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Probable Implications of Global Climate Change on Southern Resident Killer Whales

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The Southern Resident Killer Whales are the world’s most studied group of orcas. They reside in the Salish Sea around the San Juan Islands for roughly 8-9 months each year. The Center for Whale Research on San Juan Island has been documenting their three pods J, K, and L since 1976 (whaleresearch.com). Through the decades this group of orcas has faced adversity in many forms ranging from capture for entertainment parks to food scarcity to increasing marine pollution, eventually earning themselves a spot on the Endangered Species list in 2005. Although they have seemingly rebounded from an all-time low number of 67 in 1971 to 88 individuals as of December 6, 2011, their largest threat may be yet to come, climate change (Olesiuk et al, 1990).

 Climate change is a worldwide phenomenon occurring due to the anthropomorphic combustion of fossil fuels for energy and transportation functions. This increase in usage of fossil fuels has created an increased greenhouse effect in Earth’s atmosphere. The greenhouse effect occurs when molecules absorb excess greenhouse gases such as carbon dioxide, methane, and nitrous oxide, which are enormous byproducts of fossil fuel energy production. These excess greenhouse gases caught in Earth’s atmosphere absorb infrared wavelengths and intensify the Earth’s ability to heat itself, thus causing a global change of temperatures and weather patterns (UCAR, 2011). Through an array of direct and indirect impacts,Southern Resident Killer Whales and their lifestyle will become drastically altered by climate change in the coming years.

 The Pacific Northwest (where the Southern Resident Killer Whales reside) is not immune to climate change. Annual global temperature has already risen by 1.5 degrees Fahrenheit since the 1920s (WACCIA). Its already mild and damp conditions are predicted to intensify as climate change persists throughout this millennium. Global Climate models, which are used to predict the effects of global warming, are showing a consistent result of an average annual temperature rise in the Pacific Northwest. Global climate models predict that by the 2020s average temperatures will rise two degrees Fahrenheit, three degrees Fahrenheit in the 2040s, and over five degrees Fahrenheit by the 2080s (WACCIA). Drastic changes in Pacific Northwest temperatures, which are being predicted, can cause an array of problems for the Southern Resident Killer Whales’ fragile population. Temperature rise can cause alterations in precipitation, increase marine pollution, cause ocean acidification, and most importantly decimate the already dwindling number of Pacific Northwest salmon runs, which are the vast majority of the orcas’ food supply.

 Salmon are the lifeblood of the Southern Resident Killer Whales. They are a specific ecotype of Orca (*Orcinus orca*) that is genetically different from others of their same species. One of the reasons these orcas are categorized differently is because of their primary food choice, Pacific Northwest salmon. Orcas around the world eat different food sources ranging from other marine mammals, herring, squid, to even sharks. The Southern Residents obtain 96% of the nutritional needs from Pacific salmon (*Oncorhynchus spp*.), 63% are obtained from exclusively Chinook salmon (Ford et al, 1999). Even in the presence of other potential food sources, these orcas choose to forage for Chinook salmon (*Oncorhynchustshawytscha*), which are the largest of the salmonoid species in the Pacific Northwest and potentially the most threatened by climate change.

 The Pacific Northwest is home to five salmon species: chum, pink, sockeye, coho, and chinook. These five species all begin life as an egg deposited to a redd in the freshwater environment. After two-three months the alevin hatches and remains in the redd until the yolk sac has been absorbed thus transforming it into a fry. The fry then emerges from its protective nest in the gravel and is categorized as one of two types of salmon based on its next decision (Goble, 1999). Type A salmon, chum, pink, and sockeye, fledge the birth stream either to a lake or the ocean. Type B salmon, coho and chinook, will remain in the birth stream for up to three years as they develop into fingerlings (Goble, 1999). Both types of salmoniods begin the process of smolting as they move downstream and complete the transformation in the estuary before they flee to a marine environment (Goble, 1999). This convoluted process of development and emergence into two distinctly different ecosystems makes salmon particularly susceptible to complications arising from climate change.

 Pacific Northwest salmon have been threatened for decades by habitat degradation for hydroelectricity, agriculture, logging, and mining. Salmon farming, or hatcheries, keep exporting salmon, but negatively affect the wild populations that share the same habitat by competing for resources and spreading disease. Salmon need cool, aerated, clean, and fully connected streams to spawn in a freshwater environment, all of which can be easily altered by climate change. They also require a clean, disease and parasite-free marine habitat to thrive. Current salmon runs along the Washington Coast are 1.8% of historic run size; Puget Sound runs are 8%, the Columbia Basin 1.7%, the Oregon Coast 7%, and British Columbia 36.2% (Lackey, 2000). The combination of Washington, Oregon, Idaho, and California salmon runs are 5.2% of historic salmon runs (Lackey, 2000). The already diminished Pacific Northwest salmon runs face many adversities in the future from climate change, such as increased thermal stress, precipitation changes which will alter stream flow, and more hydroelectric stress.

 A large concern for the health of Pacific Northwest salmon runs is the introduction of increased thermal stress due to the predicted rise of summertime temperatures across the area. Salmon require clean, cool, oxygenated water for survival; the preferred water temperature for maximum production is below 15 degrees Celsius. Water temperatures that rise above 15 degrees Celsiuscan alter migration and breeding patters along with increase the risk of predation (EPA, 2007). If water temperatures exceed 21 degrees Celsius, migration can be halted and the elevated transmission of disease and pathogens can be fatal for juveniles and adults(McCullough, 1999). The projected climate change for the Pacific Northwest based on eight climate change scenarios is between 2-5.5 degrees Celsius (Mantua et al, 2009).The greatest impacts caused by thermal stress are estimated to affect spawning adults with summertime migrations, including a significant number of sockeye and Chinook (Mantua et al,2009).Along with the threat of climate change raising temperatures, other anthropomorphic factors such as the removal of riparian vegetation can cause increased thermal stress for salmon, and pose a greater threat to survival of all Pacific Northwest salmon runs by the late 2000s.

 Perhaps the largest threat to Pacific Northwest salmon isn’t the physical rise in habitat temperature, but the alteration of streamflow patters across the area. Runoff in Washington’s watersheds is classified in three different categories: snowmelt dominant, transient, and rainfall dominant. Climate change is predicted to alter these runoff patterns by snowmelt watersheds transitioning to primarily transient (snowmelt and rainfall) watersheds and transient watersheds becoming rainfall dominant (Mantua et al, 2009).Climate models are predicting only a slight increase in precipitation, if any, but the distribution of precipitation is predicted to become altered, causing wetter winters and drier summers. Already dry summers coupled with higher water temperatures and lower streamflows can pose a large threat to many salmon species by eliminating deep pools to escape the rising temperatures, create a reduction in spawning habitat, and a lack of connectivity to lead adults to spawning grounds and smolts to the sea (Mantua et el, 2009). Summer lowflows are predicted to increase by 50% in 2080 (Mantua et al, 2009). Transient streamflows, which are caused by combining rainfall runoff and peak snowmelts, are predicted to increase, and by the late 2000s snowpack in the higher elevations is predicted to be negligible. The lack of snowfall and increase of rain in higher elevations will preclude to intense winter flooding and extreme high streamflow in winter months. Increases in high streamflow are predicted to negatively impact fry survival in several species of salmon, including pink, chum, sockeye, and Chinook (Mantua et al, 2009) Increased winter flooding coupled with low flow in the spring and fall and extreme low flow in the summer will have a significant impact on all freshwater life stages Pacific Northwest salmon species by the late 2000s (Mantua et al, 2009).

 Climate Change will also alter the marine water temperatures and sea level in the Pacific Northwest. These changes will impact both Southern Resident Killer Whales and their primary food source, Pacific Northwest salmon. Ocean temperature and sea levels rise in the upper 700m of the Pacific Ocean were 50% higher than estimated in the 2007 IPCC report (Domingues et al, 2008). Increased ocean temperature can alter feeding ecology, migration, and behavior of Pacific Northwest salmon. Higher temperatures also increase energy demands and can change the distribution of oceanic predators, such as Southern Resident Killer Whales. How increased oceanic temperature will affect free ranging marine species is currently unknown. The ability to evolve and adapt or seek a more comfortable climate will most definitely come into play. Sea level rise from melting ice packs and higher runoff rates are predicted to negatively impact estuary habitats (Domingues et al, 2008). Destruction of estuary habitats, where salmon spend a significant amount of time feeding and developing, can alter food dynamics, predation, pollution, and disease.

 Another climate change induced marine threat to Southern Resident Killer Whales is ocean acidification. Ocean acidification occurs when the acidity increases and lowers the pH of the ocean. Acidity increases due to the oceans heightened absorption of carbon dioxide due to anthropomorphic processes (Huppert et al, 2008). In 2008, ten billion tons of carbon dioxide emissions were produced;about half of that gets absorbed by land vegetation, the other half by the ocean (Doney et al, 2008). According to Scott Doney(2008),“As atmospheric carbon dioxide rises, thermodynamics and air-sea gas transfer processes drive some of the extra carbon dioxide into ocean surface waters, leading to substantial shifts in sea water acid-base chemistry…and the chemical speciation of the large reservoir of inorganic carbon dissolved in seawater.” Some biological implications of ocean acidification are possible effects on nutrient cycling in phytoplankton, which has the ability to cause food chain alterations for every species within the oceans, along with increased solubility of calcium carbonate, which is used as a skeletal structure in many marine invertebrates including corals (Doney et al, 2008). The biological effects mentioned could negatively affect the Southern Resident Killer Whales due to inducing another threat of low marine food supply to salmon, which the Southern Resident Killer Whales depend on for sustenance. Physical impacts of ocean acidification on Southern Resident Killer Whales include a reduction of low frequency sound adsorption due to a decline in dissolved borate ions, which are pH-dependent and absorb low frequency sounds (Brewer and Hester, 2009). According to Brewer and Hester (2009), “a decline in pH of only .3 causes a 40% decrease in the intrinsic sound absorption coefficient.” All cetaceans, including Southern Resident Killer Whales are extremely acoustic creatures. An increase in anthropomorphic sound in the ocean can cause problems in every aspect of the Southern Resident Killer Whales’ life, including communication, feeding, mating, traveling and resting.

 Sea level rise as a whole will drastically increase pollution in the marine environment. Inundation, erosion, landslides, and increased flood will all wash man-made coastal debris and toxic waste into the ocean ecosystem. Changes in coastal habitat and food supply are likely to influence where Southern Resident Killer Whales forage. Indirectly, sea level rise will affect the Southern Resident Killer Whales by contributing to habitat degradation of their main food source, Pacific Northwest salmon. According to a range of “Intergovernmental Panels on Climate Change”, global sea levels are expected to rise by .08 meter (3 inches) by 2025 and up to .69 meter (27.3 inches) by 2100 (Glick et al, 2007). According to a study by the National Wildlife Federation entitled “Sea Level Rise and Coastal Habitats in the Pacific Northwest,” by 2100 estuarine beaches will experience a 65% loss, up to 44% of tidal flats will be lost, 25% of tidal and 13% of freshwater marshes will be gone, and 52% of brackish marsh could be converted to saltwater marshes. The aforementioned implications can cause a significant amount of damage to an already beleaguered salmon stock.Most salmon depend on estuarine ecosystems for food and shelter before fledging to a marine ecosystem. Sea level rise is predicted to inundate 65% of estuarine habitats by 2011, which will significantly impact survival rates for especially estuarine dependent species such as juvenile Chinook and chum (Glick et al, 2007). According to a recent study, seal level rise in the Skagit Delta estimated that the rearing of juvenile Chinook salmon would decline by 211,000 fish from a 45-centimeter (18 inch) seal level rise (Hood, 2005). Chinook and chum salmon are the most consumed by Southern Resident Killer Whales who depend on Chinook salmon for 63% of their dietary needs (Ford et al, 2000).

 Climate change is transpiring;even if fossil fuel emissions were halted or drastically reduced, it would continue to occur for years to come. The direct and indirect implications it will have on Southern Resident Killer Whales has yet to be studied in depth. Some common treads that will likely impact them, their food sources, and their geographic range are increasing temperatures, altered streamflow, ocean acidification, and sea level rise. The amalgamation of these factors are likely to progress to climate-related cetacean range shifts that are already apparent in some regions (Salvadeo et al, 2010). Southern Resident Killer Whales utilize the Salish Sea ecosystem for numerous reasons including predictability of food sources, shelter from Open Ocean and climatic factors that enhance efficiency. It is likely that as temperatures continue to increase Southern Resident Killer Whales, like other cetaceans that have been observed, will either have to expand their range, shift poleward, or contract their range based on characteristics of niches they fill (Salvadeo et al, 2010). It is a likely hypothesis that Southern Resident Killer Whales will eventually shift their range North, which in turn would overlap the Northern Resident Killer Whale range and continue to put pressure on an exhausted food source, Pacific Northwest salmon. If either of those resident pods begin to shift poleward, they will continue to overlap on other resident territory, such as the Southern Alaskan Resident pods, while adding increased competition for a limited food source (Yurk et al, 2001).

 Within the next 30-60 years, average temperatures are expected to increase from 2-5.5 degrees Celsius in the Pacific Northwest (Mantua et al, 2009). The direct effect of temperature rise on the Southern Resident Killer Whale population are largely unknown, but the direct effect it will have on their primary food source, Pacific Northwest salmon, is being widely studied. The increase in temperatures coupled with habitat destruction puts an already thematically stressed population of salmon at a high risk for survival. Current Pacific Northwest salmon runs are 5.2% of historic runs and with the addition of climate change will continue to decline (Lackey, 2000). Alterations in streamflow patterns by significant changes in precipitation patterns and increased temperatures in estuarine and marine habitats will also add a significant number of obstacles to salmon survival (Mantua et al, 2009). Ocean acidification has the ability to directly affect Southern Resident Killer Whales by causing a reduction of low frequency sound adsorption due to a decline in dissolved borate ions, which will essentially increase noise pollution for an extremely acoustic animal (Brewer and Hester, 2009). The predicted 0.08-0.69 meters of sea level rise has the ability to directly and indirectly affectSouthern Resident Killer Whales by destroying estuarine habitat, which most Chinook salmon are dependent upon, along with increasing potential toxic pollutants (Glick et al, 2007).

 With the implications of climate change pending, it will seemingly exude a copious amount of stressors on a damaged ecosystem. The ability of the Southern Resident Killer Whales to adapt to these changes will be essential for their survival. Whether that adaptation be keeping their current range but expanding food source options, moving poleward towards more abundant salmon runs, or expanding their home range even farther towards Northern Alaska and Southern California, is yet to be known. Further research needs to be completed to develop a better predictability model for Southern Resident Killer Whale climate change coping abilities.

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