extremes and summertime stream temperature and their possible consequences for freshwater salmon habitat in Washington State. Climatic Change. V102: p187. doi:10.1007/s10584-010-9845-2

Mapes, Lynda, V. November 25, 2015.

Mapes, Lynda. January 2010. For some tribes, casinos no longer a sure bet. Seattle Times. http://www.seattletimes.com/seattle-news/for-some-tribes-casinos-no-longer-a-sure-bet/

Marsik, M, Alberti, M, Hepinstall-Cymerman, J and H. Ševčíková. Forthcoming. Applying the Land Cover Change Model to the Central Puget Sound Region: Patterns and Rates of Simulated Urbanization from 2005 to 2050.

Mauger, G.S., J.H. Casola, H.A. Morgan, R.L. Strauch, B. Jones, B. Curry, T.M. Busch Isaksen, L. Whitely Binder, M.B. Krosby, and A.K. Snover, 2015. State of Knowledge: Climate Change in Puget Sound. Report prepared for the Puget Sound Partnership and the National Oceanic and Atmospheric Administration. Climate Impacts Group, University of Washington, Seattle. doi:10.7915/CIG93777D

McMicheal, Anthony. 2013. Globalization, Climate Change, and Human Health. The New England Journal of Medicine. DOI: 10.1056/NEJMra1109341

McTeer, Bob. Jan 2015. Is a Strong Dollar a Good Thing or a Bad Thing? Forbes. http://www.forbes.com/sites/bobmcteer/2015/01/24/is-a-strong-dollar-a-good-thing-or-a-bad-thing/#82ac1606b615

Meador, J.P. et al. 2016. Contaminants of emerging concern in a large temperate estuary. Environmental Pollution. Vol 213: p254. http://www.sciencedirect.com/science/article/pii/S0269749116300884

Mercer, Greg. Feb 24, 2015. The Link between Zika and Climate change. Researchers are beginning to tease out the environmental factors that play a role in helping the virus to spread. The Atlantic. http://www.theatlantic.com/health/archive/2016/02/zika-and-climate-change/470643/

Microsoft buys carbon credits in forest near Rainier to offset pollution. Seattle Times. Environment. http://www.seattletimes.com/seattle-news/environment/microsoft-buys-carbon-credits-in-forest-near-rainier-to-offset-pollution/

MIL. NA. Volcano. Last accessed 2016b. Emergency Management Division. http://mil.wa.gov/emergency-management-division/hazards/volcano.

Miles, S. and Gouran, B. 2016. U.S. Earthquake Policy Activity and Coverage. Earthquake Spectra. Vol 32. NO 1. https://www.documentcloud.org/documents/2822905-Miles-gouran2016.html

Milesi, Carla. October 2015. Stormwater facts. 2015 Puget Sound Fact Book. https://www.eopugetsound.org/articles/stormwater-facts

Monk, Becky. April 26, 2016. A record number of tourists descended on Seattle last year. Puget Sound Business Journal. http://www.bizjournals.com/seattle/news/2016/04/26/a-record-number-of-tourists-descended-on-seattle.html

Municipal Research and Services Center (MSRC). Last Modified: July 26, 2016a. Comprehensive Planning/Growth Management. http://mrsc.org/Home/Explore-Topics/Planning/General-Planning-and-Growth-Management/Comprehensive-Planning-Growth-Management.aspx

MSRC. 2016b. Urban Agriculture – Community Gardening. http://mrsc.org/Home/Explore-Topics/Parks-and-Recreation/Recreation-and-Other-Programs/Urban-Agriculture-Community-Gardening.aspx

Neff, J. (Ed). 2016. Seismic Neglect: The earthquake nightmare public officials are failing to confront. The Seattle Times. http://projects.seattletimes.com/2016/seismic-neglect/

Nisqually Land Trust. December 4, 2015. Nisqually Land Trust Makes News – and History! . http://nisquallylandtrust.org/nisqually-land-trust-makes-news-and-history/

NOAA. 2016. Coastal Blue Carbon. NOAA Habitat Conservation National Marine Fisheries Service. http://www.habitat.noaa.gov/coastalbluecarbon.html

NOAA. 2016. North of Falcon. http://wdfw.wa.gov/fishing/northfalcon/

NOAA. January 2012. From the Tides of Puget Sound to Your Plate: Northwest Shellfish Industry Provides Important Ecological & Economic Value. http://www.westcoast.fisheries.noaa.gov/publications/aquaculture/noaa_shellfish_initiative_f_sheet_011312.pdf

Northwest Indian Fisheries Commission (NWFIC). 2016. 2016 State of our Watershed. http://nwifc.org/publications/state-of-our-watersheds/

Northwest Seaport Alliance (NSA). Spring 2016. Export Connection: The Pacific Northwest's booming export business. Pacific Gateway. https://www.nwseaportalliance.com/sites/default/files/2016SpringGateway.pdf

Novak, D.J. Crane, D.E. and J.C. Stevens. 2006. Air pollution removal by urban trees and shrubs in the United States. Urban Forestry and Urban Greening. V4 (3-4). http://dx.doi.org/10.1016/j.ufug.2006.01.007

NW Council. 2016. Endangered Species Act and Columbia River Salmon and Steelhead. http://www.nwcouncil.org/history/endangeredspeciesact

NWFSC. 2008. Puget Sound Chinook. NOAA Fisheries Service. https://www.nwfsc.noaa.gov/trt/trt_documents/puget_sound_chinook.pdf

Office of Financial Management (OFM). 2015. Data book. http://www.ofm.wa.gov/databook/

Office of Planning and Community Development (P&CD). Last Viewed Sept 2016. Prosperity Quick Statistics. http://www.seattle.gov/dPd/cityplanning/populationdemographics/aboutseattle/prosperity/default.htm

OFM. 2000. International Trade and Washington Exports. Washington Economic Trends. http://www.ofm.wa.gov/researchbriefs/2000/brief008.pdf

OFM. 2010. Economy. http://www.ofm.wa.gov/trends/economy/default.asp

OFM. 2015b. Budget Drivers. http://www.ofm.wa.gov/trends/budget/fig411.asp

OFM. January 2007. Washington State: Blue Ribbon Commission on Health Care Costs and Access. Final Report. http://www.ofm.wa.gov/healthcare/planning/finalreport.pdf

OFM. July 2016a. Population Estimates. http://www.ofm.wa.gov/pop/estimates.asp

OFM. November February 2016b. 2015 Forecast of the State Population. State of Washington. Forecasting and Research Division. http://www.ofm.wa.gov/pop/stfc/stfc2015/stfc_2015.pdf

Oke, T.R. 1967. City Size and the Urban Heat Island. Atmospheric Environment. V7(8).

Organization for Economic Co-operation and Development, International Energy Agency (OECD/IEA). 2012. World Energy Outlook. Chapter 17: Water for Energy: Is energy becoming a thirstier resource? http://www.worldenergyoutlook.org/media/weowebsite/2012/WEO_2012_Water_Excerpt.pdf

Paul G. Allen Family Foundation. April 2015. Puget Sound Restoration Fund Awarded $1.5 Million Grant. Http://Www.Pgafamilyfoundation.Org/News/News-Articles/2015-News-Items/Puget-Sound-Ocean-Acidification-Grant

Peter C. Chandler, Stephanie A. King and R. Ian Perry (Editors). 2015. State of the Physical, Biological and Selected Fishery Resources of Pacific Canadian Marine Ecosystems in 2014. Canadian Technical Report of Fisheries and Aquatic Sciences 3131. http://www.dfo-mpo.gc.ca/Library/358018.pdf

Pew Research Center. February 2013. Second-Generation American: A Portrait of the Adult Children of Immigrants. http://www.pewsocialtrends.org/files/2013/02/FINAL_immigrant_generations_report_2-7-13.pdf

Phillips, J., Scott, C. and Shaun O'Neil. Spring 2015. Assessing the Vulnerability of Wastewater Facilities to Sea-Level Rise King County Wastewater Treatment Division. Michigan Journal of Sustainability. Vol 3. DOI: http://dx.doi.org/10.3998/mjs.12333712.0003.011

Pickett, S. T. A., M. L. Cadenasso, J. M. Grove, P. M. Groffman, L. E. Band, C. G. Boone, W. R. Burch, S. B. Grimmond, J. Hom, J. C. Jenkins, N. L. Law, C. H. Nilon, R. V. Pouyat, K. Szlavecz, P. S. Warren, and M. Wilson. 2008. Beyond urban legends: an emerging framework of urban ecology, as illustrated by the Baltimore ecosystem study. Bioscience 58:139-150.

Pitchford, M. NA. What's needed to ensure safety and security in UAV software. Military Embedded Systems.

Powell, S. L., Cohen, W. B., Yang, Z., Pierce, J. D., & Alberti, M. (2008). Quantification of impervious surface in the Snohomish water resources inventory area of western Washington from 1972–2006. Remote Sensing of Environment, 112(4), 1895-1908.

PSEMP Marine Waters Workgroup. 2014. Puget Sound marine waters: 2013 overview. S. K. Moore, K. Stark, J. Bos, P. Williams, J. Newton and K. Dzinbal (Eds). URL: http://www.psp.wa.gov/downloads/ psemp/PSmarinewaters_2013_overview.pdf. Contact email: marinewaters@psemp.org

PSP. 2014. Puget sound Pressures Assessment. https://sites.google.com/site/pressureassessment/hom e

PSP. 2016. Action Agenda. http://psp.wa.gov/action-agenda-what.php

PSRC. 2008. Tourism and Visitor Cluster Strategy Report. Prosperity Partnership Regional Economic Strategy. http://www.psrc.org/assets/5612/TourismVisitorStrate gy.pdf.

PSRC. 2010. Chapter 11 Energy. Annual Report. http://www.psrc.org/assets/3686/11-Energy.pdf

PSRC. Puget Sound Trends. February 2016. http://www.psrc.org/assets/13405/Trend-Jobs-201602.pdf

Puget Sound Energy (PSE). Last Accessed 2016. Wind Power. PSE: A leader in delivering clean, renewable energy. http://pse.com/aboutpse/EnergySupply/Pages/Wind-Power.aspx

Puget Sound Partnership (PSP). 2015. Report on the Puget Sound Vital Signs. https://pspwa.app.box.com/v/2015-sos-vitalsigns-report

Puget Sound Regional Council (PSRC). 2012. Adopted Transportation 2040 Plan. http://www.psrc.org/transportation/t2040/t2040-pubs/final-draft-transportation-2040/

Puget Sound Regional Council (PSRC). Regional Macroeconomic Forecast. http://www.psrc.org/assets/12566/2015PSRC-MacroeconomicForecast.xlsx .

Puget Sound River History Project. Quaternary Research Center,

Puget Soundkeeper. Last Accessed 2016. Wastewater Pollution. http://www.pugetsoundkeeper.org/wastewater-pollution/

Putnam, A.L., 1972. Effect of urban development on floods in the Piedmont Province of North Carolina. United States Geological Survey. open-file report, 87 pp.

Regional Water Supply Forum (Forum). Last Accessed 2016. Regional Water Supply. http://www.watersupplyforum.org/home/regional-water-supply.html

Report: Indian gaming revenue hits record $28.3 billion in 2013. Las Vegas Review Journal. http://www.reviewjournal.com/business/casinos-gaming/report-indian-gaming-revenue-hits-record-283-billion-2013

Rice, J., Baker, J., Biedenweg, K., Christie, P., Francis, T., Gaydos, J., MacCready, P., Milesi, C., Simenstad, C., Snover, A. & Symer, K. (Eds.). (2015). Puget Sound Fact Book, version 3.0 (p. 124). Tacoma, WA: Encyclopedia of Puget Sound, University of Washington Puget Sound Institute. Retrieved from https://www.eopugetsound.org/sites/default/files/features/resources/PugetSoundFactbook_v3.0.pdf

Rose M. Kreider, Nancy A. Bates, and Daphne Lofquist. May 13, 2016. Improving Measurement of Same-Sex Couple Households in Census Bureau Surveys. U.S. Census. http://www.census.gov/content/dam/Census/library/working-papers/2016/demo/AAPOR_Kreideretal.pdf

Rural Technology Initiative. 2007. Washington State Small Forest Landowners by WRIA. http://www.ruraltech.org/projects/wrl/fldb/maps/images/Map_SFLO_by_WRIA_e2007_v1.png

Schulz, Kathryn. July 20, 2015. The Really Big One: An earthquake will destroy a sizable portion of the coastal Northwest. The question is when. The New Yorker. Annals of Seismology. http://www.newyorker.com/magazine/2015/07/20/the-really-big-one

Seattle Office of Emergency Management (SOEM). Last Accessed 2016. Seattle Hazard Identification and Vulnerability Analysis. http://www.seattle.gov/Documents/Departments/Emergency/PlansOEM/SHIVA/2014-04-23_Terrorism.pdf

Seattle Public Utilities (SPU). 2011 Revision. Picking up the Pace Towards Zero Waste. Seattle's Solid Waste Plan. http://www.seattle.gov/Util/cs/groups/public/@spu/@garbage/documents/webcontent/02_015209.pdf

Seedstock. December 10, 2014. U.S. to See More Urban Farming in 2015 as Economics Improve, Consumer Demand Increases and More Incentives are Added. http://seedstock.com/2014/12/10/u-s-to-see-more-urban-farming-in-2015-as-economics-improve-consumer-demand-increases-and-more-incentives-are-added/

Shuster, W.D., Bonta, J., Thurston, E. Warnermeunde and D.R. Smith. 2007. Impacts of impervious surface on watershed hydrology: A review. Urban Water Journal. V2(4).

Simenstad, C. A., J. L. Burke, J. E. O'Connor, C. Cannon, D. W. Heatwole, M. F. Ramirez, I. R. Waite, T. D. Counihan, and K. L. Jones. 2011. Columbia River estuary ecosystem classification—concept and application. U.S. Geological Survey, Open-File Report 2011-1228, Seattle, Washington. Available: pubs.usgs.gov/of/2011/1228. (April 2014).

Simenstad, C.A., M. Ramirez, J. Burke, M. Logsdon, H. Shipman, C. Tanner, J. Toft, B. Craig, C. Davis, J. Fung, P. Bloch, K. Fresh, S. Campbell, D. Myers, E. Iverson, A. Bailey, P. Schlenger, C. Kiblinger, P. Myre, W. Gerstel, and A. MacLennan. 2011. Historical Change of Puget Sound Shorelines: Puget Sound Nearshore Ecosystem Project Change Analysis. Puget Sound Nearshore Report No. 2011-01. Published by Washington Department of Fish and Wildlife, Olympia, Washington, and U.S. Army Corps of Engineers, Seattle, Washington.

Stutz, Howard. March 30,2015. Report: Indian gaming revenue hits record $28.3 billion in 2013

Taylor, Paul and D'Vera Cohn. November 7, 2012. A Milestone En Route to a Majority Minority Nation. PewResearchCenter. Social and Demographic Trends. http://www.pewsocialtrends.org/2012/11/07/a-milestone-en-route-to-a-majority-minority-nation/?src=rss_main

The Washington Environmental Biomonitoring Survey (WEBS)

Tribal Fishing Resources. 2009. Tribal Salmon Culture. Salmon Culture of the Pacific Northwest Tribes. http://www.critfc.org/salmon-culture/tribal-salmon-culture/

U.S. Energy Information Administration (EIA). October 15, 2015. State Profiles and Energy Estimates. Washington. http://www.eia.gov/state/analysis.cfm?sid=WA

US Department of Labor (DOL). Workforce Futurework. https://www.dol.gov/dol/aboutdol/history/herman/reports/futurework/report/pdf/ch1.pdf

US Geological Survey (USGS). Last Accessed 2016. Water Use Data for Washington. Washington Water Science Center. http://waterdata.usgs.gov/wa/nwis/water_use?wu_year=ALL&wu_area=County&wu_county=009&wu_county=029&wu_county=031&wu_county=033&wu_county=035&wu_county=045&wu_county=053&wu_county=055&wu_county=057&wu_county=061&wu_county=067&wu_county=073&wu_categ

USDA. 2007. Census of Agriculture. Washington. County Level Data. https://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_2_County_Level/Washington/

USDA. 2015. Regional 6 Plan Revision. http://www.fs.usda.gov/detail/r6/landmanagement/?cid=stelprd3831710#listening

USDA. June 2016c. Assessing the Sustainability of Agricultural and Urban Forests in the United States. http://www.fs.fed.us/sites/default/files/fs_media/fs_document/5081-sustainability-agurb.pdf

USDA. Last Accessed 2016. Local Food Directories: National Farmers Market Directory. https://www.ams.usda.gov/local-food-directories/farmersmarkets

USDA. Last Accessed 2016b. Forest inventory and Analysis National Program. http://www.fia.fs.fed.us/

Vadala, N. April 12, 2013. 3 Ways We'll Communicate in the Future. Philly Magazine. http://www.phillymag.com/news/2013/04/12/future-communication-telepathy-holograms-new-internet/#tGPMfiGoezbTFOZv.99

Pickering, C. M. (2010). Ten Factors that Affect the Severity of Environmental Impacts of Visitors in

Protected Areas. Ambio, 39(1), 70–77. doi:10.1007/s13280-009-0007-6 WA Economic Development Council. July 15, 2012. What's the future of communication? Let's ask the experts. The Next Web. http://thenextweb.com/media/2012/07/15/whats-the-future-of-communication-lets-ask-the-experts/#gref

Washington Department of Ecology (ECY). NA. Washington Watershed Risk Assessment

Washington Department of Fish and Wildlife (WDFW). 2009. Fish, Wildlife and Washington's Economy. http://wdfw.wa.gov/publications/00728/

WDFW. July 2016. 2014 Washington State Sport Catch Report. Fishing and Shellfish. http://wdfw.wa.gov/fishing/harvest/

Washington Department of Health (DOH). 2016. Self-reported Health Status. Data Update 2016. http://www.doh.wa.gov/Portals/1/Documents/5500/GHS-SRHS2016-DU.pdf

Washington Department of Natural Resources (DNR). February 2016. Fact Sheet: Landslide Hazards. http://file.dnr.wa.gov/publications/ger_fs_landslide_hazards.pdf

Washington Economic Development Council (EDC). Last Accessed 2016. Information and Communications Technology. Quick Stats. http://www.edc-seaking.org/catalog/industry-clusters/information-and-communications-technology

Washington Environmental Council (WEC). February 2015. Capturing Carbon with Washington's Forests. https://wecprotects.org/capturing-carbon-with-washingtons-forests/

Washington Military Department (MIL). Last Accessed 2016a. Earthquake. Emergency Management Division. http://mil.wa.gov/emergency-management-division/hazards/earthquake

Washington Military Department (MIL). May 2013. Washington State Hazard Mitigation Plan. Hazard Profile: Flood. http://mil.wa.gov/uploads/pdf/emergency-management/flood_hazard_profile.pdf

Washington Military Department (MIL). October 2012. Washington State Hazard Mitigation Plan. Hazard Profile: Drought. http://mil.wa.gov/uploads/pdf/emergency-management/drought_hazard_profile.pdf

Washington Sea Grant. December 2015 Shellfish Aquaculture in Washington State. Final report to the Washington State Legislature, 84 p. https://wsg.washington.edu/wordpress/wp-content/uploads/Shellfish-Aquaculture-Washington-State.pdf

Washington State Blue Ribbon Panel on Ocean Acidification. 2012. Ocean Acidification: From Knowledge to Action, Washington State's Strategic Response. H. Adelsman and L. Whitely Binder (eds). Washington Department of Ecology, Olympia, Washington. Publication no. 12-01-015.

Washington State Recreation and Conservation Office (RCO). 2014. State of our Salmon in Watershed. 2014 Report. Puget Sound Salmon Recovery Region. Governor's Salmon Recovery Office. http://www.stateofsalmon.wa.gov/regions/puget-sound/

Watson, P., G. Taylor, and S. Cooke. 2008. "The Contribution of Agriculture to Idaho's Economy: 2006." CIS Bulletin 1144, University of Idaho Extension, http://www.cals.uidaho.edu /edComm/pdf/CIS/CIS1144.pdf.

Welch, Craig and Lynda Mapes. May 12, 2008. Saving wetlands: a broken promise.. Seattle Times.

http://www.seattletimes.com/seattle-news/saving-wetlands-a-broken-promise/

Williams-Derry, Clark. October 2014. Washington State Traffic Forecast Finally Recognizes Reality: Does Washington's new road forecast spell the end of "build now, pay later"? Sightline Institute. http://www.sightline.org/2014/10/21/washington-state-traffic-forecast-finally-recognizes-reality/

Winkless, Laurie. March 9, 2016. Urban Farming: Fad or Futureproof. Forbes. http://www.forbes.com/sites/lauriewinkless/2016/03/09/urban-farming-fad-or-futureproof/#1317e06cead8

Woolsey, M. 2009. America’s Most Improved Commutes. Forbes. http://www.forbes.com/2009/02/03/america-improved-commutes-lifestyle-real-estate_0203_improved_commutes.html

Woyke, Elizabeth. 2010. America’s Most Wired Cities. Forbes. http://www.forbes.com/2010/03/02/broadband-wifi-telecom-technology-cio-network-wiredcities.html

Yen, Wei. December 2015. Uninsured Rate Changes in Washington State’s Population Groups: 2013–14. OFM Health Care Research Center. http://www.ofm.wa.gov/researchbriefs/2015/brief074.pdf