7. Ecosystems

Abstract

Warmer water temperatures and more frequent and severe extreme events (floods and low flows) are expected in western Washington as a consequence of climate change. Sea level rise is likely to reduce near-coastal habitat for fish and influence the many plant and animal species they support. Changes in water quantity (and timing) and quality associated with climate change are projected to disturb food webs and prevent access to habitat, impacting both terrestrial and aquatic species. Increased forest disturbance (e.g. from fire and insect attack) is projected for a warmer 21st century climate, which often provides a competitive advantage for invasive species. Changes in temperature and precipitation would also likely alter the species composition of trees and vegetation in the Skagit forest. In general these changes are likely to have negative impacts on terrestrial and aquatic species in the Skagit River basin which have already been impacted by human activities.

7.1 Terrestrial Ecosystem

7.1.1 Forest Ecosystems

Changes in temperature and precipitation associated with climate change are likely to alter the species composition of trees and vegetation in the Skagit River basin (SITC, 2009). Projected drier and warmer summers would cause a significant decline in drought-susceptible species such as western red cedar (SITC, 2009). In some places, drought-susceptible species are already responding to climate change. For example, the tops of many tall western cedar trees in the Skagit County are dead due to less moisture during the drier and warmer summers (URL 1). Even relatively drought-tolerant species, particularly growing in lowland forest, would also be influenced by climate change if drier and warmer summers persist as projected (URL 1; Littell et al., 2010). Douglas fir, for example, an economically important drought-tolerant species, is projected to decrease by the end of the 2060s (Littell et al., 2010). On the other hand, warmer temperatures could help some species in high elevation grow more by decreasing snow cover which buries the trees in winter (URL 1). Tree lines may climb higher due to warmer climate (URL 1). Understory and ground vegetation species are likely to experience similar impacts of climate change to those projected for trees (SITC, 2009).

Hotter and drier summers are likely to contribute to the spread of forest pests and diseases such as mountain pine beetle, spruce budworm, and various fungi and blights that would previously have been suppressed by colder climatic condition (SITC, 2009; Littell et al., 2010). These changes in insect activities and diseases would presumably increase stress on trees, in some cases exacerbating impacts related to drought (URL 1). For example, mountain pine beetle populations in the Skagit County have been growing explosively in recent years (URL 1). The widespread mountain pine beetle attacks on high elevation white bark pine forests near White Pass (URL 1) in the Skagit basin killed about 17,000 trees in 2006 (URL 1). Although the Skagit mountain pine beetle impacts are substantial and growing rapidly, so far tree mortality has been much more serious in Eastern Washington and British Columbia (URL 1).

Warmer, wetter winters combined with warmer, drier summers and increased moisture stress are likely to cause increases in wintertime vegetation and larger summertime accumulations of woody and leafy debris on the forest floor, suggesting elevated risk of more frequent and large wildfires (URL 1; SITC, 2009; Littell et al., 2010). The average number of acres burned each year in Washington State (WA) has increased from 6,000 in the 1970s to about 30,000 in 2001 (URL 1) and is projected to increase further under climate change (SITC, 2009; Littell et al., 2010).

7.1.2 Wildlife

Shorebirds and migratory waterfowl such as snow geese, tundra swans, and ducks rely on the shallow waters and marsh habitats in the Skagit River basin to feed and rest (URL 2; Schweiger, 2007). These areas are also important habitat for other migratory bird such as bald eagles. The Skagit Wildlife Area shown in Figure 7.1 provides important habitat not only for waterfowl and shorebirds but also for marine mammals and other aquatic species (URLs 2, 3 & 4; Garrett, 2005; Skagit Watershed Council, 2005; Schweiger, 2007). The common terrestrial mammals living in the Skagit Wildlife Area are black-tailed deer, coyotes, raccoons, opossum, skunk, beaver and muskrats (URLs 4 & 5; Garrett, 2005). River otter, red fox, and harbor seals are also commonly seen (URL 5; Garrett, 2005). Small rodents such as mice, shrews, voles, and moles and reptiles such as the garter snake and painted turtle use the habitat in the Skagit Wildlife Area (URL 5; Garrett, 2005). Birds of prey in this area include osprey, bald eagles, peregrine falcon marsh hawks, red-tailed and rough-legged hawks, short-eared and barn owls, and the occasional golden eagle (Garrett, 2005; URL 5). Estuarine beaches provide spawning area for forage fish, which in turn provide food for birds, marine mammals and other wildlife (Schweiger, 2007). Invertebrates such as oysters and clams thrive in the mud flats and gravel beds of the Skagit delta and play a key role in the health of marsh habitats (Snover et al., 2005; Schweiger, 2007).

Figure 7.1 Map of the Skagit Wildlife Area (Source: Garrett, 2005).

The upper Skagit River hosts one of the largest and most visible populations of wintering bald eagles (URLs 6 & 7). Bald eagles migrate during winter (peaking in early January about two weeks after the peak of salmon spawning and dying) to eat the dead salmon carcasses that abound in the Skagit River and its tributaries (URLs 6 & 7). Other birds and wildlife that can be seen in the upper Skagit River are ducks, geese, ravens, blue herons, deer, black beer, cougar, beaver, otter, and raccoons (URL 6).

Coastal habitats that support wildlife are projected to be reduced due to sea level rise and other factors associated with human-enhanced global warming (discussed in section 7.3) (Schweiger, 2007; CCWAPWG, 2009). Losses of marsh habitats are likely to decrease water quality because marsh habitats have an ability of regulating nutrients and filtering pollutants (Schweiger, 2007). The excess nutrients such as nitrogen and phosphorus would enhance harmful algal blooms and hypoxia events (low oxygen), resulting in negative impacts on the overall food web and on individual species such as Chinook salmon. Potential reductions in salmon, forage fish and other food sources would cause a decline in many seabirds and marine mammals (Schweiger, 2007). For example, decline of chum salmon would result in the reduction in a major food source for the Bald Eagle.

Potential habitat losses are one consequence of global warming that impacts terrestrial ecosystems. Other changes associated with global warming also will have an impact on the ecosystem (Schweiger, 2007; CCWAPWG, 2009) including more frequent or severe extreme events such as floods, droughts and wind storms. Other kinds of disturbance such as increased wildfire, pests, and diseases may alter available habitat for many species (CCWAPWG, 2009; Running and Mills, 2009; Littell et al., 2010). Increases in air temperature are likely to alter seasonal temperature thresholds, i.e. earlier springs and later autumns are expected under climate change (CCWAPWG, 2009). These changes may affect the migration patterns of birds and migratory insects, resulting in potential misalignment of food availability. Amphibians may be affected by changes in the timing and extent of small scale ponding that affect breeding potential.

Some terrestrial species may be able to respond to climate change by finding more suitable habitats or food sources (Schweiger, 2007; CCWAPWG, 2009; Running and Mills, 2009). For example, cold temperature species may migrate to northward and/or higher elevations to escape warming conditions (CCWAPWG, 2009). On the other hand, some species (or individual populations) may not be able to move to acceptable habitat (or may be prevented from doing so by physical barriers to migration such as human development). Species which cannot migrate to more suitable habitat may not be able to adapt to the rapid rate of change of environmental conditions. In such cases these species or specific populations may become extinct in response to warming (Schweiger, 2007; CCWAPWG, 2009; Running and Mills, 2009).

7.2 Aquatic Ecosystems

Various species of predominantly freshwater fish (including kokanee salmon and lake, cutthroat, rainbow, brook and bull trout) are common in the Skagit basin's lakes and streams (URL 8). ESA listed bull trout, which require very cold water (below about 48°F) for spawning mostly reproduce in headwater streams (particularly those fed by groundwater or glacial melt) and the upper Skagit River. The Skagit provides habitat for the largest bull trout population in western Washington (URL 8).

Anadromous (migrating from fresh to salt water and back again during their life cycle) species such as salmon and steelhead and some predominantly freshwater species such as cutthroat trout and bull trout originating from the freshwater habitats of the Skagit River basin use freshwater, tidal delta, bay and ocean habitats during their life cycle (Beamer et al., 2005; Greene et al., 2005). For example, ocean-type Chinook salmon, a primarily of wild stock in the Skagit River basin (and comprising on the order of 60% of the total wild Chinook population in Puget Sound), use fresh water for spawning (July-October), incubating and hatching (December to March) and then migrate to the delta and the tidally dominated fjord systems of Skagit bay during February to October (Greene et al., 2005).

Salmonid productivity is strongly influenced by both water temperature and hydrologic extremes (McCullough, 1999; Rand et al., 2006; Beechie et al., 2006; Farrell et al., 2008; Crossin et al., 2008; Mantua et al., 2010; Hamlet et al., 2010). The salmonids originating in the Skagit River system are all cold-water species, requiring relatively cool water temperatures through their entire life cycle (McCullough, 1999; Hamlet et al., 2010). Under excessively warm temperatures, these cold water species experience increased metabolic rates (which they cannot control) and loss of available energy for physical activities such as swimming. Under such conditions they may seek refuge in cooler water, delaying upstream migration, or failto spawn altogether (Farrell et al., 2008; Crossin et al., 2008). Increases in water temperature also cause changes in incubation duration of eggs, time of emergence, and migration behavior of juveniles that ultimately affect survival. When water temperatures exceeding a specific threshold (which varies by species and phase of life) are encountered over a long period (i.e. several days), thermal stresses on juveniles and adults can be fatal (McCullough, 1999; Mantua et al., 2010; Hamlet et al., 2010).

Streamflow extremes such as more severe low flows and larger floods also have a negative impact on these species during their freshwater life cycles. Severe or prolonged low flows in spring or summer may impact juvenile salmon migrating to the ocean (via increased exposure to predation or other factors) or adult salmon attempting to move upstream to spawn. More extreme low flows may also exacerbate water temperature impacts (Hamlet et al., 2010; Mantua et al., 2010).

Higher flood flows during incubation have been shown to decrease Chinook salmon return rates in the Skagit River basin (Greene et al., 2005). There are several possible mechanisms that explain the negative correlation of freshwater survival with flood magnitude. Peak flows during incubation increase mortality by scouring of redds (salmon "nests"), which crushes the eggs (Montgomery et al., 1996; DeVries, 1997) or increasing fine sediment deposition that reduces available oxygen (Lotspeich and Everest, 1981). Extreme high flows also can reduce the availability of preferred or suitable slow water habitats, resulting in reduced freshwater survival rates for juveniles (Greene et al., 2005; Mantua et al., 2010).

Both factors discussed above are projected to change under climate change scenarios, with impacts to Pacific Northwest salmonid populations. Mantua et al. (2010) evaluated climate change impacts on freshwater habitats in WA. They found that projected increases in water temperature will produce steadily increasing thermal stresses on Washington's salmon populations moving from the beginning to the end of the 21st century. In the study these impacts are tied directly to increasing air temperature. As expected, the warmer A1B emissions scenarios produces more thermal stress on salmon than the somewhat cooler B1 emissions scenarios (see Figure 7.2). The potential impacts of climate change on salmon due to thermal stress in the freshwater environment are less in the Skagit River basin in comparison to more sensitive areas such as the interior Columbia River Basin (Figure 7.2).

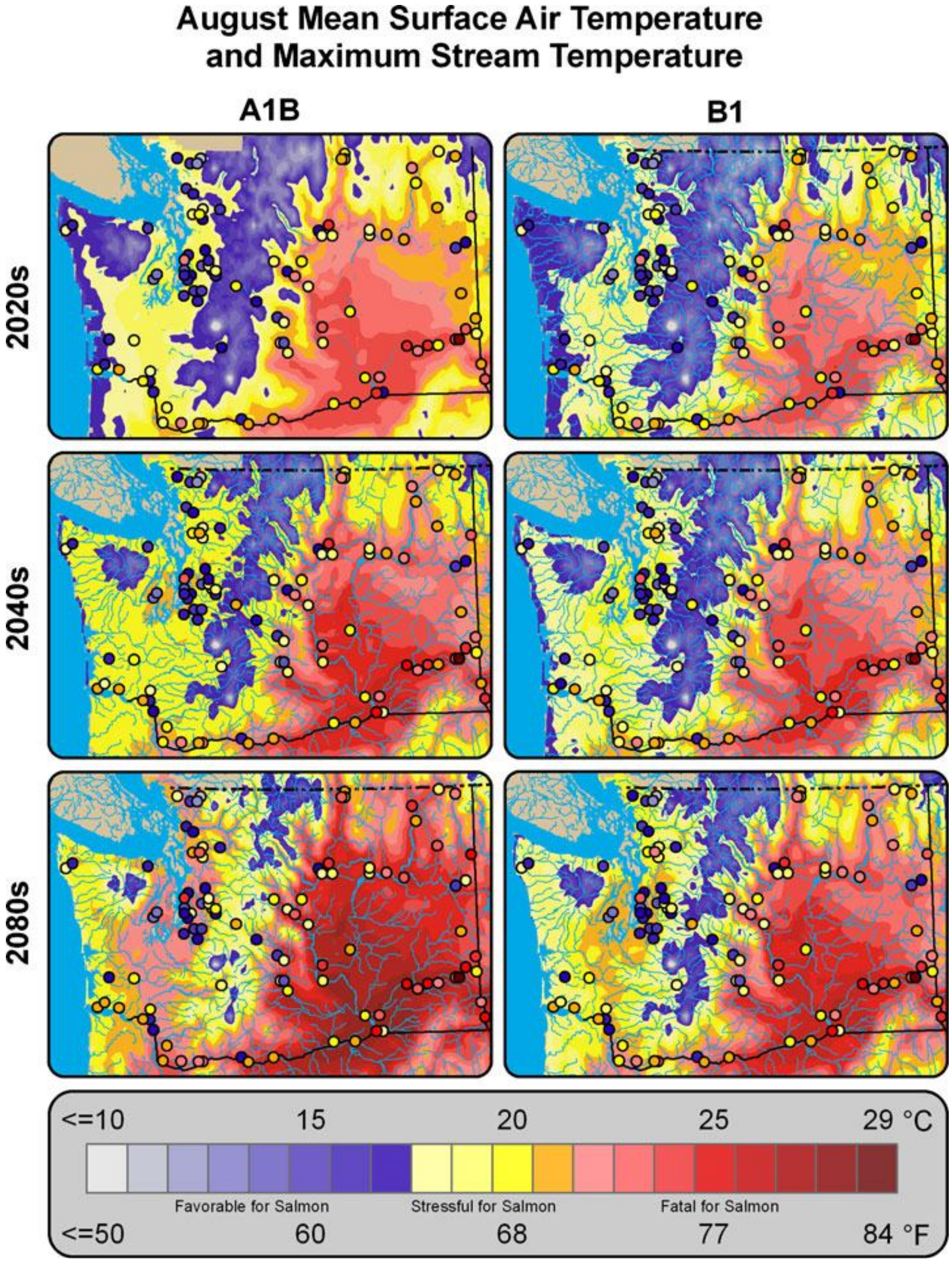


Figure 7.2 Color shading shows mean surface air temperature for August for future climate scenarios for the 2020s, 2040s and 2080s. Shaded circles show the simulated mean of the annual maximum for weekly water temperature for select locations. Multi-model composite averages based on the A1B emissions are in the left panels, and those for B1 emissions are in the right panels (Source: Mantua et al., 2010).

Recently Hamlet et al. (2010) evaluated climate change impacts on the Skagit River habitat for fish. They found that water temperature projections are differentiated by location. The east side tributaries of the Skagit River (Figure 7.3) are projected to exceed (or closely approach) thermal thresholds of 13 ^{o}C (55.4 ^{o}F) and 16 ^{o}C (60.8 ^{o}F) (see Figure 7.4), while the west side tributaries of the Skagit River (Figure 7.3) and the mainstem of the upper Skagit River remain below thermal thresholds of 13 ^{o}C (55.4 ^{o}F) (see Figures 7.5 and 7.6). The downstream site on the Skagit, at Sedro Woolley, is projected to exceed thermal threshold of 13 ^{o}C (55.4 ^{o}F) and 16 ^{o}C (60.8 ^{o}F) as shown in Figure 7.7. Seattle City Light (2010) pointed out that future climate could put more thermal stress on salmonids than what is predicted in Hamlet et al. (2010) if glacial runoff, which is not included in the study of Hamlet et al. (2010),decreases or disappears in late summer.

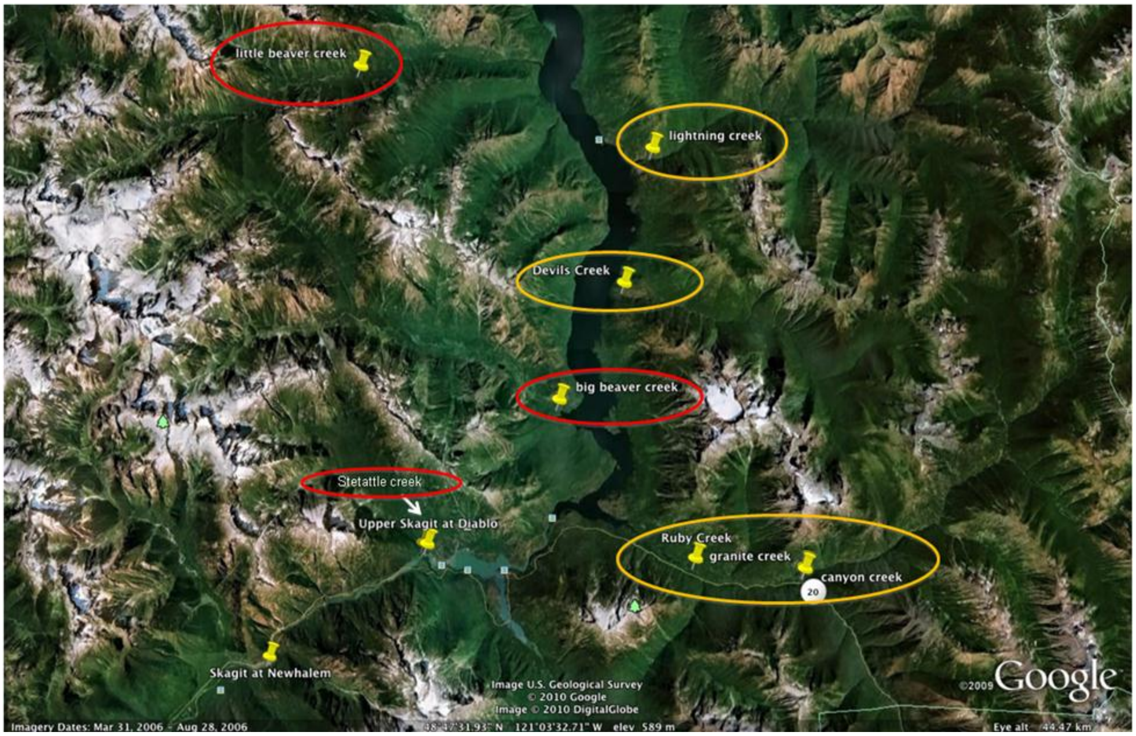


Figure 7.3 Map of study sites by Hamlet et al. (2010). Orange and red circles are the east and west side tributaries of the Skagit River, respectively.

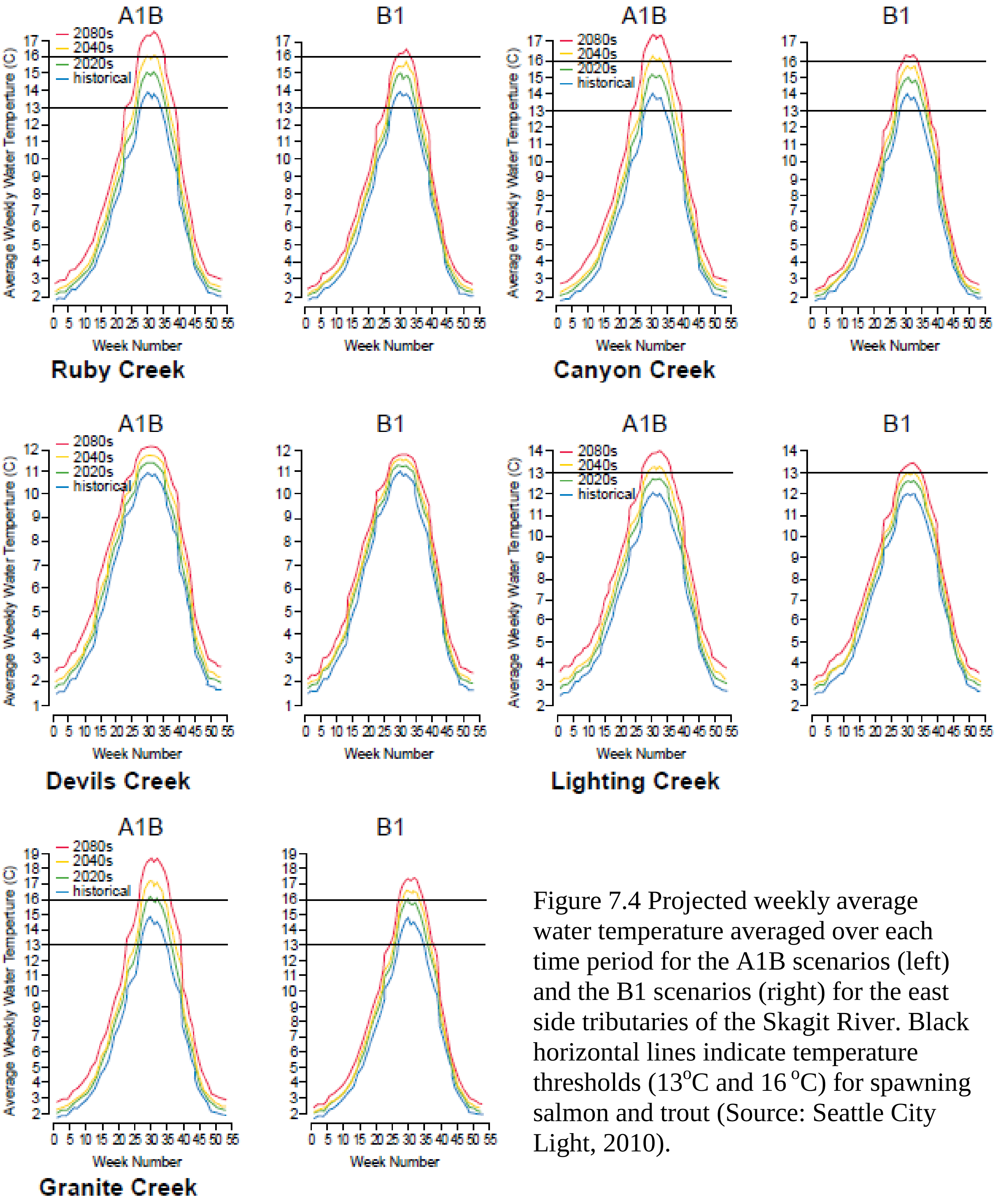
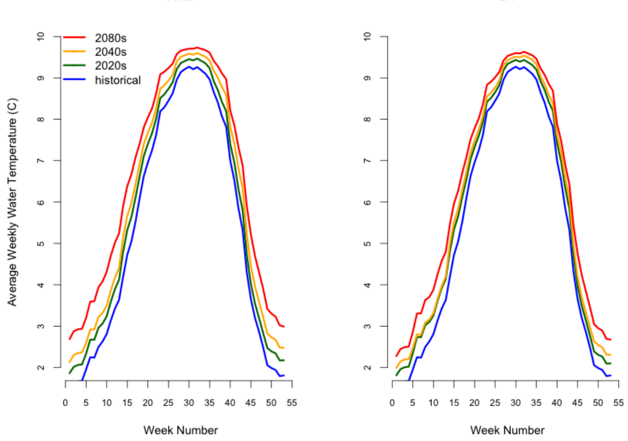
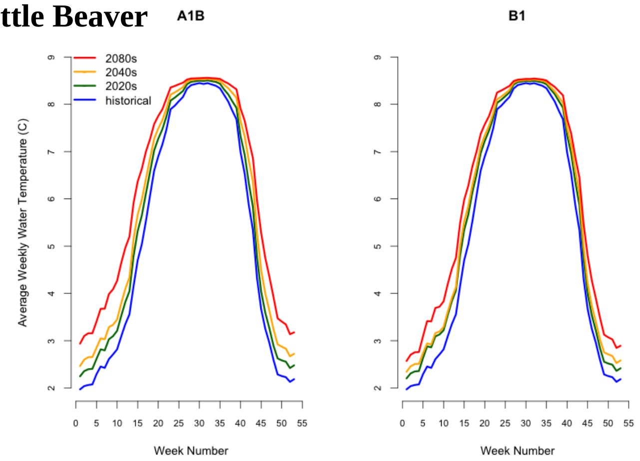


Figure 7.4 Projected weekly average water temperature averaged over each time period for the A1B scenarios (left) and the B1 scenarios (right) for the east side tributaries of the Skagit River. Black horizontal lines indicate temperature thresholds (13°C and 16 °C) for spawning salmon and trout (Source: Seattle City Light, 2010).

Stettatle Creek



Little Beaver



Big Beaver

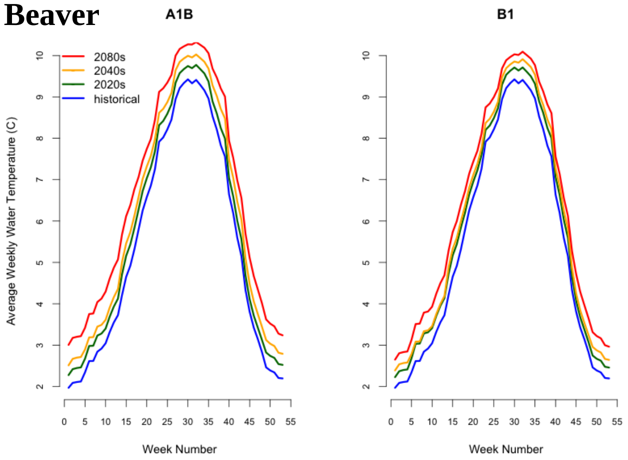
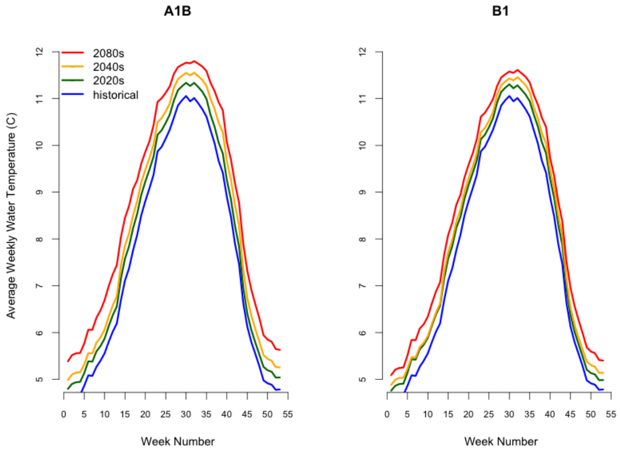
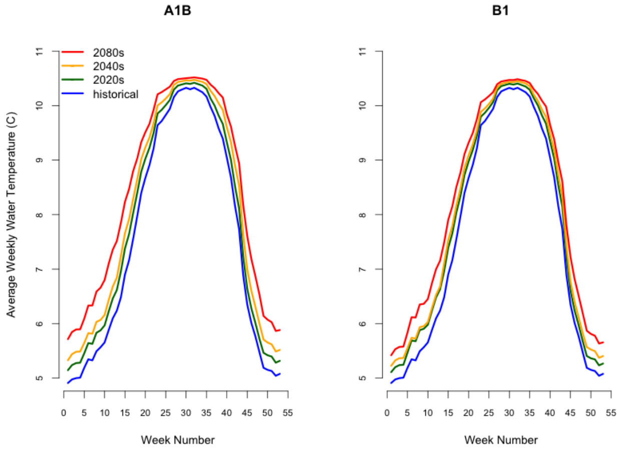


Figure 7.5 Projected weekly average water temperatures averaged over each time period for the A1B scenarios (left) and the B1 scenarios (right) for the west side tributaries of the Skagit River (Source: Hamlet et al., 2010).

Marblemount



Newhalem



Diablo

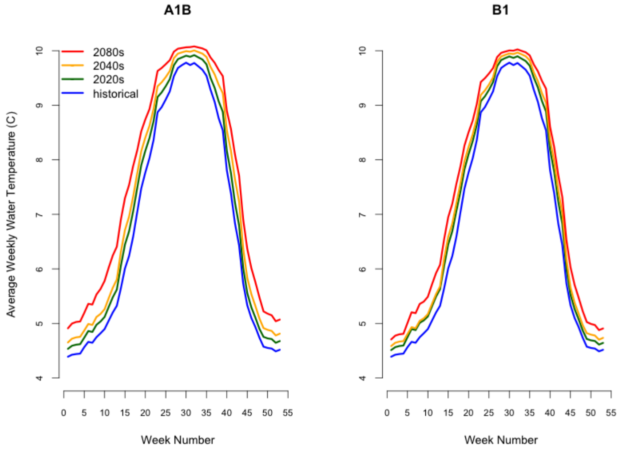


Figure 7.6 Projected weekly average water temperatures averaged over each time period for the A1B scenarios (left) and the B1 scenarios (right) for the main stem of the Skagit River (Source: Hamlet et al., 2010).

Sedro Woolley

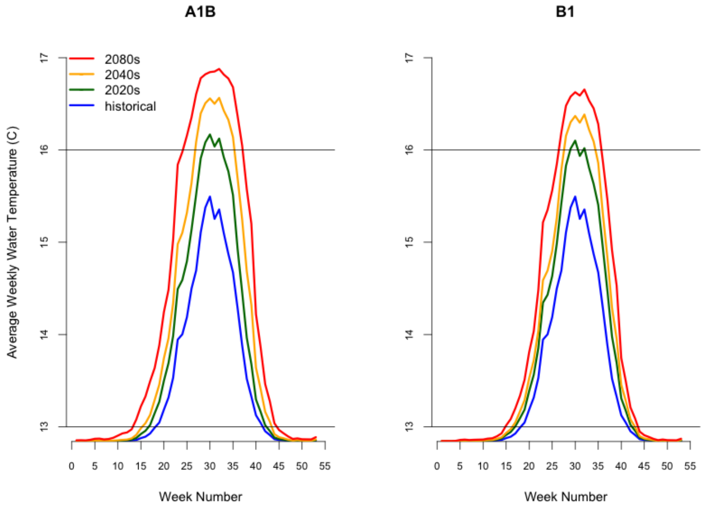


Figure 7.7 Projected weekly average water temperatures averaged over each time period for the A1B scenarios (left) and the B1 scenarios (right) for the Skagit River at Sedro Woolley (Source: Hamlet et al., 2010).

As discussed in Chapter 5, Hamlet et al. (2010) evaluated how climate change influences extreme events such as floods and low flows in the Skagit River basin. The flood risk as defined by 20, 50, and 100 year return intervals is projected to increase first in the warmer lower basin such as Mount Vernon and only later in the century in the colder headwater areas such as Ross Dam. The lowest consecutive 7-day flows with a 10-year return interval (7Q10) are projected to decrease for all sites in the Skagit River, exacerbating thermal stresses on salmon populations. Therefore, the productivity of salmonids in the Skagit River basin is expected to decline due to expected hydrologic changes and increased thermal stresses (Mantua et al., 2010; Hamlet et al., 2010; CCWAPWG, 2009).

Sea level rise is likely to reduce available habitat for juvenile chum and Chinook salmon in the Skagit estuary, resulting in a declines in these populations (URL 9; Hood, 2005; Beamer et al., 2005; Schweiger, 2007). Hood (2005) investigated the possible impacts of sea level rise on salmon habitat in the Skagit delta (discussed in following section) and then on smolt capacity. He estimated that Juvenile Chinook salmon would decline by 211,000 and 530,000 fish, respectively, for a 45 and 80 centimeters (18 and 32 inches) of sea level rise. The projected sea level rise is also likely to affect other fish species that depend on coastal habitats during their life cycle such as coho salmon, pink salmon, cutthroat trout, and bull trout (Schweiger, 2007).

7.3 Tidal Marsh Habitat

As discussed in Chapters 1 and 6, since post European-settlement began in the second half of the 19th century, estuarine habitat zones in the Skagit delta have been changed due to human actions such as diking, ditching, draining and logging (Collins, 1998; Beamer et al., 2005). Beamer et al. (2005) compared 1991 habitat conditions with reconstructed historic conditions in the 1860s to estimate the changes in the estuarine habitats in the Skagit River delta. As shown in Figure 7.8, 74.6 % of tidal delta estuarine habitat area has been lost in the entire geomorphic Skagit delta, which extends from Camano Island northward and includes Samish Bay. Swinomish Channel historically connected Skagit Bay with Padilla Bay through a wide estuarine emergent wetland and slough corridor and thus the delta area between southern Padilla Bay and Camano Island was contiguous and directly connected to the Skagit River in the 1860s. However Swinomish Channel is now a narrow dredged navigation channel. More than 90 % of the Skagit delta has also been lost from riverine and tidal influence due to dikes (Hood, 2004). As a result, the contiguous estuarine habitat area is much reduced from the mid-19th century values and is now mostly confined to the delta area near Fir Island.

As discussed in Chapter 6, sea level rise and other factors associated with climate change pose a significant threat to coastal habitats in the Skagit delta which have already been impacted by human actions. Hood (2005) used a computer model to estimate the possible impacts of sea level rise on intertidal marsh habitat within the Skagit tidal delta as shown in Figure 7.9. A 45 cm (18 inch) rise in sea level, (which was estimated to have a greater than 50 % chance of occurring based on projections available at that time), would lead to a 12 % loss (235 ha) of the tidal marshes and a 51 % loss of the estuarine shrub marsh (a middle panel in Figure 7.9). An 80 cm (32 inch) of sea level rise would result in a 22 % loss (437 ha) of the tidal marsh habitat and a 76 % loss of the estuarine shrub marsh (a right panel in Figure 7.9) (Hood, 2005; Beamer et al., 2005). Hood (2005) noted that these estimates of marsh loss due to sea level rise are preliminary and based only on direct inundation effects, i.e. the analysis didn't include the potential effects of sea level rise on the other factors which affect persistence in tidal marshes such as sediment accumulation or marsh erosion from storm-generated waves, etc. Schweiger (2007) also estimated the loss of tidal marshes and estuarine beaches for sea level rise of 28 cm (11.2 inches) by 2050 and 69 cm (27.3 inches) by 2100 as discussed in Chapter 6. Unlike the work of Hood (2005), Schweiger (2007) considered changes in land elevation due to geological factors, such as uplift and subsidence, and ecological factors, such as sedimentation and marsh accretion. Although two models by Hood (2005) and Schweiger (2007) predicted somewhat different ranges of change in the tidal marshes, both models showed that a) the area of the tidal marshes would be reduced due to sea level rise and b) the South Fork is more vulnerable to sea level rise than the North Fork.

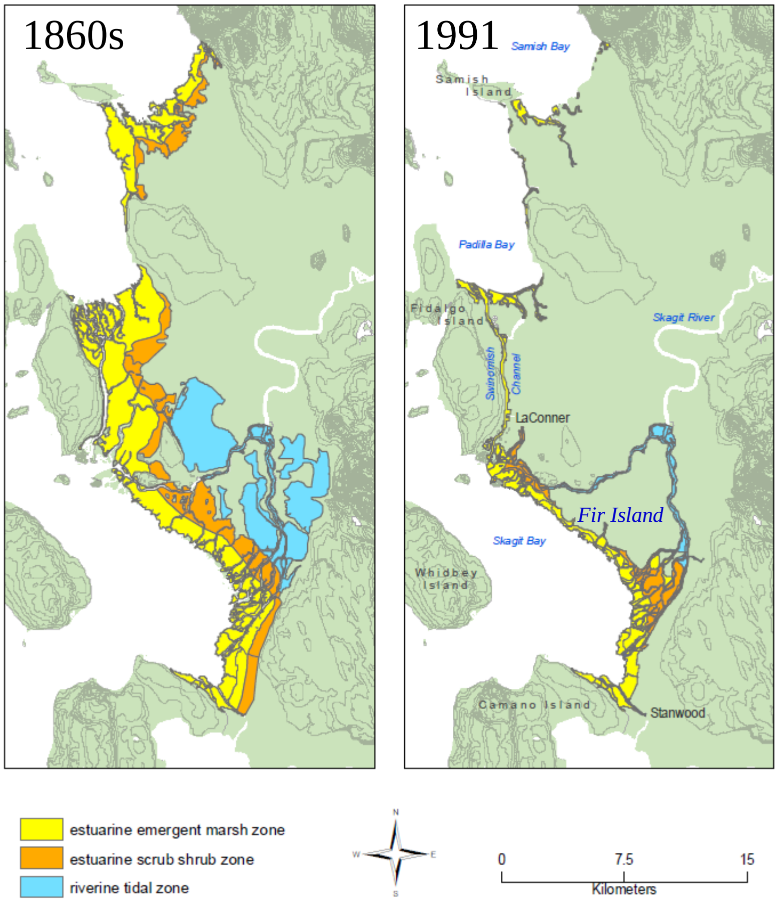


Figure 7.8 Changes to the estuarine habitat zones within the geomorphic Skagit delta. Historic (circa. 1860s) conditions were reconstructed by Collins (2000). Current habitat zones were mapped by Beamer et al. (2000) (Source: Beamer et al., 2005).

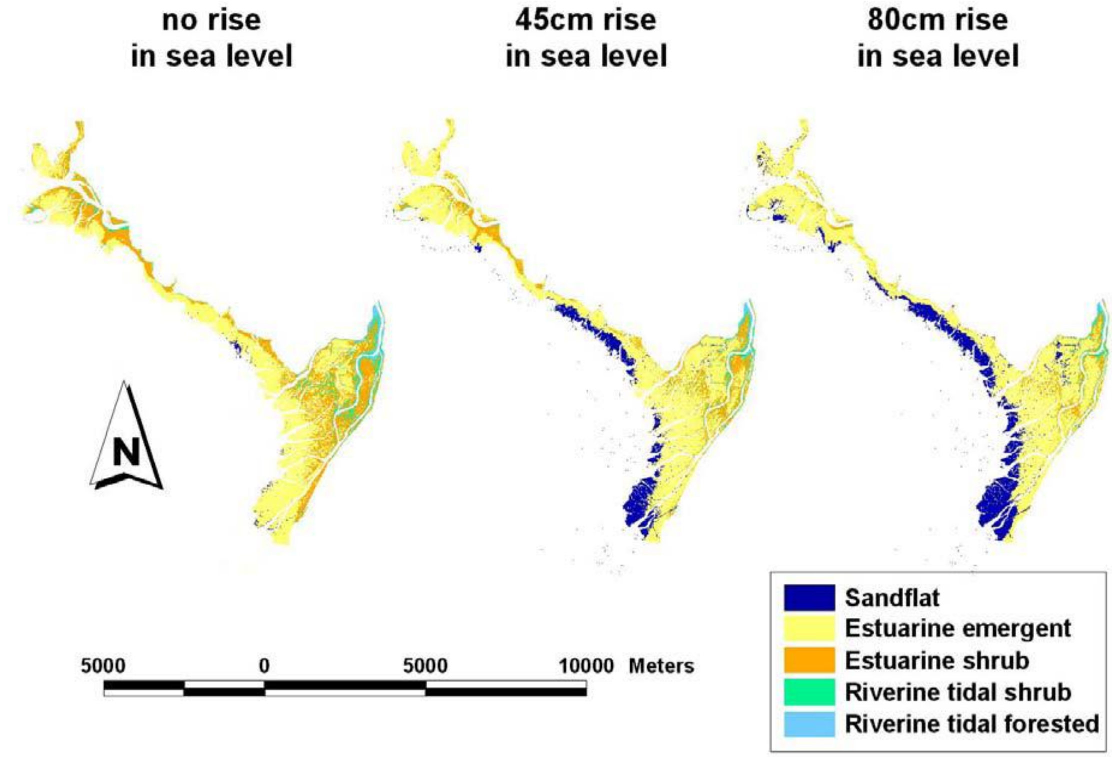


Figure 7.9 Projected estuarine habitat under two sea level rise scenarios. The marshes shown here include the North Fork mouth (NW), the South Fork mouth (SE) and bayfront marshes in between. Farmed land is to the NE of each figure, Skagit Bay to the SW (Source: Beamer et al., 2005).

7.4 Estuary and Puget Sound

Puget Sound estuaries including tidal influenced wetlands and the outer of the delta provide habitats for thousands of plant and animal species (Snover et al., 2005; Schweiger, 2007). 73 % of tidal influenced wetlands in Puget Sound have been damaged or destroyed by diking, dredging, filling, industrial and agricultural activities, and urbanization (Fresh et al., 2004; Snover et al., 2005; Schweiger, 2007; Borde et al., 2003). About one-third of Puget Sound's shoreline has been modified by seawalls, bulkheads, and other structures (Schweiger, 2007).

The remaining habitats in Puget Sound will be further threatened by climate change. Sea-level rise is one primary consequence of climate change that affects the region's coastal habitats through salt water inundation, increasing the salinity of the surface and groundwater (Schweiger, 2007). Projected sea level rise would cause further losses of Puget Sound estuaries, particularly where land areas are already sinking (i.e. central and southern Puget Sound), and/or where sediment transport is reduced (i.e. the South Fork of the Skagit River (Chapter 6)), or where upland migration of the habitats is prevented by human activities such as dikes, seawalls, and other armoring (Snover et al., 2005; Schweiger, 2007).

Higher water temperature (Figure 7.2) and the losses of pollutant-filtering coastal habitats are hypothesized to exacerbate the impact of excess nutrient runoff into coastal waters, enhancing harmful algal blooms and hypoxia events (Snover et al., 2005; Schweiger, 2007). Enhanced algal blooms and hypoxia events are likely one of the biggest threats to habitats in south Hood Canal due to relatively slow circulation in comparison with the rest of the Sound (Snover et al., 2005; Schweiger, 2007). Shifts in seasonal precipitation patterns, reduced snowpack, and the streamflow timing shifts they imply are likely to alter salinity, water clarity, stratification, and oxygen levels, resulting in additional impacts on the region's coastal habitats (Schweiger, 2007). Another emerging threat associated with increasing greenhouse gasses (e.g. CO_2) is ocean acidification (i.e. declining pH of ocean water) (Snover et al., 2005; Orr et al., 2005; Feely et al., 2009& 2010; Doney et al., 2009), which is expected to impact shellfish viability in Puget Sound (Snover et al., 2005; URLs 10 & 11). Oyster production near Olympia, WA, for example, has already declined substantially in recent years (URLs 10 & 11), and these impacts are projected to intensify (URL 10).

7.5 Summary and Conclusions

Climate change is likely to result in profound impacts to terrestrial, freshwater, and marine ecosystems in the Skagit basin. Hydrologic changes such as increasing water temperature and hydrologic extreme events (floods and low flows) will affect many fish and wildlife species. There are many uncertainties about the projection of sea level rise and its impacts on coastal habitats but there is little doubt that coastal habitats will be influenced by sea level rise. Such changes in fish and wildlife habitat will have a significant impact on the salmon, migratory birds, and other species. It is difficult to translate the potential habitat changes into specific impacts on individual species, but generally the losses of habitats would cause a decline in terrestrial and aquatic species. Other key findings include the following:

- Climate change and its consequences are likely to alter the species composition of trees and vegetation in the Skagit forest. Drier and warmer summer would cause decrease in drought-susceptible species such as western cedar trees and even drought-tolerant species such as Douglas fir. Changes in temperature and precipitation would also create more favorable conditions for forest pests, diseases and wildfire. On the other hand, warmer climate is likely to cause some species in high elevation to grow more and tree lines to climb higher by decreasing snow cover that buries trees in winter.
- More severe and prolonged summer low flow, increased flooding, and warmer air temperatures are likely to impose steadily increasing stress on cold water fish species, resulting in declining salmon and trout populations.
- Sea level rise is likely to cause losses of habitat that support terrestrial and aquatic species. The loss of pollutant-filtering habitats would decrease water quality, disturbing the overall food web and consequently impacting many species.
- Overall coastal habitats in Puget Sound are likely to decrease due to sea level rise and other factors associated with climate change, though the impacts of sea level rise on coastal habitats vary with uncertain, site-specific factors.
- The algal blooms and hypoxia events are likely to be enhanced due to warmer water temperature and the losses of pollutant-filtering habitats. The enhanced algal blooms and hypoxia events would threaten some of habitats in Puget Sound, particularly in south Hood Canal which is most susceptible to algal blooms and hypoxia events in Puget Sound.
- Ocean acidification is likely to be intensified due to increasing carbon dioxide concentration, threatening shellfish variability in Puget Sound.

URL 1: http://www.goskagit.com/home/article/climate_change_poses_threat_to_regional_icons/
URL 2: http://en.wikipedia.org/wiki/Fir_Island_%28Washington%29
URL 3:
http://wdfw.wa.gov/lands/wildlife_areas/skagit/unit.php?searchby=unit&search=Skagit%20Bay%20Estuary
URL 4:
http://www.nature.org/wherewework/northamerica/states/washington/files/skagitvisitorsguideweb_06_07.pdf
URL 5: http://en.wikipedia.org/wiki/List_of_wildlife_of_the_Skagit_River_Basin
URL 6: http://www.skagiteagle.org/IC/IC-EagleViewingTips.htm
URL 7: http://www.wildlifeviewingareas.com/wv-app/ParkDetail.aspx?ParkID=378
URL 8: http://www.outstandingwaters.org/seattle_citylight.html
URL 9:
http://www.goskagit.com/home/article/warming_shifts_odds_away_from_salmon_survival/
URL 10: http://seattletimes.nwsource.com/html/localnews/2012338264_acidification13m.html
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