LITERATURE REVIEW OF THE SOCIO-ECONOMIC CONSEQUENCES OF GLOBAL WARMING AND ABRUPT CLIMATE CHANGE IN THE PACIFIC NORTHWEST

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Introduction and Overview

The global climate is changing. Scientists with the National Center for Atmospheric Research (NCAR) and University of Washington Climate Impacts Group (CIG) believe that global warming and abrupt climate change pose significant threats to the environment of the Pacific Northwest. Changes in the environment may precipitate change in the economy, social welfare, and quality of life of the region.

The complexity of the Earth's biophysical and atmospheric systems makes the study of global warming challenging. Despite the challenges, a growing stream of scientific research is emerging on the current and potential changes in the environment of the Pacific Northwest from organizations such as NCAR and the UW CIG. By comparison, very little research to date has been undertaken to understand the potential range of socio-economic consequences that global warming and abrupt climate change may bring to the Northwest

This document examines some of the major research that has been conducted on the socio-economic consequences of global warming and abrupt climate change in the Pacific Northwest. The purpose is to: 1) identify and describe the research topics, methods, and conclusions that have been developed; and 2) to identify the gaps and future research needs related to understanding the potential range of socio-economic consequences of climate change in the Pacific Northwest.

The Executive Summary is longer than is traditionally done. However, it provides an overview of the topics that have been studied, their conclusions, and the methodologies used by researchers. Tables 1,2 (a) and 2(b) summarizes these issues.

The report itself provides a more in depth summary of each research report. Each summary is includes a summary, methodology, conclusions, and where available, further research suggested by the researchers**.** The summaries have been paraphrased from the original research report or quoted and cited where needed. All graphs and tables have been copied directly from the publications.

Executive Summary

A majority of scientists and leading scientific organizations believe that human generated greenhouse gas emissions have contributed to a general warming trend of the earth's climate. The environmental consequences of global warming in the Pacific Northwest may include, among other changes, reduced snowpack and thus less runoff from snow melt and reduced spring and summer streamflows; an increase in the intensity of storms and flooding concentrated in mid-winter months, drier and hotter summers, and sea level increase. The socio-economic studies reviewed in this document seek to understand and outline a range of possible socio-economic consequences resulting from these environmental changes. The study assess the potential consequences of climate change on agriculture, forests, estuaries and tidal marshes, salmon, the ocean and coastal communities, storm water and flooding, municipal and industrial water supplies, energy supplies, recreation, flooding, landslides, and human health impacts. A summary of the conclusions drawn for these topics and further research suggestions are presented below.

Summary of Topics, Studies, and Conclusions

Agriculture

Each species, whether it is plant or animal, is dependent on a range of climatic conditions that create a favorable place to live. The general hypothesis is that as the climate warms, vegetation patterns will shift based on the availability of water and preferable climatic conditions needed to sustain life. Crops that favor warmer temperatures will do better than others, but without an adequate supply of water they will be unable to grow properly. Consequently, the distribution of these species will change overtime, with the potential to affect local farmers and their economic livelihood.

Physicians for Social Responsibility 2000
Earlier snowmelts and higher temperatures could cause more summertime droughts, like the drought of 1999, threatening agricultural production, compromising water quality, and impairing hydroelectric power generation.

Goodstein and Matson 2004
Northwest agriculture is highly dependent on surface water irrigation. This was most dramatically illustrated in the low snowpack year of 2001 in the Klamath Basin in southern Oregon and northern California. Gross farm incomes fell between $48 and $64 million in a region that generated average revenues of $97 million the previous three years.

The lost value of irrigation water ranges from $465 million to $2.4 billion annually, depending upon the assumed initial price, demand elasticity, and a range of snowpack reduction scenarios. For irrigated agriculture and salmon alone, damages will range from .2% to 2.8% of regional GDP by 2050.

Washington EPA Report

In Washington, agriculture is about a $4 billion annual industry; two-thirds of this revenue is crops like wheat, barley, hay, and potatoes. About 28% of the state's farm acres are irrigated. With warmer temperatures, wheat yields could increase by up to 70-90%. Barley and hay fields could decrease by 4-14%, and potato yields could fall by 17%. Farm income could double or triple. The number of irrigated acres could increase, which could further stress water supplies, which may already be lower in the summer.

Oregon EPA Report

Increases in climate variability could make adaptation by farmers more difficult. Analyses that assume changes in average climate and effective adaptation by farmers suggest that aggregate U.S. food production would not be harmed, although there may be significant regional changes.

In Oregon, production agriculture is a $2.5 billion annual industry, three-fourths of which comes from crops. Almost one-half of the farmed acres are irrigated. Climate change could increase wheat yields by 2-13%. Hay and pasture yields could rise by 10% or fall by 7%, depending on how the climate changes and whether irrigation is used. Potato yields could fall by 17% as temperatures rise beyond the tolerance level of the crop. Farmed acres could remain fairly constant or could decrease by as much as 23%.

Michael 2003

Crop yields vary substantially depending on whether future climate will have lower or constant relative humidity. For irrigated wheat, yield is about 20% lower if absolute humidity is constant. With CO_2 at 560 ppm, net water demand, averaged over all crops, declines about 7%. This offset will lower water supplies to a significant extent. With CO_2 at 560 ppm, crop productivity will also increase by 10% to 15%. A 2 degree warming will likely reduce summer unregulated flows and the total water supply available (TWSA) for irrigation, increasing the probability of severe water prorationing to junior irrigators from about 14% to about 54%. Doubling the instream flow to 600 cfs increases the probability of severe prorationing to 62%. However, at 50% prorationing, about 400,000 ac-ft is "lost" between withdrawal from the river and application to crops. Although much of this "lost" water returns to the river, reducing these losses by 25%, would be enough to compensate for the lower withdrawals required for higher instream flows.

The impact on instream flow in the Yakima Valley shows that summer minimum flows could be maintained at the cost of a significantly higher probability of water prorationing for junior agricultural users. In general, the impact of climate warming on minimum flow is expected to be negative. Much of the reduction in water availability could be offset by a combination of more efficient water transportation, higher crop productivity, and water use efficiency due to enhanced CO_2. Significant uncertainties include the impact of CO_2 on plant water use, the amount of carryover moisture available to crops at the beginning of the growing season, and the impact of climate change on relative humidity (which strongly regulates water demand).

Forests

JISAO Climate Impacts Group
Declines in forest productivity in some areas could lead to a decline in long-term timber yields that could affect the region's economy. Higher timber prices and reduced availability of wood fiber could also affect other industries and sectors, although, these changes could be mitigated by increased imports of wood products from other regions. Such mitigation of economic impacts would obviously depend upon how forested areas in other regions around the world fare from climate change. A reduction in forested area could also decrease production of clean water for human consumption and recreation.

If forest fires become more widespread, adverse impacts on air quality and public health can be expected as well (p.73). Increased frequency of high intensity fire could result in increased rates of carbon cycling with a net gain in atmospheric carbon. This would create a positive feedback loop, exacerbating rates of global climate change and related rates of forest ecosystem change.

Oregon EPA Report
Hotter, drier weather could increase the frequency and intensity of wildfires, threatening the important timber-producing areas of the state. Commercial timber production could also be affected by resulting changes in growth rates, plantation acreage and management, and market conditions. The character of the forests would change, as well as the activities that depend on them.

Estuaries and Tidal Marshes

Washington EPA Report
Increases in sea level and decreases in river flow could affect estuaries, increasing salinity and decreasing tidal marsh areas. Valuable commercial shellfish communities (i.e. oysters and clams) and duck and geese populations that utilize these flats for habitat and feeding may also decline accordingly.

Salmon

JISAO Climate Impacts Group
In the past decade, restrictions on fishing opportunities (for commercial, tribal, and sports fishers) have had devastating impacts on the local economies that formerly revolved around salmon fishing. The PNW salmon economy has all but collapsed in the past decades as a consequence of the decline in salmon numbers and the concomitant effort to protect and restore remaining populations (p.58).

Goodstein and Matson 2004
The range of damage to salmon from climate change is from $359 million to $7.2 billion annually. If you incorporate estimates of regional population and income growth, this compensation figure rises to $24 billion annually by 2050. On a nationwide basis, the researchers estimate that salmon extinction could reduce welfare by close to $108 billion,

approximately 1% of national GDP, by 2050. For irrigated agriculture and salmon alone, the authors estimate a range of damages from .2% to 2.8% of regional GDP by 2050.

Francis and Mantua 2003
There is a clear linear relationships between naturally occurring and large-scale changes to the physical environment and salmon populations in the Northeast Pacific. Inter decadal environmental fluctuations, associated with the Pacific Inter decadal Oscillation (PDO), appear to have significantly reduced the ecosystem(s) carrying capacity for West Coast coho salmon since 1977. The overall productivity of salmon in Alaska has dramatically increased during this same time period in response to PDO-related climate changes. It seems likely that the polarity of the PDO climate pattern will continue to change at inter decadal time scales as it has over (at least) the past century. If and when that happens, West Coast coho salmon will once again experience favorable climatic conditions while Alaska salmon will be faced with poor marine and terrestrial climate conditions. However, wild West Coast coho salmon will continue to face the problems caused by the legacy of human land use, hatchery and harvest practices.

Climate alone is not likely to tip the balance. However, climate variability clearly has the capacity to amplify the risk and likelihood of extinction when superimposed upon salmonid ecosystems under extreme stress from humans. Since climate effects on salmon seem to be much more significant at inter decadal than annual time scales, and since inter decadal time-scale climate change can only be recognized in hindsight, the effects of climate need to be hard wired into fishery management policy (e.g. different management strategies and algorithms may be required for different climatic regimes).

Climate-related negative impacts on salmon production at the regional scale will likely have much more severe implications for individual breeding populations than for meta-populations as a whole. Clearly, this has been the case for thousands of years. However, combining the effects of human activities with climate fluctuations likely amplifies a number of these negative influences.

The salmon populations in this region, with healthy habitat, will probably survive as long as the time scale of environmental change does not exceed their rate of adaptation. On the other hand, those populations that are presently stressed by occupying healthy, marginal or fragmented habitat will most likely face more acute threats of extinction with the additional burden of significant anthropogenic climate changes.

Pacific Ocean and the Coast

JISAO Climate Impacts Group
Tourism and seasonal visitation in the spring and summer dominate economic activity in the communities along Washington and Oregon's Pacific coast. As an example, the City of Ocean Shores, Washington, with a permanent year-round population of approximately 3,300 residents, attracts more than 1.5 million visitors each year. In addition, some coastal communities also rely on commercial fishing, shellfish aquaculture, and

agricultural production to help drive their local economy. If ocean levels rise, many of these beach communities, and opportunities for tourism, could diminish.

Because beachfront property is so highly prized, much of the most significant private development along the exterior Pacific coast has been built directly along the shoreline, or in low-lying areas immediately inland. In recent years, larger multi-family developments and hotels have been added to the existing stock of oceanfront single-family homes. Depending on their exact location, these properties could be threatened by long-term erosion, storm damage and/or flooding (p.79). Within the less diversified economies of smaller communities, damage to this type of commercial and residential development could be devastating. For example, in the City of Ocean Shores, beachfront erosion now threatens an area that represents more than 10% of the City's property tax base. If climate change and erosion accelerate the erosion trends that have emerged recently along parts of the coast, this type of scenario could become more common.

Private interests in aquaculture and commercial fisheries could also be threatened by the physical changes associated with climate change. Oyster production and crabbing generate significant revenues for the communities along both Grays Harbor and Willapa Bay, Washington. Any threats to the tide flats and estuarine areas of the Coast could damage these industries. Furthermore, in other areas, flooding or saltwater intrusion may threaten lands that are productive for agriculture or grazing.

In addition to the significant private investments described above, important public assets could also be placed at risk. Currently, erosion already threatens important public resources along the Washington coast:

- For several miles along the northern shore of Willapa Bay, State Route 105 sits perilously close to the shore. Shoreline armoring and beach nourishment have been used to help stabilize the nearby shoreline, but erosion still threatens the road.
- At Ocean Shores, Washington the City's recently renovated wastewater treatment facility sites in a low-lying area that is subject to flooding and erosion.
- Near the mouth of the Columbia River, erosion is threatening facilities at Washington's Fort Canby State Park.

Threats from sea-level rise and flooding will likely be met by efforts to reinforce existing shoreline protection; however, such protection measures will be costly. For example, a detailed analysis of conditions along the waterfront in the City of Olympia, Washington suggests that existing shoreline protection will not be sufficient to safeguard some areas from inundation if the most aggressive projections of sea level rise prove to be accurate. Additional challenges will be posed by the potential for more frequent and widespread flooding as sea level rise compromises operation of the City's storm water system.

Washington EPA Report
Sea level rise could lead to flooding of low-lying property, loss of coastal wetlands, erosion of beaches, saltwater contamination of drinking water, and decreased longevity of low-lying roads and bridges. Possible responses to sea level rise include building walls to hold back the sea, allowing the sea to advance and adapt to it, and/or raise the land (by replenishing beach sand and/or elevating houses and infrastructure). Each of these responses will be costly, either in out-of-pocket costs or in lost land and structures. For example, the cumulative cost of sand replenishment to protect Washington's coastline from a 20-inch sea level rise by 2100 is estimated at $143 million to $2.3 total billion.

Oregon EPA Report
Sea level rise could lead to flooding of low-lying property, loss of coastal wetlands, erosion of beaches, saltwater contamination of drinking water, and decreased longevity of low-lying roads and bridges. Oregon has a 1,400-mile tidally influenced shoreline that consists mostly of steep slopes, pocket beaches, and small embayments, with a few natural coastal plains. The steep, rocky cliffs that dominate most of the coastline limit vulnerability to sea level rise. The sea level on the Oregon Coast is estimated to rise six inches by 2100, but the rocky shore of Oregon may limit erosion, and help protect the coastline. The cumulative cost of sand replenishment to protect the coast of Oregon from a 20-inch sea level rise by 2100 is estimated at $60-$920 total million.

Whitmore 2004
Lost recreation value to Oregon residents for Oregon coastal beaches will be $39 million annually for a scenario of 25% beach loss, $92 million for 50% beach loss, and $132 million for 75% beach loss. Existence value for Oregon residents was calculated to be $67 million annually for a 25% beach loss scenario, $123 million annually for 50% beach loss and $197 million annually for 75% beach loss.

Some of Oregon's beaches are likely to be lost for recreation while others will experience slight apparent change. As many beaches become recreationally unusable, people will visit less affected ones, increasing visitor density leading to crowding on those beaches. A more complex analysis of the costs of rising sea level would incorporate information about visitor rates at particular locations and the likely affect on beach width on those beaches resulting from rising sea level.

Among the costs of global climate change, Oregon coastal beaches will lose value to recreational users and to people who value knowing that the resource's current amenity condition will be protected from the consequences of rising sea level.

Hydroelectric Power

Physicians for Social Responsibility 2000
Earlier snowmelts and higher temperatures could cause more summertime droughts, like the drought of 1999, threatening agricultural production, compromising water quality, and impair hydroelectric power generation.

JISAO Climate Impacts Group
If climate change decreases summer flow and if rising temperatures increase the demand for electricity, then the price of summer hydropower could rise substantially (p.38). On the flip side, the price of winter hydropower could drop as supply increases and demand decreases (due to lower demand for heating) (p.38). The deregulation of the electric utilities vastly complicates any analysis of the possible future economic impacts of climate change on hydropower, because we know very little about how the markets will operate in the future and about how they will respond to stresses such as climate variability and change.

Northwest Power Planning Council 2004
The expected annual change in hydroelectric generation due to climate change depends heavily on forecasted changes to future precipitation (a very uncertain factor). The power-system benefits or costs of climate change correspond directly with the change in runoff volume.

Runoff volume (fuel for the hydroelectric system) makes a big difference in total annual generation. Under the MPI scenario (warm and dry), the hydroelectric system is estimated to lose about 700 average megawatts (aMW) of energy in 2020 and 2,000 aMW by 2040. Current annual hydroelectric generation for the Columbia River system is about 16,000 aMW under average conditions and about 11,600 aMW for the driest year.[1] These energy losses are not cheap. The estimated regional annual cost of the MPI scenario is $231 million in 2020 and $730 million by 2040.

For a warm-and-wet scenario, the economic outlook is much better. With more fuel for the hydroelectric system, the region is forecasted to see about 2,000 aMW more energy by 2020 and about 300 aMW more by 2040. The corresponding economic benefits are presented in Table 3 below. Under the combination scenario, the region will see a slight increase in generation by 2020 and a net loss of generation by 2040. This scenario shows a net increase in generation (and revenue) by 2020 but a net loss of generation and revenue by 2040.

In addition to the impacts to river flows, hydroelectric generation, and temperature, climate change will also affect the Northwest's interactions with other regions. Currently, both the Northwest and Southwest benefit from differences in climate. During the winter peak demand season in the Northwest, the Southwest generally has surplus capacity that can be imported to help with winter reliability. In the summer months, the opposite is true and some of the Northwest's hydroelectric capacity can be exported to help the Southwest meet its peak demand needs. This sharing of resources is cost effective for both regions.

Under a severe climate change scenario (as seen in the MPI example) the Northwest could see increased summer demand with greatly decreased summer hydroelectric production. It is possible that the Northwest could find itself having to plan for summer

[1] For another perspective, hydroelectric energy losses due to measures provided for fish and wildlife concerns amount to about 1,100 aMW.

peak needs as well as for winter peaks. In that case, the Northwest would no longer be able to share its surplus capacity with the Southwest. This would obviously have economic impacts in the Southwest where additional resources may be needed to maintain summer service. This would likely raise the value of late summer energy, thereby increasing the economic impact of climate change to the northwest.

Oregon EPA Report
Oregon is a major producer of hydropower, and lower flows could affect its ability to meet energy production requirements, fish protection, irrigation, recreation, and water supply.

Governor's Advisory Group – Draft for Public Comment [no date provided]
Utility companies in the Pacific Northwest invested some $2.4 billion between 1990 and 2002 in energy-efficient technologies, resulting in savings of some 2600 aMW annually. The entire $2.4 billion investment pays for itself in electricity bill savings about once every 18 months. These investments have also created new jobs insulating houses, installing thermostats, and designing and building energy-efficient windows and manufactured housing. Along the way, markets were developed in other states for those same windows and manufactured housing units, bringing new dollars and jobs back into Oregon.

Recreation

Oregon EPA Report
The public demands high lake levels in the summer for recreation. Lower streamflows and lake levels would exacerbate current stresses and increase competition among water uses.

Water Quality

Oregon EPA Report
Lower summer flows and higher temperatures could impair water quality by concentrating pollutants and reducing the ability of streams to assimilate wastes.

Washington EPA Report
Water quality could be degraded further than it is already.

Physicians for Social Responsibility 2000
Earlier snowmelts and higher temperatures could cause more summertime droughts, like the drought of 1999, threatening agricultural production, compromising water quality, and impairing hydroelectric power generation.

Physicians for Social Responsibility [no date provided}
Both droughts and floods can impair water quality.

Water Supply

Goodstein and Matson [no date provided]
The water supply development cost implies a cost to Portland of $6,590,000 per year. Scaling this figure up, the projected cost of developing new municipal supplies in Washington and Oregon is estimated to be $116,000,000. The researcher's estimated cost for water supply development is conservative, because Portland's water supply is dependent on rain rather than snowpack, and it does not take into account the water supply needs of industrial users not served by the municipality.

Palmer and Haun [no date provided]
Many US water supply systems may be negatively impacted by climate change, particularly those that use snowmelt as a source of water. This includes the majority of the large population centers in the western US. Although annual precipitation in watersheds may increase in some regions, the timing of the precipitation may not correspond to those periods during high water demand. Runoff will likely occur earlier in the spring, due to temperature increases, and summer flows will be lower due to the combination of smaller spring runoff and lower summer precipitation.

These impacts will not be limited to municipal water supplies as other studies by the author have indicated, but will have significant impacts on power production and the ability to meet environmental flows.

Climate change will have a significant impact on the hydrology of the Bull Run watershed and will impact the safe yield of Portland's water system. For seven typical dry years, climate change will reduce the amount of water that can be used to meet water demands by an average of 1.5 billion gallons and increase demand during the draw down period by 2.8 billion gallons, resulting in 4.3 billion gallons of reduced minimum storage. These climate impacts exacerbate the need that exists to provide some 9.6 billion gallons of increased demands due to regional growth.

In approximately 50% of the years, climate change impacts by the year 2040 would decrease minimum system storage by more than 1 billion gallons each year. This decrease results from earlier spring runoff that cannot be captured in the reservoirs and lower summer flows due to the earlier streamflow recessions.

Hersh and Wernstedt 2001
The vulnerability of drinking water systems in the Willamette basin to extreme events driven by climate disturbances is very uncertain in nature. There is some evidence, albeit limited, that more intense El Niño - Southern Oscillation (ENSO) cycles and global climate change-- might lead to a higher incidence of extreme events. The operational burdens placed on water utility operators by increases in the frequency or intensity of extreme events may cause little disruption to drinking water provision. However, the combination of hydrologic effects and current institutional stresses—population growth, the added costs of complying with provisions in the Endangered Species Act, the constraints to develop water rights, the political environment of flood policy and planning

and fiscal issues—could make some water utilities more susceptible to extreme weather events associated with a changing climate.

Physicians for Social Responsibility [no date provided]
Changes in precipitation amounts and patterns could lead to more flooding in some areas and droughts in others, therefore decreasing supply. Water supply may be contaminated due to salt-water intrusion caused by rising sea levels.

Flooding

An increase in precipitation, coupled with an increase in the severity of storms, and rising sea levels, will ultimately lead to more flooding.

Physicians for Social Responsibility 2000
Severe flooding in Washington in February 1996 killed three and caused an estimated $800 million in damages. More frequent and severe floods could result in larger property damage, cause injuries, and spread illnesses through contaminated water.

Physicians for Social Responsibility [no date provided]
A projected increase in sea level of one to three feet by 2100 could bring flooding and coastal erosion, particularly when complicated by storm surge.

Goodstein and Matson [no date provided]
Average damage due to flooding in the region over the past twenty years is $259 million dollars (2002 dollars). Using this estimation, the researchers assumed a modest 10 percent average increase in flooding by 2040 from climate change, and estimated the cost of climate change in terms of increased flooding to be $26 million.

Payne et. al. [no date provided]
It is impossible to state explicitly the changes in flood risk and/or damages that would accompany the projected hydrologic changes; however, the opportunity costs associated with maintaining the same general flood control policy appear to be much higher than the associated benefits. This study suggests that the reconsideration of flood control needs and values in the context of instream flow and hydropower production considerations posed by a warmer PNW climate would be highly desirable.

Landslides/Erosion

Physicians for Social Responsibility 2000
More extreme weather events could cause more landslides like the January 1997 landslide in Snohomish County that brought down 75,000–150,000 cubic meters of earth, swept five cars of a passing freight train into Puget Sound, and killed a family of four.

Health Impacts

Physicians for Social Responsibility 2000
Severe flooding in Washington in February 1996 killed three and caused an estimated $800 million in damages. More frequent and severe floods could result in larger property damage, cause injuries, and spread illnesses through contaminated water. Warmer temperatures could expand the habitat of ticks that carry Lyme disease and lengthen the season during which people are outdoors, increasing the state's average of fourteen cases per year. Warmer ocean temperatures and changes in water stratification could increase shellfish contamination incidents by bacteria, such as Vibrio parahaemolyticus which sickened 56 Washingtonians in July and August of 1997. Warmer summer temperatures could worsen air pollution by increasing concentrations of ground-level ozone and other pollutants in the air that exacerbate asthma, a condition suffered by one in nine adults and one in ten children.

Physicians for Social Responsibility [no date provided]
Water supply may be contaminated due to salt water intrusion caused by rising sea levels. There could be an increase in injuries from potential extreme weather, including floods.

Decreased air quality, causing more frequent and severe attacks of asthma and worsening of other respiratory and cardiac problems, could result from worsening ozone (smog) levels; greater emissions of nitrogen dioxide, sulfur dioxide, particulate matter, and other toxic pollutants; smoke from forest fires sparked by drought; and increased pollen levels.

A greater risk of infectious disease could result from contaminated water (from animal and human waste) used for drinking and recreation. This is more apt to occur after heavy rainfall and can lead to bacterial, parasitic, and viral infections.

Increased risk of mosquito-carried diseases such as malaria and dengue fever. Heat-related deaths could increase significantly. Senior citizens, the very young, and the poor are at greatest risk of death from heat stress.

Washington EPA Report
Winter-related mortality in Washington could increase if warming occurs because the frequency of air masses associated with inclement weather is expected to increase. One study has estimated that a 3°F warming in Seattle, Washington would increase winter-related mortality from 15 today to about 40[2]. The elderly, particularly those living alone, are at greatest risk.

There is concern that climate change could increase concentrations of ground-level ozone. For example, high temperatures, strong sunlight, and stable air masses tend to increase urban ozone levels. Air pollution is also made worse by increases in natural hydrocarbons emissions during hot weather. If a warmer climate causes an increase in

[2] The unit of measurements was not specified

the use of air conditioners then air pollutant emissions from power plants will also increase.

Increased emissions and accelerated atmospheric chemistry could slow progress being made in Washington to provide healthy and clean air. Currently, the Seattle-Tacoma area does not meet the national health standards for ozone and particulate matter. The particulate matter standard is also not met in Olympia, Spokane, Wallula, and Yakima. Ground-level ozone has been shown to aggravate existing respiratory illnesses such as asthma, reduce lung function, and induce respiratory inflammation.

Oregon EPA Report

Higher temperatures and increased frequency of heat waves may increase the number of heat-related deaths and the incidence of heat-related illnesses. Oregon, with its occasional, intense heat waves, may become more prone to heat waves if its climate changes. In Portland, heat-related deaths are estimated to increase by nearly 150% given a summer warming of 4°F (although increased air conditioning use may not have been fully accounted for). The elderly, especially those living alone, are at greatest risk. There will be little change in winter-related deaths in Portland if the temperature warms by 2-3°F.

Warming and other climate changes could expand the habitat and infectivity of disease-carrying insects, thus increasing the potential for transmission of diseases such as malaria and dengue (“break bone”) fever. Warmer temperatures could increase the incidence of Lyme disease and other tick-borne diseases in Oregon because populations of ticks, and their rodent hosts, could increase under warmer temperatures and increased vegetation. St. Louis and California encephalitis are present in California, and some studies indicate that these diseases could move north under a warmer climate. Western equine encephalitis has also been found in domestic animals in Oregon. Mosquitoes can carry these diseases, which can be lethal or cause neurological damage to humans. If conditions become warmer and wetter, mosquito populations could increase, thus increasing the risk of transmission of malaria and other mosquito-borne diseases. Increased runoff from heavy rainfall could increase water-borne diseases such as giardia and cryptosporidia.

Goodstein and Matson [no date provided]

The health of people living in urban areas will not only be affected by a limited supply of clean water, but also by an increase in temperature. The severity of heat stroke and exhaustion among the elderly is likely to increase as temperatures rise. The prevalence of mosquitoes carrying diseases, such as Malaria, will directly affect human health as their distributions shift from climate change.

Further Research

1) Understand the behavior of North Pacific climate so that scientists can make more accurate predictions of summer climate in the PNW. This would include knowing more about the severity of temperatures in the summer and the timing and onset of fall rains (JISAO Climate Impacts Group).
2) Understand the full range of natural climate variability, and the impacts past climate variations have had (JISAO Climate Impacts Group).
3) Study the direct and indirect impacts of climate on Northwest forests (JISAO Climate Impacts Group).
4) Quantify the impacts of climate variability on the region's coasts (JISAO Climate Impacts Group).
5) Explore the implications of shifts in consumption patterns, transportation requirements, land-use planning, and so forth, in the context of a changing climate.
6) Analyze the socioeconomic and institutional policies on coping strategies arising from climate change to determine the most economically and political feasible coping strategy, and determine the best approach to implementing them. Once we know more of these answers, we should create a regional climate service that will provide relevant and timely information concerning climate fluctuations and trends on a variety of timescales (JISAO Climate Impacts Group).
7) Obtain a larger set of historical water conditions from 1929 to 1999 and a correlated set of monthly temperatures and electricity prices for each water condition (Northwest Power and Conservation Council 2004).
8) Revise summer demand response to temperature changes to incorporate the latest data on air-conditioning penetration rates (Northwest Power and Conservation Council 2004).
9) Refine river-flow adjustments (Northwest Power and Conservation Council 2004).
10) Evaluate the economic impacts of climate change on coastal sea level rise, forestry, forest ecosystems, recreation and human health (Goodstein and Matson 2004).
11) Understand the relationship between climate patterns and domoic acid and research ways to minimize the hazard (Physicians for Social Responsibility 2000).
12) Better understand the relationships among climate change, the health of ecosystems, and the health of the public (Physicians for Social Responsibility [no date provided]).
13) Attain more exact estimates of the costs of climate change on coastal communities (Whitmore 2004).

Methodology

Dramatic weather patterns in the past few years are convincing even determined skeptics that there are some changes in global climate. Changes in the climate will certainly affect our health, environment, and economy but the extent of these effects remain uncertain. This uncertainty makes planning difficult and highlights the most prudent course of action, that is, to reduce the rate of climate change. Like other environmental problems that threaten our well being such as air and water pollution, global climate change is caused largely by human activities. The major source of uncertainty relates to the future emissions of greenhouse gases that will force the climate to change. These emissions are driven by complex factors such as population growth, economic growth, and energy policy and so on. Many previous researches have attempted to know about climate change impacts. Our report is based on some research done in the Northwest, Oregon State and Washington State and relies on their techniques used to measure the climate change impacts and methodologies applied to their study. The objective of this report is to find the best applicable methodology used by different researchers in this area. Some of the commonly used methodologies to project the uncertainties in climate change include:

- Observation,
- Existing Data (Historical and present),
- Model / Scenarios
- Survey / Interviews
- Qualitative
- Quantitative
- Literature Review.

Table (1) shows the methodologies used by researchers and gives a clear idea as to which methodology is applicable to the given study and how many previous studies have used similar methodology.

Table 2(a), 2(b).shows the subject areas addressed in regional impacts of climate change in the previous studies (Agriculture, Salmon, Strom water/Flooding, Municipal / Industrial water supply, Beach loss study, Costal infrastructure, Recreation and tourism, Forests and fire, Public health, Population decline Energy and Business and urban economy) to understand the potential impacts of climate change in Pacific Northwest, Oregon and Washington. This aids in developing a solution to reduce the impact on climate change in this region and gives us clear vision to find the solution for the future problems.

Table 1(a): Subject Areas Addressed in Studies

Study / Publication Date		Page #	Agriculture	Salmon	Strom water /Flooding	Municipal/ Industrial water supply	Beach Loss Study	Coastal Infrastructure
Northwest								
JISAO	-	24		■		■		■
Goodstein	-	28			■	■		
Hydro-system	Nov 2004	31						
Goodstein	July 2004	35	■	■				
Mantua	April 2003	37		■				
Washington								
EPA	Sep 1997	40	■					■
Payne	-	42			■			
WA PSR	Sep 2004	44	■					
Scott	2002	46				■		
Oregon								
EPA	Sep 1998	48	■			■		■
Governor's AG	Oct 2004	50						
Palmer	-	52				■		
Hersh	Sep 2001	55				■		
OR PSR	Feb 2002	57				■		
Whitmore	May 2004	60					■	

Table 1(b): Subject Areas Addressed in Studies

Study / Publication Date	Page #	Recreation / Tourism	Forests /Fire	Public Health	Population decline	Energy	Business and urban economy
Northwest							
JISAO -	24		■				
Hydro-system Nov 2004	28					■	
Goodstein -	31						
Goodstein July 2004	35						
Mantua April 2003	37						
Washington							
EPA Sep 1997	40			■			
Payne -	42					■	
WA PSR Sep 2004	44		■	■		■	■
Scott 2002	46						
Oregon							
EPA Sep 1998	48		■	■			
Governor's AG Oct 2004	50			■			■
Palmer -	52						
Hersh Sep 2001	55						
OR PSR Feb 2002	57			■			■
Whitmore May 2004	60						

Table 2: Methodologies Used

Study / Publication Date		Page #	Observation Data	Exiting Data (Historical and Present)	Model /Scenarios	Survey/ Interviews	Literature	Qualitative	Quantitative
Northwest									
JISAO	-	24	■					■	
Hydro-system	Nov 2004	28			■				■
Goodstein	-	31		■					■
Goodstein	July 2004	35		■					■
Mantua	April 2003	37					■		
Washington									
EPA	Sep 1997	40						■	■
Payne	-	42			■		■	■	
WA PSR	Sep 2004	44							
Scott	2002	46			■		■		■
Oregon									
EPA	Sep 1998	48						■	■
Governor's AG	Oct 2004	50					■		■
Palmer	-	52			■				■
Hersh	Sep 2001	55				■		■	
OR PSR	Feb 2002	57					■		
Whitmore	May 2004	60			■	■			■

Table 3: Proposed Further Research

Study / Publication Date		Proposed Further Research
Northwest		
JISAO	-	The behavior of North Pacific climate, the direct and indirect impacts of climate on NW forests and impacts of climate variability on the region's coasts
Hydroelectric system draft	Nov 2004	A larger set of historical water conditions from 1929 to 1999 and correlated set of monthly temperatures and electricity prices
Goodstein	July 2004	Coastal sea level rise, forestry, forest ecosystems, recreation and human health.
Mantua	April 2003	N/A
Washington		
EPA	Sep 1997	N/A
Payne	-	N/A
WA PSR	Sep 2004	Relationship between climate patterns and domoic acid and all practicable steps to minimize the hazard
Scott	2002	N/A
Oregon		N/A
EPA	Sep 1998	N/A
Governor's AG	Oct 2004	N/A
Palmer	-	N/A
Hersh	Sep 2001	N/A
OR PSR	Feb 2002	Relationships among climate change, the health of ecosystems, and the health of the public and Research and Development of additional ways to sustainable increase crop yields
Whitmore	May 2004	Attain more exact estimates of the costs of climate change

Pacific Northwest

Impacts of Climate Variability and Change in the Pacific Northwest

The Joint Institute for the Study of the Atmosphere and Ocean (JISAO) Climate Impacts Group, University of Washington. [No date provided]

Summary

The Climate Impacts Group (CIG) at the University of Washington used qualitative, observational data to prepare this report. In it, they describe the possible impacts of human-induced climate change on our water resources, salmon, forests, and coasts of the Pacific Northwest (PNW). The report does not seek to prove that climate change is occurring or that it is due to human activities. This Assessment has begun a national process of research, analysis, and dialogue about the coming change in climate, its impacts, and what Americans can do to adapt to an uncertain and continuously changing climate. It is built on a solid foundation of science conducted as part of the United States Global Change Research Program (USGCRP).

Methodology

No concrete numbers were given to represent the socio-economic impacts of climate change. Rather than use climate change models, they used observed data to establish the impacts of observed climate variations on a variety of biophysical parameters. Where possibly, they empirically established the impacts of climate variability on key components of the physical, biological, and human environment in the Northwest.

Conclusions

Salmon – Fisheries

In the past decade, restrictions on fishing opportunities (for commercial, tribal, and sport fishing) have had devastating impacts on the local economies that formerly revolved around salmon fishing. The PNW salmon economy has all but collapsed in the past decades as a consequence of the decline in salmon numbers and the concomitant effort to protect and restore remaining populations (p.58).

Hydropower

If climate change decreases summer flow and if rising temperatures increase the demand for electricity, then the price of summer hydropower could rise substantially (p.38). On the flip side, the price of winter hydropower could drop as supply increases and demand decreases (due to lower demand for heating) (p.38). The deregulation of the electric utilities vastly complicates any analysis of the possible future economic impacts of climate change on hydropower, because we know very little about how the markets will operate in the future and about how they will respond to stresses such as climate variability and change (p.38).

Forests

Climate changes are predicted to result in major changes in the production of goods and services from the forests of the PNW (p.72). Reductions in forest area, coupled with an increase in stress from summer drought, can reduce the average productivity of forestlands. Declines in forest productivity in some areas could lead to a decline in long-term timber yields that could affect the region's economy. Higher timber prices and reduced availability of wood fiber could also affect other industries and sectors, although, these changes could be mitigated by increased imports of wood products from other regions. Such mitigation of economic impacts would obviously depend upon how forested areas in other regions around the world fare from climate change.

A reduction in forested area could also decrease production of clean water for human consumption and recreation. If forest fires become more widespread, adverse impacts on air quality and public health can be expected as well (p.73). Increased frequency of high intensity fire could result in increased rates of carbon cycling with a net gain in atmospheric carbon. This would create a positive feedback loop, exacerbating rates of global climate change and related rates of forest ecosystem change.

Oceans - Coastal

Tourism and seasonal visitation in the spring and summer dominate economic activity in the communities along Washington and Oregon's Pacific coast. As an example, the City of Ocean Shores, Washington, with a permanent year-round population of approximately 3,300 residents, attracts more than 1.5 million visitors each year. In addition, some coastal communities also rely on commercial fishing, shellfish aquaculture, and agricultural production to help drive their local economy. If ocean levels rise, many of these beach communities, and opportunities for tourism, could diminish (p.79).

Because beachfront property is so highly prized, much of the most significant private development along the exterior Pacific coast has been built directly along the shoreline, or in low-lying areas immediately inland. In recent years, larger multi-family developments and hotels have been added to the existing stock of oceanfront single-family homes. Depending on their exact location, these properties could be threatened by long-term erosion, storm damage and/or flooding (p.79). Within the less diversified economies of smaller communities, damage to this type of commercial and residential development could be devastating. For example, in the City of Ocean Shores, beachfront erosion now threatens an area that represents more than 10% of the City's property tax base. If climate change and erosion accelerate the erosion trends that have emerged recently along parts of the coast, this type of scenario could become more common.

Private interests in aquaculture and commercial fisheries could also be threatened by the physical changes associated with climate change. Oyster production and crabbing generate significant revenues for the communities along both Grays Harbor and Willapa Bay, Washington. Any threats to the tide flats and estuarine areas of the Coast could damage these industries. Furthermore, in other areas, flooding or saltwater intrusion may threaten lands that are productive for agriculture or grazing (p.79).

In addition to the significant private investments described above, important public assets could also be placed at risk. Currently, erosion already threatens important public resources along the Washington coast (p.79-80):

- For several miles along the northern shore of Willapa Bay, State Route 105 sits perilously close to the shore. Shoreline armoring and beach nourishment have been used to help stabilize the nearby shoreline, but erosion still threatens the road.
- At Ocean Shores, Washington the City's recently renovated wastewater treatment facility sites in a low-lying area that is subject to flooding and erosion.
- Near the mouth of the Columbia River, erosion is threatening facilities at Washington's Fort Canby State Park.

Threats from sea-level rise and flooding will likely be met by efforts to reinforce existing shoreline protection; however, such protection measures will be costly. For example, a detailed analysis of conditions along the waterfront in the City of Olympia, Washington suggests that existing shoreline protection will not be sufficient to safeguard some areas from inundation if the most aggressive projections of sea level rise prove to be accurate. Additional challenges will be posed by the potential for more frequent and widespread flooding as sea level rise compromises operation of the City's storm water system.

Further Research

JISAO stated that inaccurate elevations used in most climate models have negatively affected the quality of climate-change scenarios that they rely on (p.85). Consequently, the accuracy of some models used to predict climate change at the local level will need to be improved.

The researchers also stressed a need to better understand the behavior of North Pacific climate so that scientists can make more accurate predictions of summer climate in the PNW. This would include knowing more about the severity of temperatures in the summer and the timing and onset of fall rains. The authors feel it is necessary to confirm or refute the assumption that increasing concentrations of greenhouse gases influence temperature and precipitation trends. JISAO is currently exploring the climatology of extreme weather events, but more work needs to be done to understand the full range of natural climate variability, and the impacts past climate variations have had.

The direct and indirect impacts of climate on Northwest forests needs to be analyzed further, as well as quantifying the impacts of climate variability on the region's coasts. In addition, the implications of shifts in consumption patterns, transportation requirements, land-use planning, and so forth, need to be explored in the context of a changing climate. Extensive socioeconomic and institutional policy analysis also needs to be done on coping strategies arising from climate change to determine the most economically and political feasible coping strategy, and to determine the best approach to implementing them. The researchers recommend that once we know more of these answers, we should create a regional climate service that will provide relevant and timely information concerning climate fluctuations and trends on a variety of timescales.

The Costs of Climate Change in the Pacific Northwest: Municipal Water Supply & Flooding

Goodstein, Eban and Laura Matson [no date provided][3]

Summary

The Goodstein and Matson study is based on Palmer and Hahn's[4] study of the impacts of climate change on Portland, Oregon's water supply, the Bull Run Watershed, and the consequent ability of the Portland Water Bureau to provide water for the city. In this report, Goodstein and Matson estimate the cost of climate change to urban and industrial water consumers in Washington and Oregon. They have also extended the cost of meeting the projected Portland water shortfall to the rest of the region.

Methodology

Water Supply Development Costs

Knowing the projected water shortage for the city of Portland allowed the researchers to estimate the cost to develop new water supplies for other municipalities in the Pacific Northwest. To project the regional water development requirements due to climate change, Goodstein and Matson used a ratio of the projected Portland shortage to the population of Portland and compared it to the regional population.

To evaluate the cost of new water supply development they used figures from Frederick and Schwartz[5]. Goodstein and Matson quote Frederick and Schwartz:

> Recycling municipal and industrial wastewater is assumed to be the lowest cost source of new supply. It is assumed that up to 10 percent of these uses can be recycled at an average cost of $400/af ($1,228/mg)….
>
> If supplies and demand are still not in balance, it is assumed that an unlimited quantity of new water can be developed at $1,000/af ($3,069/mg). In coastal areas and in areas with abundant supplies of brackish water desalination is a likely source of new supplies. In other areas, water storage projects or imports might be alternative sources of supply.

In calculating the cost of water supply development in the Pacific Northwest, Goodstein and Matson used the lowest estimation Frederick and Schwartz offer: $400/af or $1,228/mg in constant 1995 dollars ($499/af and $1,532/mg in 2002 dollars).

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[3] No pages numbers were provided in the document to reference direct quotes or specific information
[4] Palmer, R. & Hahn, M. (2002). The Impacts of Climate Change on Portland's Water Supply. Portland: Portland Water Bureau.
[5] Frederick, K. & G. Schwartz. (2000). Socioeconomic Impacts of Climate Variability and Change on U.S. Water Resources. Discussion Paper 00-21, Resources for the Future.

Flooding Damage Costs

To estimate the cost of increased flooding the researchers took the average annual flood damages in the region during the past twenty years and assumed a moderate increase of 10 percent in flooding due to climate change.

In their analysis they used flood damage data from a 2002 report produced by the Environmental and Societal Impacts Group of the National Center for Atmospheric Research. In their report, the authors estimate the cost of direct physical damage to property, crops, and public infrastructure due to flooding in the United States. Goodstein and Matson elected to take the average damages of the last twenty years instead of the historic average cost of flooding because the costs of flooding have increased over time from economic and population growth.

Conclusions

Water Supply Development Costs

The water supply development cost implies a cost to Portland of $6,590,000 per year. Scaling this figure up, the projected cost of developing new municipal supplies in Washington and Oregon is estimated to be $116,000,000. Table 2 summarizes the researchers results:

Table 1: Municipal Water Supply Development

	Population	**Required Water Development** (billion gallons)	**Cost of Developing New Supplies** (2002$)
Portland	529,121	4.3	$6,590,000
Oregon	3,421,399	27.8	$42,600,000
Washington	5,894,121	47.9	$73,400,000
Region	9,315,520	75.7	$116,000,000

The researcher's estimated cost for water supply development is conservative, because Portland's water supply is dependent on rain rather than snowpack, and it does not take into account the water supply needs of industrial users not served by the municipality.

Flooding Damage Costs

The researchers used flood damage data from a 2002 report produced by the Environmental and Societal Impacts Group of the National Center for Atmospheric Research to create the data found in Table 2. These damage estimations do not include all costs that may result from flooding.

Table 2: Regional Flood Damage, thousands of 2002 dollars

	Oregon	**Washington**	**Region**
1982	0	0	0
1983	6,176	14,333	20,510
1984	46,418	1,316	47,733
1985	46	0	46
1986	31,358	18,824	50,182
1987	858	28,730	29,586
1988	123	11	134
1989	100	328	428
1990	1,137	62,446	63,584
1991	9,922	250,681	260,603
1992	36	199	235
1993	2,033	2,403	4,435
1994	0	189	189
1995	13,639	301	13,941
1996	3,934,664	454,522	4,389,186
1997	216,880	68,464	285,343
1998	13	3,954	3,968
1999	2,700	3,048	5,749
2000	7,528	641	8,168
2001	7	2,406	2,412
Average	**213,682**	**45,639**	**259,321**

Average damage due to flooding in the region over the past twenty years is $259 million dollars (2002 dollars). Using this estimation, the researchers assumed a modest 10 percent average increase in flooding by 2040 from climate change, and estimated the cost of climate change in terms of increased flooding to be $26 million.

Effects of Climate Change on the Hydroelectric System

Northwest Power and Conservation Council, Draft 4. November 2004.[6]

Summary

In this report, the Northwest Power and Conservation Council use three climate change scenarios to illustrate the potential economic costs of climate change on the Northwest's hydropower system. In addition to this report, the Council has been looking at the potential effects of control polices aimed at reducing greenhouse gas emissions on the relative cost-effectiveness of resources available to the Northwest. This involves posing different scenarios about the probability, timing and magnitude of carbon control measures and assessing their effect on different portfolios in terms of cost and risk. The Council's electricity price forecasting model, AURORA©, is being used to assess the possible impact of carbon dioxide control measures on electricity prices and what changes in the composition of the generating resource mix of carbon dioxide might induce.

Methodology

Downscaled[7] hydrologic and temperature data for the Northwest was obtained from the Joint Institute for the Study of Atmosphere and Ocean (JISAO) Climate Impacts Group at the University of Washington. This data was derived primarily from two General Circulation Models (GCMs), the Hadley Centre model (HC) and the Max Planck Institute model (MPI).

To assess climate change impacts to the power system, the Council used two computer models. The first, GENESYS[8], simulates the physical operation of the hydroelectric and thermal resources[9] in the Northwest. The second, AURORA©, forecasts electricity prices based on demand and resource supplies in the West.

Conclusions

Using these models, the researchers found that; 1) the expected annual change in hydroelectric generation due to climate change depends heavily on forecasted changes to future precipitation (a very uncertain factor) and 2) power-system benefits or costs of climate change correspond directly with the change in runoff volume.

The Hadley Centre (HC) model generally shows an overall increase in precipitation across the year. The Max Planck Institute (MPI) model tends to forecast a drier future. The third model is based on a combination of model runs (COMP).

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[6] No pages numbers were provided in the document to reference direct quotes or specific information
[7] A technique used to obtain information for localized areas from global general circulation models
[8] For more information about the model see: www.nwcouncil.org/GENESYS
[9] The thermal resources used were not provided

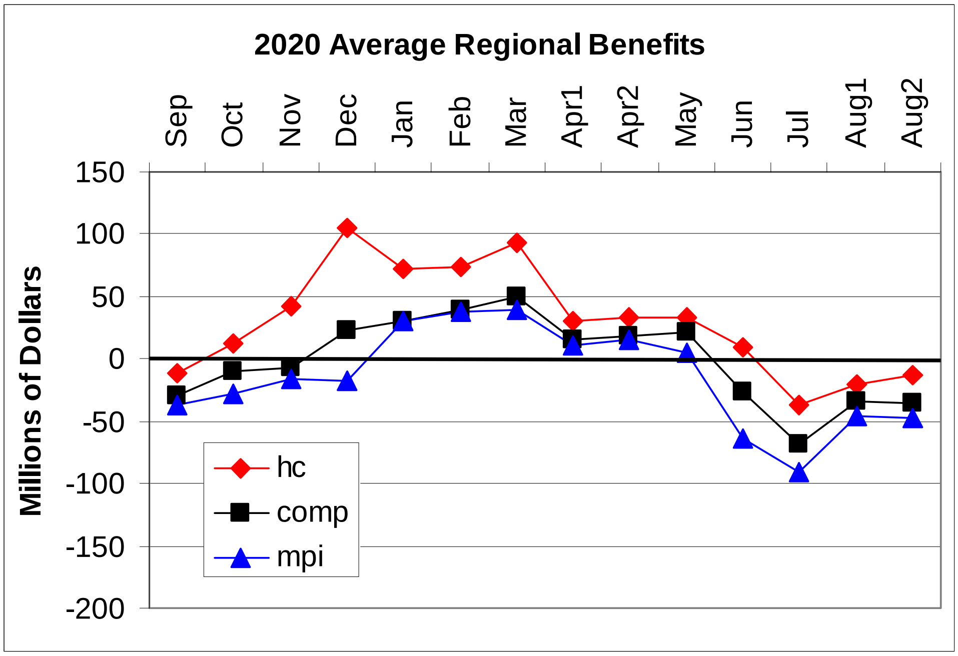
The average annual change in hydroelectric generation is provided in Table 3 (reproduced below) for each climate change scenario for both 2020 and 2040. What is clear from this table is that runoff volume (fuel for the hydroelectric system) makes a big difference in total annual generation. Under the MPI scenario (warm and dry), the hydroelectric system is estimated to lose about 700 average megawatts (aMW) of energy in 2020 and 2,000 aMW by 2040. Current annual hydroelectric generation for the Columbia River system is about 16,000 aMW under average conditions and about 11,600 aMW for the driest year.[10] These energy losses are not cheap. The estimated regional annual cost of the MPI scenario is $231 million in 2020 and $730 million by 2040.

For a warm-and-wet scenario, the economic outlook is much better. With more fuel for the hydroelectric system, the region is forecasted to see about 2,000 aMW more energy by 2020 and about 300 aMW more by 2040. The corresponding economic benefits are presented in Table 3 below. Under the combination scenario, the region will see a slight increase in generation by 2020 and a net loss of generation by 2040. This scenario shows a net increase in generation (and revenue) by 2020 but a net loss of generation and revenue by 2040.

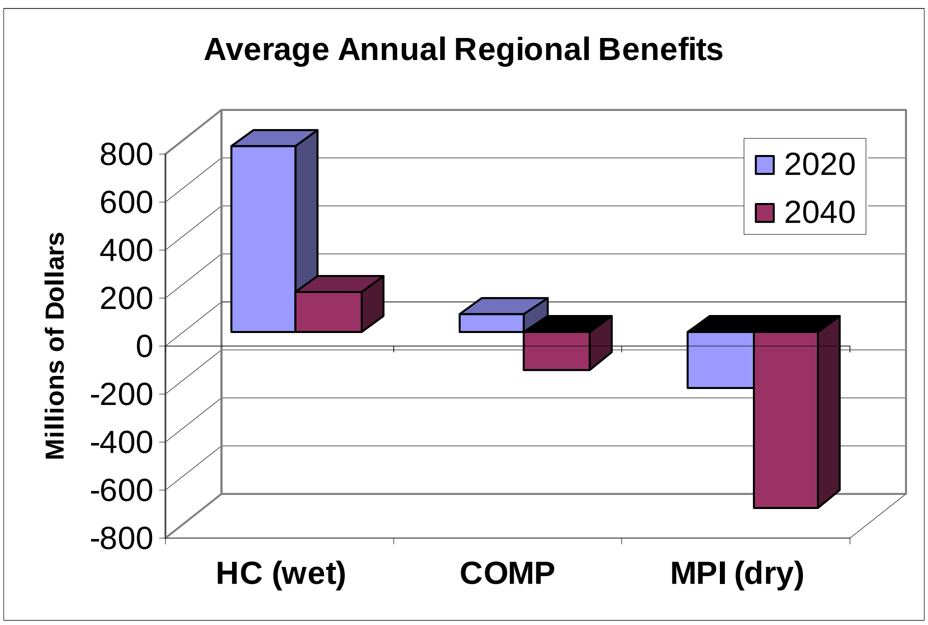
Table 3: Summary of Energy and Cost Impacts from this Publication

	Change in Annual Energy (average megawatts)		**Annual Benefits (Millions)**	
	2020	**2040**	**2020**	**2040**
HC (wet)	1982	333	777	169
COMP	164	-477	74	-155
MPI (dry)	-664	-2033	-231	-730

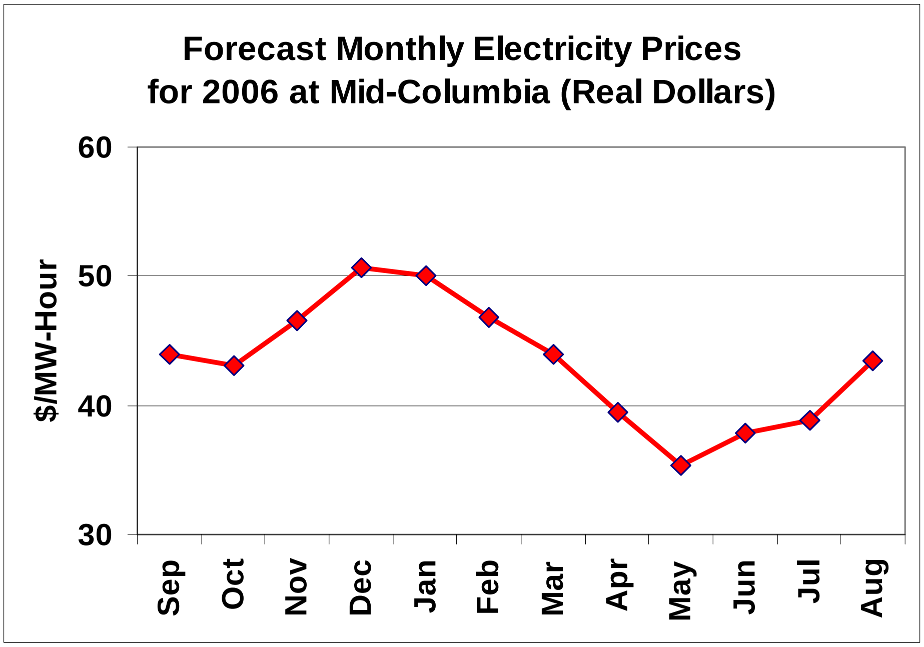
[10] For another perspective, hydroelectric energy losses due to measures provided for fish and wildlife concerns amount to about 1,100 aMW.



Graph 1: 2020 Average Regional Benefits of Climate Change Scenarios



Graph 2: Average Regional Benefits of Climate Change Scenarios for 2020 and 2040



Graph 3: Forecasted Monthly Electricity Prices for 2006 at Mid-Columbia (Real Dollars)

In addition to the impacts to river flows, hydroelectric generation, and temperature, climate change will also affect the Northwest's interactions with other regions. Currently, both the Northwest and Southwest benefit from differences in climate. During the winter peak demand season in the Northwest, the Southwest generally has surplus capacity that can be imported to help with winter reliability. In the summer months, the opposite is true and some of the Northwest's hydroelectric capacity can be exported to help the Southwest meet its peak demand needs. This sharing of resources is cost effective for both regions.

Under a severe climate change scenario (as seen in the MPI example) the Northwest could see increased summer demand with greatly decreased summer hydroelectric production. It is possible that the Northwest could find itself having to plan for summer peak needs as well as for winter peaks. In that case, the Northwest would no longer be able to share its surplus capacity with the Southwest. This would obviously have economic impacts in the Southwest where additional resources may be needed to maintain summer service. This would likely raise the value of late summer energy, thereby increasing the economic impact of climate change to the northwest.

Further Research

There are several areas where the authors felt they could improve this analysis. First, a larger set of historical water conditions from 1929 to 1999 should be used. Secondly, a correlated set of monthly temperatures and electricity prices should also be used for each water condition. Summer demand response to temperature changes will be revised to incorporate the latest data on air-conditioning penetration rates. In addition, river-flow adjustments are being refined, as are some other data from the Climate Impacts Group.

Climate Changes in the Pacific Northwest: Valuing Snowpack Loss for Agriculture and Salmon

Goodstein, Eban, and Laura Matson. July 2004.

Summary

In this paper the authors provide a cost estimate of climate change for two stream-related sectors in Washington and Oregon: irrigated agriculture and salmon populations.

Methodology

To estimate the loss from agriculture, the authors used summer surface water reductions for the low snow years of 1992 and 2001, and translated those into county-level declines in available irrigation water, valued at a range of shadow prices[11] and price elasticity[12].

To evaluate impacts on salmon, they collected willingness-to-pay (WTP) valuations for restoring regional wild fish populations to value declines in fish populations.

Conclusions

Agriculture

Northwest agriculture is highly dependent on surface water irrigation. This was most dramatically illustrated in the low snowpack year of 2001 in the Klamath Basin in southern Oregon and northern California. Gross farm incomes fell between $48 and $64 million in a region that generated average revenues of $97 million the previous three years.

The authors estimate the lost value of irrigation water ranges from $465 million to $2.4 billion annually, depending upon the assumed initial price, demand elasticity, and a range of snowpack reduction scenarios.

Salmon

The range of damage to salmon from climate change is from $359 million to $7.2 billion annually. If you incorporate estimates of regional population and income growth, this

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[11] Shadow prices are a method of establishing the economic value of a benefit or a cost when market prices are unavailable or distorted because the commodity or service in question is a public good not traded in "free" markets. Shadow prices are derived by establishing the value of the benefits (or costs) in another market context.

12 The price elasticity of demand for a good or service is a measure of the kind of response (in demand for that good or service that can be expected from consumers, given change in that price). Specifically, it is the percentage change in the quantity of a given item purchased, divided by the percentage change in the price of that same item. For most goods and services the price elasticity is negative: as the price rises, the volume purchased or desired goes down.

compensation figure rises to $24 billion annually by 2050. On a nationwide basis, the researchers estimate that salmon extinction could reduce welfare by close to $108 billion, approximately 1% of national GDP, by 2050.

Agriculture + Salmon

For irrigated agriculture and salmon alone, the authors estimate a range of damages from .2% to 2.8% of regional GDP by 2050.

Future Research

They hope to evaluate the economic impacts of climate change on other sectors, including coastal sea level rise, forestry, forest ecosystems, recreation and human health.

Climatic Influences on Salmon Populations in the Pacific Northwest

Francis, Robert and Nathan Mantua. Fisheries Research Institute. April 2003.

Summary

In this report, the authors have examined the role of climate variability in driving salmon population changes and developed a paradigm for the role of climate variations in the concern over future salmon extinctions. A number of studies have verified the fact that many stocks of Pacific salmon are endangered. For example, the Wilderness Society (1993) estimates that naturally reproducing Pacific salmon are mostly extinct or imperiled in 56% of their historic range in the Pacific Northwest and California. This undesirable state of affairs is attributed to both natural variability and a legacy of human activities that are related to land use, harvest and hatchery practices [13](p.37).

One of the most obvious and important characteristics of the climate system is its variability. At a time scale ranging from seasonal to millennial, climate records from around the globe indicates that the normal state of the physical environment is one of dynamic change. Throughout the history of their existence, Pacific salmon and the ecological communities that they are a part of demonstrated tremendous resilience by evolving upon and adapting to a naturally variable environmental template. Thus, from a long-term historical perspective it seems clear that natural climate variability, by itself, should not be a primary concern in maintaining salmon stocks (p.37).

Anthropogenic influences on the salmon's environment played a primary role in the author's discussion of climate influences on salmon extinctions. They say Human activities have degraded and in some cases completely eliminated much of the Pacific salmon's historic stream and estuarine habitat in the past century and a half. In many ways, human actions have forced semi-permanent changes to the salmon landscape that parallel those typically associated with climate change (p.37).

Methodology

In this report, the researchers presented results from two distinct analyses. First, they adopted a Pacific Basin-scale perspective and searched for linear relationships between climate and salmon meta-population variability along the Pacific Coast, from Alaska to California. These approaches yield a robust large-scale pattern of salmon meta-population responses to climate variability. In the second approach, they select a few case studies that illustrate complex, nonlinear relationships between climate and salmon population variability. With case studies, they examine a hierarchy of spatial scales, starting with a regional perspective of meta-populations, then later they step down to more local spatial scales, getting closer to evolutionarily significant units (ESUs) of salmon populations. In this approach they have seen issues mostly applicable to the climatic influences on salmon extinctions and potential listings under the Endangered

[13] National Research Council (NRC) 1996

Species Act (ESA). They obtained salmon-landings data from the agencies in the pacific fisheries and wildlife agencies(p.38).

Conclusions

The results of their analysis demonstrated clear linear relationships between naturally occurring and large-scale changes to the physical environment and salmon populations in the Northeast Pacific. Of particular interest to the issue of climatic influences on salmon extinctions, inter decadal environmental fluctuations, associated with the Pacific Inter decadal Oscillation (PDO), appear to have significantly reduced the ecosystem(s) carrying capacity for West Coast coho salmon since the 1977 regime shift. The overall productivity of salmon in Alaska has dramatically increased during this same time period in response to PDO-related climate changes. they results agree with those of previous studies that identify the first few months of the salmon's ocean life as the period of critical climatic influences on survival, which in turn, suggests that coastal and estuarine environments are key areas of biophysical interaction. It seems likely that the polarity of the PDO climate pattern will continue to change at inter decadal time scales as it has over (at least) the past century. If and when that happens, West Coast coho salmon will once again experience favorable climatic conditions while Alaska salmon will be faced with poor marine and terrestrial climate conditions. However, wild West Coast coho salmon will continue to face the problems caused by the legacy of human land use, hatchery and harvest practices.

In summary, the lessons to be learned regarding the effects of climate on the extinction of salmon populations:

1) Climate alone is not likely to tip the balance. However, climate variability clearly has the capacity to amplify the risk and likelihood of extinction when superimposed upon salmonid ecosystems under extreme stress from humans.
2) Since climate effects on salmon seem to be much more significant at inter decadal than annual time scales, and since inter decadal time-scale climate change can only be recognized in hindsight, the effects of climate need to be hard wired into fishery management policy (e.g., different management strategies and algorithms may be required for different climatic regimes).
3) Climate-related negative impacts on salmon production at the regional scale likely have much more severe implications for individual breeding populations than for Meta-populations as a whole. Clearly, this has been the case for thousands of years. However, combining the effects of human activities with climate fluctuations likely amplifies a number of these negative influences.

It is also important to note that human activities have not only altered the salmon's terrestrial and estuarine environments, but they have also contributed to the envelope of climate variability by rapidly increasing the concentrations of radiatively important gases in the atmosphere. At present, the analysis of the climate record for the Pacific Basin suggests that anthropogenic climate change, if it is occurring, it proves that there has been swamped by natural variability in this century. However, anthropogenic changes to the

Earth's radiation budget are expected to lead to rapid changes to the climate system over the next few decades and centuries

In authors opinion the salmon populations in this regions with healthy habitat will probably survive as long as the time scale of environmental change does not exceed their rate of adaptation. On the other hand, those populations that are presently stressed by occupying healthy, marginal or fragmented habitat will most likely face more acute threats of extinction with the additional burden of significant anthropogenic climate changes (p.68).

Washington

Report on Climate Change and Washington

Environmental Protection Agency. September 1997.

Summary

The Environmental Protection Agency is responsible for educating the public about climate change. This particular brochure was produced for Washington State. In it, the EPA makes references to the socio-economic impacts of climate change on human health, coastal communities, agriculture, and commercial ecosystems. A similar report was produced for Oregon (see the Oregon section of this document).

Methodology

None given.

Conclusions

Health Impacts (p.3)

Winter-related mortality in Washington could increase if warming occurs because the frequency of air masses associated with inclement weather is expected to increase. One study has estimated that a 3°F warming in Seattle, Washington would increase winter-related mortality from 15 today to about 40[14]. The elderly, particularly those living alone, are at greatest risk.

There is concern that climate change could increase concentrations of ground-level ozone. For example, high temperatures, strong sunlight, and stable air masses tend to increase urban ozone levels. Air pollution is also made worse by increases in natural hydrocarbon emissions during hot weather. If a warmer climate causes an increase in the use of air conditioners then air pollutant emissions from power plants will also increase.

Increased emissions and accelerated atmospheric chemistry could slow progress being made in Washington to provide healthy and clean air. Currently, the Seattle-Tacoma area does not meet the national health standards for ozone and particulate matter. The particulate matter standard is also not met in Olympia, Spokane, Wallula, and Yakima. Ground-level ozone has been shown to aggravate existing respiratory illnesses such as asthma, reduce lung function, and induce respiratory inflammation.

[14] The unit of measurements was not specified

Coastal Areas (p.3)

Sea level rise could lead to flooding of low-lying property, loss of coastal wetlands, erosion of beaches, saltwater contamination of drinking water, and decreased longevity of low-lying roads and bridges. Possible responses to sea level rise include building walls to hold back the sea, allowing the sea to advance and adapt to it, and/or raise the land (by replenishing beach sand and/or elevating houses and infrastructure). Each of these responses will be costly, either in out-of-pocket costs or in lost land and structures. For example, the cumulative cost of sand replenishment to protect Washington's coastline from a 20-inch sea level rise by 2100 is estimated at $143 million to $2.3 total billion.

Agriculture (p.4)

Increases in climate variability could make adaptation by more difficult. In Washington, agriculture is about a $4 billion annual industry; two-thirds of this revenue comes from crops like wheat, barley, hay, and potatoes. About 28% of the state's farm acres are irrigated. With warmer temperatures, wheat yields could increase by up to 70-90%. Barley and hay fields could decrease by 4-14%, and potato yields could fall by 17%. Based on increases in yield, farm income could double or triple. The number of irrigated acres could increase, which could further stress water supplies, which may already be lower in the summer. Water quality could also be degraded further.

Ecosystems (p.4)

Increases in sea level and decreases in river flow could affect estuaries, increasing salinity and decreasing tidal marsh areas. Valuable commercial shellfish communities (i.e. oysters and clams) and duck and geese populations that utilize these flats for habitat and feeding may also decline accordingly.

Report on Mitigating the Effects of Climate Change on the Water Resources of the Columbia River Basin

Payne, Jeffrey, Wood, Andrew, Hamlet, Alan, Palmer, Richard, and Dennis Lettenmaier
[no date provided]

Summary

This paper was developed to investigate potential effects of climate change on hydrology and water resources of the Columbia River Basin (CRB). Evaluations were done using simulations from the U.S. Department of Energy and National Center for Atmospheric Research Parallel Climate Model (DOE/NCAR PCM).

Methodology

This study focused on three climate projections for the 21 century based on a "Business As Usual" (BAU) global emission scenario evaluated with respect to a control climate scenario based on static 1995 emissions. Time-varying monthly Parallel Climate model (PCM)[15] temperature and precipitation changes were statistically downscaled and temporally disaggregated to produce daily forcing that drove a macro-scale hydrologic simulation model of the Columbia River basin at ¼ degree spatial resolution. For comparison with the direct statistical downscaling approach, a dynamical downscaling approach using a regional climate model (RCM) was also used to derive a hydrologic model forcing for 20-year subsets from the PCM control climate (1995-2015) scenario and from the three BAU climate (2040-2060) projections (p.3).

***PCM Scenarios**:* Parallel Climate Model *(PCM)* is a coupled land-atmosphere-ocean General circulation model (GCM) that simulates the evolution of climate and its dependence on greenhouse gas (GHG) concentrations(p.4).

***RCM Scenarios* :**The Regional Climate Model, RCM is used to dynamically downscale 20-year segments (July 2040-June 2060) of each PCM , "Business As Usual" (BAU)ensemble member of the PCM control run (1995-2015), and of the PCM historical run from the PCM scale to ½ degree spatial resolution (p.6)

CRB VIC model application: The hydrologic model used in this study is the Variable Infiltration Capacity model (VIC) (Liang et al., 1994). VIC is a grid cell based model that represents fluxes of water and energy at the land surface. This model has been widely used for simulation of large river basins. Monthly stream flows were resolved by

[15] The Parallel Climate Model (PCM) is used to predict climate states resulting from global warming and allows researchers to examine particular quantities such as the precipitable water available in the atmosphere.

adjusting VIC parameters governing infiltration rate and base flow recession to improve the agreement of simulated and observed flows(p.6).

CRB water resource management model application: This study used by the Columbia River Simulation Model (ColSim) has been used to assess various aspects of the Columbia River's water resource system, including the effects of climate variability and operating system design (Miles et al., 2000) and the economic value of long-lead streamflow forecasting for hydropower (Hamlet et al., 2002). ColSim is able to evaluate the sensitivity of the system to both changes in climate and operating policies for the following objectives Flood Control, Hydropower, Instream Flow Targets for Fish, Agricultural Withdrawals and Recreation (p.7).

CRB Water resource policy alternatives: the climate change-induced system performance decreases in the CRB arose mainly from inflow seasonality shifts. Four alternative reservoir operating policies for mitigating performance reductions have been used 1) lower flood evacuation quantities and earlier reservoir refill schedules; 2) the reallocation of firm hydropower production from winter demands to summer months; 3) increases in reservoir storage allocations for environmental targets; and 4) a combination of the previous three alternatives using heuristic combinatorial techniques(p10).

Conclusions

The climate change scenarios suggest that a moderate Progressive warming reaching 2.1^{o}C in will produce a gradual shift toward diminished snowpacks and earlier snowmelt runoff, accompanied by reduced summer and fall low flows. As in previous studies, this is the dominant predicted signature of global warming on the hydrology of PNW streams over the next century. Because precipitation- changes in the downscaled climate scenarios were secondary to temperature effects, predicted annual average runoff volume changes (relative to control climate runoff) were predicted to be small – generally less than 5 percent. Although annual average temperatures and precipitation in the future scenarios were broadly similar for RCM and PCM after statistical downscaling, Although the monthly time step used in this study makes it impossible to state explicitly the changes in flood risk and/or damages that would accompany the projected hydrologic changes, the opportunity costs associated with maintaining the same general flood control policy appear to be much higher than the associated benefits. This study suggests that the reconsideration of flood control needs and values in the context of instream flow and hydropower production considerations posed by a warmer PNW climate would be highly desirable (p.20).

Health Effects of Climate Change and Energy in Washington

Physicians for Social Responsibility (PSR),Washington Advisory Board. July 2000.

Summary

This report describes the impacts that climate change could have on human health in Washington, a state likely to face serious challenges due to climate changes. Washington typically experiences large seasonal variations in precipitation with dry summers and wet winters. Nearly all climate models predict that global climate change will exacerbate these conditions, making summers drier and winters wetter, thereby increasing the intensity and frequency of floods in winter and the risk of drought in summers. Floods not only destroy property and threaten lives, but also increase the risk of infectious disease and cause psychological stresses ranging from depression to post-traumatic stress disorder. Droughts may threaten the agricultural sector of Washington's economy, impair hydroelectric power generation on which Washington is heavily dependent, increase the risk of certain kinds of infectious diseases, and increase the risk of forest fires. Future climatic conditions may increase the intensity and frequency of extreme weather events—snow, floods, storms, high winds, and lightning—that incur high health and economic tolls(p.3).

Methodology

Literature review

Conclusions

Health Effects (p.4)

- Global warming could increase the number of severe weather events in Washington, already a leader in Presidentially- declared weather disasters with four in 1997 alone.
- Severe flooding in Washington in February 1996 killed three and caused an estimated $800 million in damages. More frequent and severe floods could result in larger property damage, cause injuries, and spread illnesses through contaminated water.
- Earlier snowmelts and higher temperatures could cause more summertime droughts, like the drought of 1999, threatening agricultural production, compromising water quality, and impairing hydroelectric power generation.
- More extreme weather events could cause more landslides like the January 1997 landslide in Snohomish County that brought down 75,000–150,000 cubic meters of earth, swept five cars of a passing freight train into Puget Sound, and killed a family of four.

- Warmer temperatures could expand the habitat of ticks that carry Lyme[16] disease and lengthen the season during which people are outdoors, increasing the state's average of fourteen cases per year.
- Warmer ocean temperatures and changes in water stratification could increase shellfish contamination incidents by bacteria, such as Vibrio parahaemolyticus which sickened 56 Washingtonians in July and August of 1997.
- Warmer summer temperatures could worsen air pollution by increasing concentrations of ground-level ozone and other pollutants in the air that exacerbate asthma, a condition suffered by one in nine adults and one in ten children.

Further Research

The links between climate patterns and domoic acid [17]are still unclear, so researchers recommend future research should be done to understand the relationship between climate patterns and domoic acid and they also recommend future research in "all practicable steps to minimize" the hazard.

[16] Lyme disease (LD) is a multi-system bacterial infection caused by a spirochete Borrelia burgdoferi (Bb).
[17] Domoic acid is a neurotoxin that is deadly for humans; found in various marine algae

Integrated Impact of Climate Warming on Yakima Valley Water Demand and Availability

Scott, Michael. Stöckle, C.O., and A. Kemanian, Washington State University. 2002.

Summary

This paper discusses the estimated impact of climate warming on water availability for instream flow in the Yakima Valley of Washington State. Current state law and regulation provides for minimum flows to sustain anadromous and resident fish and to maintain water quality, but climatic change could significantly change the flow regime of the Yakima. In addition, there would be an uncertain, but probably significant, shift in the demand for water by irrigated crops grown in the valley(p.1).

Methodology

This paper uses an integrated model framework (CropSyst model [18] and DHSVM[19]) to estimate the effects of climate change on water supply demand and instream flow in the Yakima River valley(p.1).

Conclusions

Preliminary CropSyst model results indicate that crop yields vary substantially, depending on whether future climate has lower or constant relative humidity. For irrigated wheat, yield is about 20% lower if absolute humidity is constant. Constant relative humidity is assumed. Initial analysis indicates that with CO_2 at 560 ppm, net water demand, averaged over all crops declines about 7%. This offsets lower water supplies to a significant extent. With CO_2 at 560 ppm, crop productivity also increases by 10% to 15%.

Preliminary water analysis indicates that climate warming likely would reduce summer unregulated flows and the total water supply available (TWSA) for irrigation, increasing the probability of severe water prorationing to junior irrigators from about 14% to about 54% with 2ºC warming (the level of TWSA for the 50% level of prorationing is shown in Figure 1). If additional protection of instream flows is undertaken beyond the bare minimum implied by 300 cfs to keep river temperatures down and flows up, then inflow protection is more costly to agriculture. For example, doubling the instream flow to 600

[18] CropSyst (Cropping Systems Simulation Model) is a multi-year, multi-crop, daily time step crop growth simulation model, developed with emphasis on a friendly user interface, and with a link to GIS software and a weather generator (Stockle, 1996).(Pg .1 Scott Michael report)

[19] DHSVM(Distributed Hydrologic Soil Vegetation Model) is a detailed hydrology model. At each time step, the model provides a simultaneous solution to the energy and water balance equations for every grid cell in the watershed. (Wigmosta and Lettenmaier 1999) (pg.1 Scott Michael report)

cfs increases the probability of severe prorationing to 62%. However, at 50% prorationing, about 400,000 ac-ft is "lost" between withdrawal from the river and application to crops. Although much of this "lost" water returns to the river, reducing these conveyance losses by 25%, although possibly costly, would be enough to compensate for the lower withdrawals required for higher instream flows.

This initial integrated assessment of the impact on instream flow in the Yakima Valley of shifted water demand and supply for a climate warming shows that summer minimum flows could be maintained at the cost of a significantly higher probability of water prorationing for junior agricultural users. In general, the impact of climate warming on minimum flow is expected to be negative. The integrated assessment also shows that much of the reduction in water availability shown in Figure 1 could be offset by a combination of more efficient water conveyance and higher crop productivity and water use efficiency due to enhanced CO_2. Significant uncertainties include the impact of CO_2 on plant water use, the amount of carryover moisture available to crops at the beginning of the growing season, and the impact of climate change on relative humidity (which strongly regulates water demand)(p.3).

Oregon

Report on Climate Change and Oregon

Environmental Protection Agency. September 1998.

Summary

The Environmental Protection Agency is responsible for educating the public about climate change. This particular brochure was produced for Washington State. In it, the EPA makes references to the socio-economic impacts of climate change on human health, coastal communities, agriculture, and commercial ecosystems. A similar report was produced for Washington (see the Washington section of this document).

Methodology

None given.

Conclusions

Health Impacts (p.3)

Higher temperatures and increased frequency of heat waves may increase the number of heat-related deaths and the incidence of heat-related illnesses. Oregon, with its occasional, intense heat waves, may become more prone to heat waves if its climate changes. In Portland, heat-related deaths are estimated to increase by nearly 150% given a summer warming of 4°F (although increased air conditioning use may not have been fully accounted for). The elderly, especially those living alone, are at greatest risk. This study also projects little change in winter-related deaths in Portland if the temperature warms by 2-3°F.

Warming and other climate changes could expand the habitat and infectivity of disease-carrying insects, thus increasing the potential for transmission of diseases such as malaria and dengue ("break bone") fever. Warmer temperatures could increase the incidence of Lyme disease and other tick-borne diseases in Oregon because populations of ticks, and their rodent hosts, could increase under warmer temperatures and increased vegetation. St. Louis and California encephalitis are present in California, and some studies indicate that these diseases could move north under a warmer climate. Western equine encephalitis has also been found in domestic animals in Oregon. Mosquitoes can carry these diseases, which can be lethal or cause neurological damage to humans. If conditions become warmer and wetter, mosquito populations could increase, thus increasing the risk of transmission of malaria and other mosquito-borne diseases. Increased runoff from heavy rainfall could increase water-borne diseases such as giardia and cryptosporidia.

Coastal Areas (p.3)

Sea level rise could lead to flooding of low-lying property, loss of coastal wetlands, erosion of beaches, saltwater contamination of drinking water, and decreased longevity of low-lying roads and bridges. Oregon has a 1,400-mile tidally influenced shoreline that consists mostly of steep slopes, pocket beaches, and small embayments, with a few natural coastal plains. The steep, rocky cliffs that dominate most of the coastline limit vulnerability to sea level rise. The sea level on the Oregon Coast is estimated to rise six inches by 2100. Nonetheless, the rocky shore of Oregon may limit erosion, and help protect the coastline. The cumulative cost of sand replenishment to protect the coast of Oregon from a 20-inch sea level rise by 2100 is estimated at $60-$920 total million.

Water Resources (p.3.)

Oregon is a major producer of hydropower, and lower flows could affect its ability to meet energy production requirements, fish protection, irrigation, recreation, and water supply. The public demands high lake levels in the summer for recreation. Lower streamflows and lake levels would exacerbate current stresses and increase competition among water uses. Additionally, lower summer flows and higher temperatures could impair water quality by concentrating pollutants and reducing the ability of streams to assimilate wastes.

Agriculture (p.4)

Increases in climate variability could make adaptation by farmers more difficult. Analyses that assume changes in average climate and effective adaptation by farmers suggest that aggregate U.S. food production would not be harmed, although there may be significant regional changes.

In Oregon, production agriculture is a $2.5 billion annual industry, three-fourths of which comes from crops. Almost one-half of the farmed acres are irrigated. Climate change could increase wheat yields by 2-13%. Hay and pasture yields could rise by 10% or fall by 7%, depending on how the climate changes and whether irrigation is used. Potato yields could fall by 17% as temperatures rise beyond the tolerance level of the crop. Farmed acres could remain fairly constant or could decrease by as much as 23%.

Forests (p.4)

Hotter, drier weather could increase the frequency and intensity of wildfires, threatening the important timber-producing areas of the state. Commercial timber production could also be affected by resulting changes in growth rates, plantation acreage and management, and market conditions. The character of the forests would change, as well as the activities that depend on them.

An Oregon Strategy for Greenhouse Gas Reduction:

Governors Advisory Group on Global Warming. State of Oregon. Draft Report to the Governor. October 2004.

Summary

This document addresses the health, social, environmental, and economic costs associated with global warming, and how we can alleviate these costs through energy-efficient technologies. It also looks at what the Pacific Northwest has already done to offset these costs through: services, goods, and investment opportunities. Lastly, it addresses the steps Oregon should take to develop a global climate change plan.

Methodology

None Given

Conclusions

Utility companies in the Pacific Northwest invested some $2.4 billion between 1990 and 2002 in energy-efficient technologies, resulting in savings of some 2600 aMW annually (p.18). That's equivalent to five large coal plants' worth of electricity they did not have to generate, at a fraction of the cost of nuclear generation, gas, coal, or any other source, and at near-zero environmental cost. The entire $2.4 billion investment pays for itself in electricity bill savings about once every 18 months (p.18).[20] These investments have also created new jobs insulating houses, installing thermostats, and designing and building energy-efficient windows and manufactured housing. Along the way, markets were developed in other states for those same windows and manufactured housing units, bringing new dollars and jobs back into Oregon.

Today, if Oregonians had the option of driving more fuel-efficient cars that still met their needs, and the option of driving them fewer miles to work or shopping, we'd see a similar return on investment when gasoline prices rise as they have in 2004 (p.19). We would be better insulated against the disruptions such price spikes cause in our state's economy, and the dollars we saved could circulate within Oregon, creating more Oregon jobs and goods (p.19).

The authors stress that adopting more energy-efficient technologies will mean cleaner air, and healthier people, with fewer kids handicapped by asthma and other respiratory diseases (p.19). Regulatory tools, such as building codes, seem to be the most effective way to reduce emissions and save money.

[20] Per personal communication with Tom Eckman, Conservation Program Director, Northwest Power Planning Council, September 16, 2004. Assumed average avoided cost – or value of savings – of 5.5 cents kWh, or $55/MWh. In 2001, when West Coast market prices for electricity spiked to $250/MWh and higher, the savings realized in the Pacific Northwest would have been appreciably greater.

The author provides the reader with an analogy between the costs of global warming and buying into an insurance policy (p.17). We buy insurance policies against events that would otherwise cost far more to cope with. Avoiding the potentially destructive storms, floods, and forest fires that are projected to accompany global warming would likely be less costly than the repairs we would need to make otherwise.

The Potential Impacts of Climate Change on Portland, Oregon's Water Supply

Palmer, Richard, and Margaret Haun. University of Washington. April 2003

Summary

This paper evaluates the impact of climate change on municipal water supplies using the City of Portland, Oregon and its Bull Run River watershed as a case study. Portland Water Bureau's (PWB) ability to provide water reliably from the Bull Run system in the future is also evaluated. Forecasted climate change from four General Circulation Models (GCMs) is used to translate past meteorological events into streamflow forecasts using a distributed watershed model. Hydrologic impacts from climate impacted forecasts suggest an increase in winter flows and a decrease in spring and summer flows associated with the timing of precipitation and the timing of snowmelt runoff. Water demand is anticipated to increase by 8% due to climate change during the summer months, resulting in longer period of reservoir drawdown. The average loss in safe yield of one of the GCM's by the year 2040 is 21 mgd (million gallons a day). Increase in water demand due to regional growth is expected to be twice that of climate change, making climate changes a significant, but not dominant, impact on the region's ability to supply water reliably(p.1).

Reports indicate that one of the most important impacts of climate change is on the world's water supplies. In a review of over 1000 relevant peer-reviewed studies, Gleick et al. (2000) concluded that "in many cases and in many locations, there is compelling scientific evidence that climate changes will pose serious challenges to our water systems" (p.6). These reports have noted that not all regions will be impacted equally, with some regions experiencing particularly negative effects, while other areas may actually benefit from climate change. The impacts of climate change on U.S. water resources is expected to be most profound in the west, where the runoff cycle is largely determined by snowmelt (Cohen et al., 2000). Many previous studies indicate that the effects of warmer climates on the seasonality of runoff in such regions will likely shift a portion of spring and summer melt runoff earlier in the year (U.S. EPA, 1989; Piechota and Dracup, 1997; Lettenmaier et al., 1999; IPCC, 2001).

Water supply systems in the western U.S. are negatively influenced due to such shifts in runoff seasonality, because, although streamflows are heavily regulated, snowpack represents significant water storage that helps to augment low stream flows during relatively dry summers (Hamlet and Lettenmaier, 1999; VanRheenen et al., 2003, in review).

Pacific Northwest basins hold particular interest because of the interplay of two factors, precipitation and temperature. All of the major water resource systems in the Northwest rely on snowpack to provide a significant source of water in the late spring and early summer. Changes in temperature and precipitation alter the delicate interaction between the amount of precipitation that falls as rain and the amount that falls as snow.

Temperature directly influences the eventual accumulation of snow during the winter and the temporal variability with which this snow melts and is released in a watershed. The extent to which climate change may impact a watershed and its use are a function of several factors including the magnitude of the change in climate, the degree to which the watershed has already reached its sustainable use, and the physical setting of the watershed. Small shifts in climate (precipitation and temperature) may or may not result in significant changes in a watershed. Generally, watersheds that are already at their sustainable level of use may be significantly impacted by even minor shifts in climate. Watersheds that are located at very high elevations may not be impacted by modest changes in temperature, as most of their precipitation will continue to fall as snow. Watershed at low elevation will likewise be unaffected, as precipitation will continue to fall as rain. Changes in winter total precipitation may not impact water supply systems, as this water is not typically captured for later use. Changes in spring and summer precipitation may have significant impacts on the drawdown and refill cycle of a reservoir.

Methodology

This report describes the models the authors have used, the analysis process, and the results that were generated for the Bull Run system. The hydrology of the Bull Run watershed, the interaction between the basin's hydrology and the (Portland Water Bureau's) PWB's system of reservoirs. They discussed the models and model assumptions used in the analysis and presented the climate change impact that comes from the (General Circulation Models) GCMs and also showing how climate change is modeled within the watershed. The impact of climate change on the water supply system performance was also explained and later they summarize the major conclusions and provide recommendations for planning and management strategies for the Bull Run system(p.7)

Conclusions

The results of this study suggest that many US water supply systems may be negatively impacted by climate change, particularly those that use snowmelt as a source of water. This includes the majority of the large population centers in the western US. Although annual precipitation in watersheds may increase in some regions, the timing of the precipitation may not correspond to those periods during high water demand. Runoff will likely occur earlier in the spring, due to temperature increases, and summer flows will be lower due to the combination of smaller spring runoff and lower summer precipitation. These impacts will not be limited to municipal water supplies as other studies by the author have indicated (Lettenmaier et. al, 1999; Wood et al., 1997), but will have significant impacts on power production and the ability to meet environmental flows. The primary conclusion of this study is that climate change will have a significant impact on the hydrology of the Bull Run watershed and will impact the safe yield of Portland's water system. For seven typical dry years, climate change will reduce the amount of water that can be used to meet water demands by an average of 1.5 billion gallons and increase demand during the drawdown period by 2.8 billion gallons, resulting in 4.3 billion gallons of reduced minimum storage. These climate impacts exacerbate the need that exists to provide some 9.6 billion gallons of increased demands due to regional growth (p.18). This primary conclusion is based upon the following:

- The streamflows in the Bull Run watershed are controlled predominantly by rainfall rather than snowpack. Snowpack does provide additional flows in the early spring, but these are typically exhausted before the supply system begins it drawdown in late June(p.19).
- The average climate change signal from the four general circulation models result in increased temperatures (1.5 - 2.0 C) and slightly increased precipitation(p.19).
- The impacts of climate change are not uniform from year to year. The years for which climate change will have the greatest impacts are those that had high winter precipitation, cool winter and spring temperatures, and/or warm summer temperatures (p.20).
- The shift in the timing and volume of spring runoff in the Bull Run basin associated with climate change, particularly by 2040, will decrease the average maximum winter snowpack. This will result in an increase in the frequency of low flow in early summer. This shift will result in a number of droughts as extreme as 1992 (p.20).
- In approximately 50% of the years, climate change impacts by the year 2040 would decrease minimum system storage by more than 1 billion gallons each year. This decrease results from earlier spring runoff that cannot be captured in the reservoirs and lower summer flows due to the earlier streamflow recessions (p.20).

Gauging the Vulnerability of Local Water Utilities to Extreme Weather Events: Willamette Valley in Northwest Oregon

Hersh, Robert, and Kris Wernstedt. September 2001.

Summary

In this report, the authors examined the current vulnerabilities of drinking water utilities in the Willamette Valley in northwest Oregon due to extreme weather events and also the institutional pressures that have influenced these utilities having coped with past floods and droughts. During the1990s, water utility operators in the Willamette Valley had to deal with notable climate extremes. Drought affected water system operations in the early 1990s and, in the latter part of the decade, severe flooding, accompanied by mudslides and other threats to utility infrastructure, presented a challenge to many operators trying to maintain service to their customers and growth pressures in the region, new regulatory demands on water utilities, and institutional changes related to water use further complicated the situation for the operators (p.1).

In this report, they have measured three aspects: the vulnerability of water utilities to extreme weather events, the range of institutional choices and constraints that influence the way water utilities respond to these events and finally how the water utility operators responded to severe weather events. It also discusses how to evaluate the prospects of adaptation to changing climate and institutional conditions in the face of such experiences(p.2).

Methodology

Telephone interviews (The first quarter of the interview asked for background information on ownership, staffing, and characteristics of the service population, with the remainder of the questions ranging over an array of topics related to revenue streams and rate schedules), mailed and faxed the questionnaire. Later they followed up with personal interviews by appointment(p.8).

Conclusions

The vulnerability of drinking water systems in the Willamette basin to extreme events driven by climate disturbances is very uncertain in nature. There is some evidence, albeit limited, that more intense El Niño - Southern Oscillation (ENSO) cycles and global climate change might lead to a higher incidence of extreme events. The operational burdens placed on water utility operators by increases in the frequency or intensity of extreme events may cause little disruption to drinking water provision. However, the combination of hydrologic effects and current institutional stresses—population growth, the added costs of complying with provisions in the Endangered Species Act, the constraints to develop water rights, the political environment of flood policy and planning and fiscal issues—could make some water utilities more susceptible to extreme weather events associated with a changing climate(p.21).

Health Effects of Climate Change and Energy in Oregon

Physicians for Social Responsibility (PSR), Oregon Advisory Board

Summary

This Report emphasizes the future danger to Oregon and economic diversity. Climate change has the potential to threaten the quality of life by fundamentally changing some important aspects of Oregon's environment in ways that can affect the health of Oregon residents. Threatened water supplies, droughts, floods, deteriorating air quality, and heat waves could take their toll on the health of Oregon residents. Changes in climate will certainly affect health and the environment, but the extent of these effects remains uncertain. This uncertainty makes planning difficult and highlights the most prudent course of action: reduce the rate of climate change. Like other environmental problems that threaten our well-being such as air and water pollution, global climate change is caused, largely, by human activities. This report discusses many of the potential health effects that climate change could cause and many of the solutions that can be implemented today to help slow the rate of climate change and to help residents of Oregon reduce its negative impacts.

Methodology

This report is based on many methodologies used from different sources

1) The Intergovernmental Panel on Climate Change, a United Nations sponsored group of more than 2,500 experts from all aspects of the field of climate change, recently published its third report to government officials worldwide stating that by 2100 average global surface temperatures may increase 2.5□ to 10.4□ (1.4 to 5.8□) if countries continue to rely on burning fossil fuels for energy. Rates of warming over land areas are likely to be higher (p.6).

2) The National Academy of Sciences, in a special study recently commissioned by President Bush, provided their best answers to some key questions on climate change and concluded, "Greenhouse gases are accumulating in Earth's atmosphere as a result of human activities, causing surface air temperatures and subsurface ocean temperatures to rise."(p.6)

3) The Climate Impacts Group at the University of Washington analyzed seven climate projection models for the Pacific Northwest region and found an average projected increase of 5.3□ from the mid-20th century to the year 2050. The region has already warmed about 1□ since the mid-20th century. These higher temperatures, and the accompanying changes in climate such as precipitation, could affect many aspects of Oregon's environment; perhaps most importantly Oregon's supply and quality of water, which can affect human health. The majority of Oregon's water resources, over 100,000 miles of rivers and streams, are maintained by snowfall and snowmelt (p.6)

4) Water supply is highly sensitive to climate change. A decrease in supply would have detrimental impacts on agriculture, industry, energy production, and residential use. Some models project an overall increase in precipitation in Oregon, but this precipitation is more likely to come during the fall and winter in the form of rain, rather than snow, in the warmer winter climate. With less snow falling and snowmelt arriving earlier in the year, the snowpack is very likely to diminish, reducing water supplies. Additionally, the change in runoff amounts may cause flooding and affect irrigation and water management (p.7)

Conclusions

According to physicians who have studied global warming and its effects, the major health risks in Oregon could include the following (p.8):

Changes in the quality and supply of water:

- Changes in precipitation amounts and patterns could lead to more flooding in some areas and droughts in others, therefore decreasing supply.
- Water supply may be contaminated due to salt water intrusion caused by rising sea levels.
- Both droughts and floods can impair water quality.

Decreased air quality, causing more frequent and severe attacks of asthma and worsening of other respiratory and cardiac problems, could result from :

- Worsening ozone (smog) levels.
- Greater emissions of nitrogen dioxide, sulfur dioxide, particulate matter, and other toxic pollutants.
- Smoke from forest fires sparked by drought.
- Increased pollen levels.

Increased accidents and injuries:

- A projected increase in sea level of 1 to 3 feet by
- 2100 could bring flooding and coastal erosion, particularly when complicated by storm surge.
- There could be an increase in injuries from potential extreme weather, including floods.

Greater risk of infectious diseases:

- Water used for drinking and recreation can become contaminated by animal and human wastes. This is more apt to occur after heavy rainfall and can lead to bacterial, parasitic, and viral infections.
- Increased risk of mosquito-carried diseases such as malaria and dengue fever.

More heat-related illness:

- Number of heat-related deaths could increase significantly.
- Senior citizens, the very young, and the poor are at greatest risk of death from heat stress.

Further Research

Researchers recommend following for future research:

- Continued research is needed to better understand the relationships among climate change, the health of ecosystems, and the health of the public, but this Report also states that enough is known to support taking action now.
- Research and Development of additional ways to sustainable increase crop yields should also be a priority.

Report on the Value of Oregon Beaches: An Analysis of the Non-Market Costs of Climate Change on Oregon Coastal Beaches.

Susan Whitmore. Lewis and Clark College. May 2004.

Summary

The aim of this study was to estimate the non-market costs of a sea level rise in Oregon, which have not previously been estimated. Specifically, calculating lost use value and existence value through the administration of a combined contingent valuation and travel cost study questionnaire. By estimating existence value for future damages to a resource, this study avoids problems of separating use and passive-use values encountered by other contingent valuation studies. Further, this study also provides a method to estimate existence value for individual resources harmed by the consequences of climate change.

Methodology

Survey was conducted using online and on-site face-to-face interviews. An indirect travel cost model of demand for beach recreation is applied to calculate current use value. A CV study is used to model people's willingness to pay (WTP) for beach protection, which is inferred as existence value. Estimates for both use and existence values are calculated under different beach loss scenarios (p.17).

Conclusions

This study estimates lost recreation value to Oregon residents for Oregon coastal beaches to be $39 million annually for a scenario of 25% beach loss, $92 million for 50% beach loss and $132 million for 75% beach loss. Existence value for Oregon residents was calculated to be $67 million annually for a 25% beach loss scenario, $123 million annually for 50% beach loss and $197 million annually for 75% beach loss (p.43).

A beach unharmed by the consequences of climate change is a difficult good for which to create a CV scenario. Any scenario that directly addresses the cause of climate change as a solution will not be able to isolate the value for one particular resource. This study presents a method that can be used to isolate particular resources, by using a technological solution rather than a solution that addresses climate change directly. This solution is not without costs however. Many people gave protest zeros in this study because the proposed solution doesn't directly ameliorate climate change. However, more protest zeros may be an acceptable trade off to not being able to value a particular good damaged by climate change at all. Until global warming becomes less of a contentious issue, people will bring heuristics to the surveys and will not be able to accurately estimate the actual value for a good with the scenario as given (p.43).

This study presents a very simplified approach to calculating the costs of rising sea level. Not all beaches will be inundated at the same rate because of differences in beach slope. Moreover, some beaches are very wide while others are very slim. Approximately 100 miles of Oregon's 362 miles of coast has no dry sand at high tide looking at the Northern Oregon Coast, Tillamook and Lincoln counties, and beach widths at mid-tide range from 10 meters to 180 meters, where the mean is 69 meters. Some of these beaches are likely to be lost for recreation while others will experience slight apparent change. As many beaches become recreationally unusable, people will visit less affected ones, increasing visitor density leading to crowding on those beaches. A more complex analysis of the costs of rising sea level would incorporate information about visitor rates at particular locations and the likely affect on beach width on those beaches resulting from rising sea level (p.44).

This study does show that among the costs of global climate change, Oregon coastal beaches will lose value to recreational users and to people who value knowing that the resource's current amenity condition will be protected from the consequences of rising sea level (p.44).

Further Research

Further study may be done to attain more exact estimates of these costs. These impacts should not be ignored when weighing the benefits and the costs of climate protection policy.

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