Pacific Salmon vs. Hydropower Dams was written by a senior Biology major for a course entitled *Environmental Geography* (GEOG 310) which the author took as an elective course. The assignment was simply to "write a twenty-page paper on an issue in environmental geography." In reviewing the paper, the author identifies History, Geography, Biology, and Environmental Studies as disciplines whose concepts, methodologies or modes of inquiry, and/or perspectives are integrated or synthesized. "This paper connects the history of dams, the geography of the Columbia and Snake Rivers, the biology of salmon, and environmental issues associated with the previous."

Pacific Salmon vs. Hydropower Dams

Geography 310

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Historically, the Columbia River in the Pacific Northwest was the most prolific salmon-producing river in the world. In the early 19th century, runs of all five salmon species occurring in the Pacific Northwest resulted in 10-35 million spawners each year (Reisner and Bates 1990)! However, since the construction of dams on the Columbia River, there has been a loss of more than 80 percent of the total run. Today, even with the existance of special hatcheries and fish ladders, only 2.5 million fish survive (Reisner and Bates 1990).

Although dams in the Columbia/Snake river basin have interrupted many of the salmon's river runs, they have also brought economic success to the area. The dams provide hydroelectricity to millions of people as well as allow navigation from the Pacific Ocean (Wade 1999). Currently there is a large debate about whether four federally owned dams should be removed from the Snake and Columbia Rivers. This paper will discuss the controversy of dams in the Pacific Northwest. More specifically, I will examine the benefits of dams of the region, and then examine their effects on the environment and salmon population.

In the past century, our nation has experienced an explosion: an explosion of dams built and a conquest of water resources. Between 1902 and 1930, the U.S. government built around fifty dams. Between 1930 and 1980, 1000 more were constructed (Reisner and Bates 1990). Although since 1980 virtually no new dams have been built, we are realizing some of the consequences of water impoundment and beginning to deal with a nation of aging dams.

For much of western history, Europeans abided by the "common law" that included rivers as part of God's plan through nature (Pisani 1996). God determined the course of streams, and thus it was natural for water to be a moving, wandering entity. The construction of a dam, or diversion of water, was viewed as an "unnatural" act. The industrial revolution, however, encouraged businesses to seek more profitable methods of commerce and industry, leading to indifference about the "natural" state (Pisani 1996). For example, 19th century gold miners discovered that it was easier to find gold if water was diverted. By 1850, there were 24 dams built on one 28-kilometer stretch of the Tuolumne River in California (Pisani 1996)! Thus, dams began to be viewed as beneficial for economic reasons.

Dams also were built as water storage and distribution facilities. The western frontier of the United States offered the nation a vast amount of land and many resources. The only roadblock to economic triumph was the limited supply of water. Shortly after Columbus arrived, Spanish conquistadors explored and settled the American west. However, their colonization was much slower than the later U.S. expansion, mostly due to these limited water resources (Reisner and Bates 1990). During the 19th century, the western environment deployed a harsh blow to many hopeful settlers. By 1893, only 40,000 of the former million families remained in the semiarid plains of Kansas and Nebraska (Reisner and Bates 1990). The western settlers who survived were those who settled along rivers or streams and began some form of irrigation. Irrigation provided a steadiness of water in the west, allowing crops to grow in desert conditions. Over 3.5 million acres were irrigated in the west by the early 1890's (Reisner and Bates 1990).

In an effort to reclaim desert "wasteland," the Reclamation Act of 1902 was passed. The plan called for the government to design and build dams and canals while irrigation districts and farmers were made responsible for getting the water to their land

(Reisner and Bates 1990). Many dams constructed during this era were built by Native American labor. Native Americans were paid in wages with the goal of training them in manual labor and time management. In 1906, the Commissioner of Indian Affairs discussed the use of Native American labor for building the Zuni Dam in New Mexico:

> "The lesson taught by the experiment with Indian labor at this dam is unquestionably that if the Indian can be weaned from his habits of irregularity of days and hours, induced to postpone or rearrange his religious festivities so that they shall not interfere with the demands of his employment, and taught the white man's idea of laying something aside for to-morrow instead of spending all to-day, he can be made into a very valuable industrial factor in our frontier country," (Pisani 1996).

Therefore, dams were also used as a tool to further control Native American populations, a method to indoctrinate them with American culture and values.

The construction of dams would also serve another purpose as the country rebuilt following a worldwide economic depression. In the 1930's, Franklin Delano Roosevelt introduced the New Deal Act with the intention of stimulating the paralyzed economy by providing jobs (Reisner and Bates 1990). The most jobs were created by building new public works, and the Bureau of Reclamation and Army Corps of Engineers (both major constructors of dams) headed up the process. Thus, a new era of dam and reservoir building was begun (Morgan 1971). By 1936, only four years after FDR took office, the five largest modern structures on the planet had been constructed: Hoover, Boneville, Fort Peck, Shasta, and Grand Coulee dams (Reisner and Bates 1990). New Deal planners held an "almost religious belief in the value of public hydroelectric power development," (Reisner and Bates 1990). For the Corps of Engineers, this zeal led to the construction of an average of ten large dams per year for the next 50 years (Reisner and Bates 1990)! The country apparently could not have "too many" dams.

Not until Jimmy Carter's presidency was it discussed that the federal water resources program was in need of reform (Reisner and Bates 1990). Environmental groups began to respond by suing dam-building agencies and slowing the progress of projects in construction. President Reagan was willing to finish some of the dam projects already in progress, but did not mind if no new dams were built during his presidency (Reisner and Bates 1990). Since this time, the construction of new dams has nearly halted and some older dams are even being removed (Wade 1999).

The life span of a dam can vary, depending on its location and building materials. More often than not, the long-term lifespan of a dam was not considered during its construction. As water accumulates in reservoirs, much of the silt that it carries is deposited. Over many years, a reservoir may completely fill with sediment (McCool and Cochran 1997; Worster 1985). According to the American Society of Civil Engineers, the expected life of a dam in the American West is 50 years (Wade 1999). As of 1998, more than 25 percent of U.S. dams were over 50 years old. By 2020, that number is projected to reach 85 percent (Wade 1999), foreshadowing a period in which most of our dams will be deemed useless. According to the National Performance of Dams Program at Stanford University, there are more than 87,500 dams in the United States today. Nearly half are privately owned, while the remaining are owned by local, state, or federal government (Wade 1999). Slightly more than 4 percent of these generate hydroelectric energy with 1,124 operating for that purpose only (Wade 1999).

The construction of dams in the American west has allowed many people to live in what would normally be desert conditions. For example, in 1904 William Mulholland stated that Los Angeles had only enough water resources to sustain a half million people.

Today, however, with the advent of imported water, 13 million people inhabit the city, living in "fake tropical splendor or squalor," (Reisner and Bates 1990). However, the environmental degradation associated with dam construction has often been overlooked. Marc Reisner and Sarah Bates argue in their book, *Overtapped Oasis*, that nothing has taken a greater toll on the natural heritage of the west than reservoirs, aqueducts, and dams. The effects of diverted water have literally changed the natural features of many desert ecosystems (1990).

The Columbia River is the largest river flowing into the Pacific Ocean from North America (Marts 1999). Beginning in the Purcell Range of Canada, this river picks up snowmelt from the Columbia Glacier and is already massive by the time it reaches the U.S. border. At Grand Coulee, an enormous canyon formed by the Columbia in Washington state, the river originally had an average flow of 61,000 cubic meters per second (Reisner 1986). This massive amount of water with such a large drop made it an ideal spot for the production of hydroelectric power. Thus, beginning in the 1930's, the government began to dream about harnessing the power of the Columbia River for hydropower, irrigation, flood control, and navigation.

Today there are 11 dams on the Columbia River and many more on its tributaries (Marts 1999). The four lower dams on the Columbia and Snake Rivers provide large navigation locks that allow ships from the Pacific Ocean to enter and transport goods to and from the inland (Marts 1999). For instance, huge logs from the forestry industry can be sent down the river on large barges. Dams also provide a measure of flood relief. Farms can now be built to the edge of the Columbia River with little fear of flooding and loss of precious crops.

However, one of the biggest uses of dams in this region is for hydropower. Hydropower is electricity that is produced from generators driven by water turbines that convert the potential energy in falling water to mechanical energy ("Hydroelectric Power" 1999). According to the National Hydropower Association, the United States is the second largest producer of hydroelectricity in the world, with hydropower making up 10-12 percent of our electricity. Hydropower provides electricity to 33.2 million consumers nationwide and could provide power to all the homes in California, Florida, New York, Pennsylvania, Ohio, and North Carolina combined (NHA 1999).

The Columbia River is one of the world's greatest sources of hydroelectric power. With its tributaries, the Columbia River provides a third of the potential hydropower in the United States (Marts 1999). The Grand Coulee is the largest dam on the Columbia River and was completed in 1941 (Marts 1999). At the time of its construction, it was heralded as the eighth wonder of the world (Minard 1992). Built in the Grand Coulee gorge, this dam produces an enormous amount of hydroelectric power. All power plants in the region are connected, and surplus power is sold to southwestern states during the summer (Marts 1999).

According to *The Economist*, America's largest power plant is this conglomeration of dams on the Columbia River and tributaries. These hydropower dams can produce 8500 megawatts of power in a dry year (as much as 12 nuclear power plants). The Grand Coulee Dam alone produces as much power as six nuclear plants ("Will the Salmon..." 1990). Today four-fifths of the electricity consumed in the Pacific Northwest comes from hydroelectricity. The average Oregonian pays half as much as the average Californian for power because of this extremely efficient and cheap form of renewable energy ("Will the Salmon..." 1990).

Even beyond looking at its low cost, hydropower offers many benefits to the consumer and environment. Hydropower, or harnessing the power of falling water, is a renewable resource and thus offers an alternative to fossil fuels. Water is constantly replenished in the river system through precipitation and snowmelt and thus cannot be depleted like non-renewable resources such as oil reserves. In 1996, by using hydropower we avoided the use of 126 million metric tons of coal, 18 million barrels of oil, and 133 billion cubic meters of natural gas. By doing so, 327 million tons of carbon dioxide were prevented from being released into the air (NHA 1999). Waterpower has been called the world's best energy source: it is more reliable than the wind; works at night (unlike the sun), and a hydrosystem will produce 3-10 times more energy than photovoltaic or wind power ("A New Era..." 1994). Thus, hydropower has led the genre of renewable resource usage for many years.

Hydroelectric power is extremely clean and does not result in any waste products (ash, uranium, etc.) or release any greenhouse gasses. It is inexpensive largely because the method is remarkably efficient. The operation and maintenance costs of hydroelectric power plants are only a third of the costs associated with a typical nuclear or fossil fuel facility (not including fuel costs) (NHA 1999). Hydroelectric plants can also quickly and inexpensively respond to changes in energy demand, allowing plants to conserve energy (Edwards et al. 1999).

Interestingly, hydropower from the Columbia River has been viewed as vital to the United States' success in the Second World War. It was this energy that cheaply powered the plutonium factory at Hanford, Washington that was to create the atomic bomb. Boeing also used this electricity to build half of the country's aeroplanes, including the plane that dropped the bombs over Hiroshima and Nagasaki (Will the Salmon… 1990). The use of hydroelectricity also made the production of aluminum much cheaper (Borah 1952). Thus, the United States as a whole largely depended on the power produced by the mighty Columbia and her tributaries.

Once dams were in place for the production of hydroelectricity, water also began to be used for irrigation purposes. The miracle of irrigation allowed arid regions in the American west to be transformed into profitable land. By 1910, 5,200,000 hectares had been reclaimed in America through irrigation, producing harvests of $250,000,000 and supporting 300,000 families (Blanchard 1910). The west was viewed as a great expanse ready to be watered and reclaimed. This is apparent in the closing lines of a 1910 *National Geographic* article by C.J. Blanchard: "The beacon of hope shines brightly in the west. It beacons the landless man to the manless land." Irrigation was largely responsible for transforming the west into a habitable and profitable region.

On May 29, 1952 water was released for the Grand Coulee Irrigation Project, a million-acre state and federal undertaking in the Columbia River Basin (Borah 1952). This project diverted excess water from the Grand Coulee Dam into irrigation pipes that would water sagebrush deserts in the region. To show the promise of additional water, volunteers built a working farm in less than 24 hours after the water was released, as a "farm-in-a-day" gift to Donald D. Dunn from the Veterans of Foreign Wars (Borah 1952).

Today, the irrigation of Washington's "sagebrush country" has transformed the region into a bountiful harvest-land. The region is renowned for its melons, squashes, apples, onions, corn, cucumbers, cauliflower, roses, and many other crops (Boyer 1974). It has been likened to the Nile River valley in fertility and transformation. For example, this irrigated land in Washington produces more bushels of potatoes per acre than even Maine or Idaho (Boyer 1974).

The upper Snake River basin (southern Idaho and east central Oregon) also relies heavily on irrigation from surrounding dams. Over 1.2 million hectares of this region is irrigated with surface water (Moore et al. 1996). Irrigation has utilized the huge reserves of water held behind dams, creating a system of regular and reliable water to otherwise semi-arid environments. This movement of water has allowed many people to populate the area and to make a living through agriculture.

It would be difficult to imagine the Columbia River Valley without dams. They have ensured the growth of the Pacific Northwest by improving the economy. Dams continue to provide cheap electricity, flood control, increased navigation, irrigation, and recreational areas to millions of people in the region.

However, dams in the Pacific Northwest have not been totally beneficial. Rather, populations of salmon have rapidly declined since the transformation of the Columbia River into one long lake, barricaded with dams. The Columbia River Basin provides habitat for six species of anadromous salmon (Chinook, Coho, Chum, Sockeye, Pink, and Steelhead). Anadromous fish are born in freshwater rivers and tributaries and then travel to the ocean, where they live for two to five years. At the completion of their life cycle, anadromous fish return to the stream in which they were born, mate, and then die (PSCO 1999).

Salmon feed at sea for a year or more until they decide to move upstream. Once they reach freshwater they no longer eat, instead relying on fat reserves. Each fish finds its way to where it was hatched; using scent and other navigational aids that are not yet understood (Van Dyk 1990). Once a hen salmon reaches home, she digs a nest in the riverbed, thrashing her body to make a hollow. As she is doing this, two or three males may hover close, fighting for breeding rights. When the nest is completed, the hen releases her eggs and the strongest male releases sperm to fertilize the eggs. The female sweeps a protective cover over the nest and then both parents die (Van Dyk 1990).

The eggs hatch into alevins, translucent fish with food pouches on their bellies. Alevins develop into fry, and fry become smolts or salmon that head out to sea. Most juveniles never make it home again. If a female lays 3000 eggs, around 300 will survive to become fry. Only four to five of these will ever reach maturity and fewer still will return to spawn (Van Dyk 1990)!

When all of these factors are taken into consideration, it is easy to see how the addition of obstacles, such as dams, could greatly affect the population size of Pacific salmon. Historically, the Columbia River was the most prolific salmon-producing river in the world. In the early 19th century, salmon runs of all species totaled between 10-35 million spawners each year. Today only 2.5 million fish survive (Reisner and Bates 1990). The largest factor of salmon decline can be attributed to hydropower dams. These dams kill between 80-95 percent of the migrating young steel and salmon each year ("Columbia and Snake Rivers" 1999). Today, there are 214 native and naturallyspawning Pacific salmon and steelhead stocks in California, Oregon, Washington, and Idaho that are at high or moderate risk of extinction (Moore, et al. 1996).

Salmon are adapted to the cool, clear, rapidly moving waters of the Columbia River and its tributaries. The addition of dams has converted this area into a long series of warmer, sediment-filled, and sluggish lakes. The committee on Fish Passage Technologies has stated that:

> "hydropower development may adversely affect fish by blocking or impeding biologically significant movements, and altering the quantity, quality, and accessibility of necessary habitat. Fish moving downstream that pass through hydropower turbines can be injured or killed, and the inability of fish to pass upstream of hydropower projects prohibits them from reaching spawning grounds,' (*Fish Passage Technologies* 1995).

In addition, there has been an increase in salmon diseases, such as that caused by the fish pathogen, *Flexibacter columnaris*. This pathogen was first recognized as a severe disease problem in the Columbia River in the early 1940's. Since that time, highly virulent strains have become dominant and are now widespread throughout the Columbia River system. Warm water, such as that found in the lakes behind dams, often enhances the development of bacterial diseases, and lowers the resistance of salmon to infection (Becker and Fujihara 1978).

There are many methods by which hydropower companies are trying to reduce salmon mortality, and increase fecundity. First, hatcheries have been developed in order to increase population numbers. Females are caught and their eggs are removed into buckets. The eggs are then fertilized with sperm from several males to ensure genetic diversity. Hatcheries generally release the young upstream to return to the ocean, whereas fish farms raise salmon to maturity in holding tanks. William McNeil, a researcher at the Oregon State University Hatfield Marine Science Center states that "the supply of salmon is as robust as it ever has been and is even increasing. The wild stocks are being over fished. Pollution and dams also take their toll of wild stocks, but the burgeoning farms and hatcheries more than make up the deficit," (Van Dyk 1990). However, Van Dyk notes that if hatchery fish breed with wild stock which are adapted to one particular river, then a genetic resource built up over tens of thousands of years could be weakened (1990). This interbreeding could lead to a case of genetic erosion, in which unique gene pools could be lost. Today, maybe only 20 percent of Columbia salmon runs consist of wild fish (Van Dyk 1990).

Other methods involve dam structure modifications in order to lead fish in the right direction. The National Marine Fisheries Service and the United States Fish and Wildlife Service have the authority to prescribe mandatory fish passage techniques under section 18 of the Federal Power Act ("Fish Passage Technologies" 1995). The main method of directing fish upstream is through the use of fish ladders. Adult fish ladders have been integrated into the design of dams beginning with the Bonneville dam in 1938 (Columbia River Basin 1999). Fish ladders generally perform well, and fish lifts or elevators may be used when a fish species will not use the ladders. However, an inadequate flow of water over the ladders may cause delays in migration ("Fish Passage" 1995).

Several other methods have been tested to ensure the movement of adult salmon upstream. Fish pumps are a highly controversial method in which adults are forced into bypass pipes for passage upstream ("Fish Passage" 1995). This technique may lead to serious injuries as well as disorient fish. Another controversial method is the transportation of adult salmon upstream on trucks or barges. This method raises concerns of the amount of handling on fish behavior, health, and distribution ("Fish Passage" 1995). Because of health concerns, fish ladders are by far the most common method to ensure fish migration upstream.

Fishery biologists are also concerned that juvenile salmon are able to make the perilous journey to the ocean. The main method used is the construction of screens to keep juvenile fish away from the turbines of hydropower dams. These juvenile bypass systems divert 80-90 percent of steelhead salmon, 60-70 percent of spring and summer Chinook salmon, and around 30 percent of fall Chinook salmon from going through the turbines (PSCO 1999). Hydropower corporations are currently examining ways to make these screens even more efficient.

Other methods are used in the Columbia River basin to transfer juvenile salmon downstream. In some areas, juveniles are transported around dams in trucks, thus decreasing the possibility of turbine entrapment. However, even slight delays in migration caused by shipping may impact the physiological development of salmon. The use of transportation also exposes juveniles to disease, stress from overcrowding, and an increased chance of predation upon release ("Fish Passage" 1995). Another, more controversial method, that is used is called spilling. Spilling occurs when excess water is spilled over a dam allowing the fish to flow over the dam. However, this may have impacts on the health of the fish, as they fall from large heights, and excess atmospheric nitrogen is churned into the water ("Fish Passage" 1995).

Although hydropower companies are required by law to use fish passage technologies, the fact remains that salmon populations are rapidly declining. The seriousness of salmon population decline was revealed on March 15 of this year as nine

Northwestern salmon species were added to the United States Endangered Species List ("Northwest Salmon" 1999). The habitat of Pacific salmon includes the cities of Seattle and Portland, and this is the first time that an Endangered Species Act listing directly affects a metropolitan area.

In order to improve conditions for salmon, the Clinton Administration is scheduled to make key decisions about the modification of five government owned dams along the Columbia and Snake Rivers ("Columbia and Snake" 1999). The Columbia and Snake Rivers Campaign is currently lobbying for the partial removal of four dams on the lower Snake River and lowering the reservoir behind the John Day dam on the Columbia River. These modifications are predicted to restore over 200 miles of river habitat and return salmon and steelhead populations to the harvestable levels of the 1960's ("Columbia and Snake" 1999). Scientists say that there is a 98 percent certainty that these changes will save the salmon, but current recovery efforts will not ("Columbia and Snake" 1999).

The four dams under consideration on the lower Snake River are the Lower Granite, Little Goose, Lower Monumental, and Ice Harbor dams. These dams were completed in 1975 in order to increase hydropower and navigation in the area. Plans call for the partial removal of the earthen portion of each dam. This would allow the river to return to its natural channel and flow around the remaining concrete parts. Partial removal is less expensive than complete removal, and would be reversible ("Columbia and Snake" 1999). According to the Columbia and Snake Rivers Campaign, there are several reasons why partial removal of these dams would be beneficial to salmon:

1) Young salmon will use natural river flows to move easily and safely reach the ocean.
2) Young fish will no longer have to go through deadly turbines.
3) Deadly high temperatures and increased levels of predators in the existing reservoirs will be eliminated.
4) Adult fish will not have to fight over fish ladders to move upstream.
5) Spawning habitat currently covered by silt and deep water will be exposed.

The Clinton administration is scheduled to choose the best method to recover Snake River salmon within the next several months ("Columbia and Snake" 1999).

The John Day dam on the Columbia River is constructed differently, and therefore the dam will not be removed. Instead, plans call for the reservoir behind the dam to be lowered 40 vertical feet below current levels. John Day reservoir is the longest (122 kilometers), slowest, and deadliest reservoir for salmon on the Columbia River. According to the Columbia and Snake Rivers Campaign, lowering the reservoir will:

1) Shrink the length of the reservoir to make migrations easier.
2) Reduce the high water temperatures of the reservoir.
3) Expose 35 miles of spawning habitat at the upstream end of the reservoir.
4) Reduce impacts from predators on young fish.
5) Increase river flow to help young fish reach the ocean.

The John Day dam plans are only in the beginning stages and will not be decided upon by the U.S. government until a later date.

Opponents to the modification of the five dams feel that the loss of navigation on Snake River reservoirs could be devastating to their economy. Currently, dams allow navigation of barges all the way to Lewiston, Idaho. Without barges, either all goods will have to be transported by truck or rail, or goods will be diverted to another city. Opponents state that dam removal would place more large trucks on the road and increase congestion (Young 1999). Farmers in eastern Washington state that the removal of dams will increase their shipping cost of grain, although studies have shown that there will be little effect (Higgens 1999).

Other concerns revolve around the depletion of five percent of hydropower in the Pacific Northwest. Paper companies are concerned that any increase in operating costs, such as an increased power cost, would put their companies at a competitive disadvantage in the world market (Young 1999). However, a 1998 study by the Northwest Power Planning Council found that modifying the five dams will have minimal impact on residential power rates, causing an increase of only $1-3 on a monthly bill ("Columbia and Snake" 1999).

The construction of dams in the Pacific Northwest has not only altered the rivers, but also the way of life and the local economy. Hydropower offers a cheap, clean, and efficient method of electricity. It should not be necessary to remove and demolish all of the existing dams. However, Pacific salmon have been part of the Pacific Northwest ecosystem for tens of thousands of years. As populations continue to plummet, many species have been placed under protection of the Endangered Species Act. In order to save these species, it may be necessary to modify some of the existing dams on the Columbia and Snake Rivers. Only in doing so may we be able to save this legacy.

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