Ecosystem Service Valuation: Opportunities for Increased Protection and Conservation in Clallam County, WA.

by

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A Thesis
Submitted in partial fulfillment
of the requirements for the degree
Master of Environmental Studies
The Evergreen State College
December 2012

This Thesis for the Master of Environmental Studies Degree

by

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has been approved for

The Evergreen State College

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ACKNOWLEDGEMENTS

I would like to take a moment to acknowledge the Evergreen State College. I appreciate all the help and mentoring I received from all the Masters of Environmental Studies (MES) faculty and staff. I would also like to extend my gratitude to the adjunct faculty that made the program a great learning experience and brought to the classroom their numerous skills and shared their unique knowledge. A special heart warmed thank you to my thesis reader Ralph Murphy, his feedback, comments and constant brainstorming of ideas resulted in this finished thesis. The entire MES cohort, with whom I grew and shared every new concept, idea and experience. I would like to extend a special thanks to: Matt Ritter, Melissa Pico, Heather Kowalewski, Tim Benedict and Allison Osterberg.

Much appreciation also goes to Earth Economics, who provided the tools and knowledge to make this thesis possible. The whole Earth Economics staff helped with the review and editing of the final product. A special thanks to: Maya Kocian, Jen Harrison-Cox, David Batker, Tedi Dickison and Anna Milliren.

Thank you and the best of luck.

ABSTRACT

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Conserving our natural environment has become an interdisciplinary effort for many years. Economics is a discipline that not only is a part of conservation but also maintains a crucial role. As an economic analysis, ecosystem valuations can help minimize the gap created by the interaction of different disciplines. This thesis focuses on an economic approach to environmental management, using Clallam County in Washington State as a case study. This county, as many others, is mandated by State law to update their Shoreline Master Program (SMP), and plans to use this ecosystem assessment as an integrative part of this update. Through benefit transfer methodology, an ecosystem service valuation for Clallam County is presented. Based on a total of 15 ecosystem services over 11 land cover types, Clallam County's services contribute roughly $1 billion to $12 billion a year to the local and regional economy. The net present value for Clallam County analyzed over a 50-year period with a nominal rate is over 350 billion, and at 4% discount rate, 150 billion. These values will be integrated into the SMP update and used to inform the No Net Loss policy. Approaching environmental management policies with a multidiscipline analysis enables further conservation of natural environments. Ecosystem services currently represent zero value in our markets, appointing a representative value enhances essential understanding of their environmental, economic and social importance.

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Chapter 1- Purpose of Thesis

This thesis attempts to lessen the gap between different disciplines to better understand of the value of the environment. Taking an interdisciplinary approach to the subject of conservation, relates economics, ecology and society hoping to enable a clear communication between disciplines, therefore achieving the overarching goal of conserving ecosystems' health and functionality.

Introduction

Recently the study of the environment has incorporated many different disciplines. As more knowledge is gained regarding natural processes their understanding becomes more complex. Even though nature is not assigned monetary worth, valuing the benefits that environmental processes provide is an important tool for its protection. The importance of placing a dollar value to natural capital can inform decision makers and politicians to better understand the significance of conserving important ecosystems.

The case study used in this thesis, Clallam County, was divided into 11 land cover types: Agricultural Land, Beach, Estuary, Forest, Fresh Marsh, Grasslands, Open Water, Pasture, Salt Marsh, Shrub and Wetland. Each land cover across Clallam County produces a unique array of ecosystem services. These services were identified, and a preliminary subset was valued with dollar estimates based on eight valuation techniques: market value, avoided cost, factor income, travel cost, replacement cost, hedonic pricing, group valuation and contingent valuation. The 15 ecosystem services examined for Clallam County include aesthetic and recreational value, biological control, disturbance regulation, erosion control, food provision, gas and climate regulation, habitat and nursery, nutrient cycling, pollination, science and education, raw materials, waste treatment, soil formation, water supply and water regulation.

Ecosystems support economies, and provide foundational economic goods and services. Healthy natural surroundings enable cities, communities, households and their residents to thrive. However, society has underinvested in ecosystems. When free flood protection provided by natural systems is lost to development, the results are costly to repair flooded houses and other built infrastructure. When salmon, drinking water, storm water conveyance, local climate regulation and other benefits disappear, the economy suffers from both the direct damage to the ecosystem and the expensive tax districts and construction costs that are needed to replace natural capital.

Context- Research Question

Ecosystem service valuation (ESV) is a tool used to quantify benefits, goods and services provided by the environment. In recent years many publications have addressed the definition of ecosystem services, and have also discussed the many methodologies used on how to quantify them. In environmental economics many values that are used to measure ecosystem services are prone to unpredicted changes, and therefore estimates can sometimes be considered subjective (Batker *et al*., 2010). However, ESV lessens the gap between undervalued ecosystems and promotes their conservation and protection; therefore providing both monetary and non-monetary values that are concise and understandable to many distinct professions. This tool has become widely accepted and useful within the economic, political and environmental communities.

Clallam County has a state requirement to update their Shoreline Master Program (SMP). Local governments utilize SMPs to regulate shoreline use in Washington State. The SMP can also be integrated with other local government systems for administration and enforcement of land use regulations. In order to highlight the importance of conserving and protecting their ecosystems, Clallam County plans to include ESV values in their updated version of the SMP-No Net Loss policy to bolster claims in achieving the set goals. Clallam County is a case study that assesses the use of ESV values not only in conserving the local environment, but also as an important tool to enhance regulatory documents and recommend ways in which these economic values can be applied.

Chapter 2- Literature Review: Ecosystem Services

An extensive literature review was completed for this thesis. There are many new economic and ecological concepts that not only have to be explained but also related to the overall purpose of this thesis. Starting with the differences between environmental and ecological economics, leading to an agreement upon what is considered economic sustainability in this study. One of the main reasons for this chapter is to introduce ecosystem goods and services as explained by the best available science.

Environmental Economics and Ecological Economics

Although each discipline approaches environmental issues differently they both share traditional founding economic theories. In order to understand the position taken by both environmental economics and ecological economics (but not describing these disciplines in great depth) there are several central concepts that these disciplines acknowledge as key for the understanding of conserving natural resources and healthy environments.

Environmental economics, or neoclassical economic theory, approaches environmental situations with allocation of non-renewable resources and renewable resources overtime. Traditional economics deals with scarcity and depletion. Economic analysis uses models to explain common property resources and public goods. As leading concepts in economic theory, externalities and external costs and benefits explain environmental issues. Environmental economics helps frame environmental questions to enhance models that are useful in everyday decision-making (Harris, 2006).

Ecological economics takes a different approach to environmental issues. This branch of economics has a broader perspective in framing environmental questions. A concept that typically stands out in this discipline is carrying capacity defined by population levels and consumption activities. Ecological economics argues that standard theory does not factor sufficient weight for human impacts on the environment, and calls for a need of major structural changes to adapt to environmental needs (Harris, 2006). While environmental economics relies heavily on traditional economic theory, ecological economics searches for alternative approaches of environmental questions other than the traditionally used economic models.

Economic Sustainability

Economic sustainability depends on environmental sustainability. Natural systems provide goods and services that are directly linked to the growth of a countries' economy. Restoring health to ecosystems is critical to improve quality of life and to secure sustainability, justice, and economic progress in the area. From this basic idea, four essential goals to a healthy economy arise: sustainability, justice, economic progress and good governance (Batker *et al*., 2010).

Sustainability, although an immensely broad term, simply refers to the ability to live within a physical scale that does not destroy basic natural systems that maintain the economy (Batker *et al*., 2010). Justice and rights both help frame and define the value of ecosystems. The distribution of the value to many goods and services is determined by how individual rights are conferred. Also, valuation of the benefits provided by ecosystems can commonly be decided upon their contingent value, mirroring an environmental worth placed by society. Economic progress is typically measured by the Gross Domestic Product (GDP), an index measuring only the production and sales of material items. Ecological economics suggests alternative measurement for economic progress, one that includes happiness and quality of life as a representation of this increase. Good governance has the possibility of creating and sustaining institutions, private and public, market or non-market. Government institutions need to operate efficiently at the scale of the issue or problem at hand, project specific in order to achieve meaningful results (Batker *et al*., 2010).

Ecosystem Goods and Services

In defining ecosystem goods and services many past and current authors have explained the main ideas behind these concepts and their differences. As many other concepts in the ecological community, they must be explained in the context of the research question and the purpose of the investigation.

Ecosystem goods are tangible, quantifiable items or flows, like, timber, drinking water, fish, crops and wildlife. Most goods are considered exclusive, meaning they can have property rights that can exclude the use or ownership of that good to others. These excludable goods can be valued; therefore they are tradable and marketable. The flow of these good can produce economic return. To achieve economic efficiency, the value of ecosystem goods and services should be considered. The true value of an ecosystem good is only as real as the ecosystem service or process that happened to produce that good. By including the value of the entire suit of ecosystem goods and services the relationships and trade-offs can be better understood (Batker *et al.,* 2010).

Ecosystem services are valuable benefits that are not as obvious as ecosystem goods. Ecosystem services is a term that has been used for more than a couple decades, Gretchen C. Daily defines it as: "…ecosystem services are the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life" (p. 23). Unlike ecosystem goods, ecosystem services are not tangible items you can weigh or hold. Flood protection, recreational value, aesthetic value, storm protection, waste treatment, climate stability and water filtration are a few of the services provided. Services are harder to value than goods because many times they are not present in market values. Paradoxically, ecosystem services are critical to both our quality of life and for economic production (Daily, 1997; Costanza *et al.*, 1997; Batker *et al.*, 2010).

In general, ecosystem services are non-exclusive, meaning that if someone enjoys a service this does not prevent another from doing so as well. An ecosystem service such as enjoying the view of Mt. Rainier is not exclusive to one person but available to many, therefore it is not considered an excludable service.

In an ecosystem service market, beneficiaries of an ecosystem service pay those who offer to provide the ecosystem service. The effectiveness of ecosystem service markets will likely be seen in coming years as new markets develop for habitat, climate control, temperature and water quality (Batker *et al.,* 2010). A number of factors make ecosystem service markets more challenging than markets for goods. A flow of services cannot be measured in the same terms, quantitative productivity over time, as goods. Quantifying the amount of flood protection provided by a given forest and the value of that flood protection is much more difficult than calculating the potential for timber harvest (Batker *et al.*, 2010). Regardless of the difficulty in measuring service flows, this value is usually higher then the production of goods of that same ecosystem.

The trade and overall utilization of these goods and services form an essential part of the economy. Not only do natural services produce goods, but also provide "…actual life-support functions, such as cleansing, recycling, and renewal, and they confer many intangible aesthetic and cultural benefits as well" (Daily, 1997 pg. 25).

Although the complexity of ecosystems and their functions is widely known, the loss of many of the natural cycles and processes has led to the deeper appreciation of the intrinsic value of the services ecosystems provide. The further an ecosystem is disrupted the more human effort it takes to replace the service once provided. In doing so, a true and tangible value on the services taken for granted is illuminated. Lack of interest and knowledge of organisms' biology and ecosystem basics has also led to a general depreciation of ecosystems. For example, much of the coastal mangrove vegetation, in the Pacific Mexican coast, has been removed for development. This ecosystem was never considered aesthetically worth preserving, now it is a widely known fact that mangroves provide a unique ecosystem where certain commercial species spend their early life cycles in these waters and also provide ultimate natural buffer zones preventing coastal erosion (FAO, 2003). The destruction of these ecosystems has had a tremendous impact on the ecology, as well as an impact on the regional economy. In recognizing these interrelations between social needs and the role nature plays, is where discipline such as ecological and environmental economics commence.

Five Important Capitals

There are five basic capitals, worth describing in detail in order to accomplish economic and environmental sustainability. These are natural, human, social, built and financial capital (Batker *et al*., 2010).

Natural capital represents resources provided by the earth. These can be renewable or non-renewable, organic and inorganic materials, ecosystems and the biodiversity existing within them. Human capital, or individuals and their accomplishments, references an array of skills that people gain in life, such as education, professionalism, work experience, and overall knowledge. The skills individuals' gain allows them a better and higher quality of life. Social capital is the network created by organizations, institutions, laws, other social groups; all that provide for a working and cooperative social structure. Built capital is the infrastructure that allows human and social capital to advance forward. It may also mean uprising technologies, machines, tools, and transportation. Financial capital is the subset of human capital, used as the currency to which a known and agreed value is placed (Batker *et al*., 2010).

To understand more of the relationship between natural capital and economic value, interconnectivity is key. Natural capital provides economic wealth and enables the other types of capital to prosper. Unlike built capital, healthy natural capital, or ecosystems, are self-maintaining. This influences the value of natural capital over time and relies on the provisioning of outputs in perpetuity, increasing in value over time. Built capital, on the other hand, depreciates over time and maintenance is needed in order to keep it running (Batker *et al*., 2010).

Ecosystems also have important structural components that allow an efficient functionality. These components can be viewed as functions and processes, which allow natural capital to provide goods and services. Different ecosystem functions support different types of processes and ultimately provide different outputs. No one single process can create a single benefit, for this reason interconnectivity is also essential in natural systems and their value should be considered as such. The valuation process has always been one of the most debatable concerns in ecological economics. Many environmentalists believe that valuing can over simplify and underestimate the true worth of nature. This argument will always highlight the limitations of placing an economic value to a natural process. Nevertheless throughout the years valuing ecosystem services prove to be advantageous. There are many approaches to determine the value of services.

A common approach would be a utilitarian viewpoint used by economists especially in a cost-benefit analysis. Armsworth *et al.* (2007) states that this analysis provides a "convenient way of ascertaining social values of alternative policies and thus offers a way to make difficult decisions" (pg. 42). The utilitarian way of viewing the different alternatives can also be criticized because it does not attempt to correct differences in awareness or education among individuals, all essential in making lasting changes.

Ecosystem Service Valuation (ESV)

Knowing the value and importance of ecosystem functionality is the first step in enabling the identification and classification of ecosystem services. Although different services have been identified for over a decade, to this day uncertainty in their classification still varies. "In 2001, scientists from NASA, the World Bank, the United Nations Environmental Program, the World Resource Institute, and other institutions examined the effects of ecosystem change on human well being. The product of this collaboration was the Millennium Ecosystem Assessment (MEA), which classifies ecosystem services into four broad categories describing their ecological role" (MEA Introduction, 2003).

Today, a number of federal agencies in the United States, including the Environmental Protection Agency, the United States Geological Service, and the United

States Department of Agriculture house dedicated ecosystem services departments to advance understanding of how ecosystem services can be promoted to improve long-term economic prosperity for the nation. Agencies like the Federal Emergency Management Agency (FEMA) are developing tools to include ecosystem services in their benefit-cost calculations that dictate their floodplain policy, including grants and loans. Large private corporations such as PUMA and Dow Chemical have also begun to account for their impact on ecosystem services (Batker *et al*., 2010).

Ecosystems provide a wide variety of valuable public goods and services at the least cost over long periods of time, and in most cases they are the best systems for producing such goods and services. It would be impractical, and in some cases impossible and simply undesirable, to replace these economically valuable natural systems with more costly and less efficient human built substitutes. When ecosystems are valued as assets and brought to the center of economic decision-making, their cost-effective services are less likely to be lost.

Ecosystem services can be categorized in different ways. This study follows the approach developed by DeGroot *et al.* (2002), dividing 23 ecosystem services into four functional categories: Regulating Services, Habitat Services, Provisioning Services and Information Services. This approach is consistent with the MEA, as well as much of the scientific and economic literature. The four categories of ecosystem services are described below and summarized in Table 1.

- Provisioning services provide basic goods including food, water and materials. Forests grow trees that can be used for lumber and paper, wild and cultivated crops provide food, and other plants may be used for medicinal purposes. Rivers provide fresh water for drinking and fish for food. The coastal waters provide fish, shellfish and seaweed.

- Regulating services are benefits obtained from the natural control of ecosystem processes. Intact ecosystems provide regulation of climate, water, soil, flood and storms, and keep disease organisms in check.
- Habitat services provide refuge and reproduction habitat to wild plants and animals and thereby contribute to the (*in situ*) conservation of biological and genetic diversity and evolutionary processes.
- Information services provide humans with meaningful interaction with nature. These services include spiritually significant species and natural areas, places for recreation, and educational opportunities through science.

Conclusion

Although environmental and ecological economics have many differences, both disciplines integrate ecology and economy. Recognizing the important role the economy plays in maintaining resources is key to conservation. Identifying the ecosystem services present in a region results in an Ecosystem Service Valuation (ESV), where a simple representation of these services and their values are analyzed. Although authors may vary in the methods used to calculate these values, a commonality among them is the valued benefit of the good provided by the services, assessed in an economic representation. These values can then be used to influence decision and policy makers to enhance protection of natural capital.

Table 1. Ecosystem goods and services classifications. This table provides the 23 types of ecosystem services characterized by Rudolf DeGroot. They are separated into four main types of services and briefly explained (De Groot, 1992).

	Good/Service	Economic Benefit to People
Provisioning	Water Supply	Water for human consumption, irrigation, and industrial use.
	Food	Food for human consumption.
	Raw Materials	Biological materials used for clothes, fuel, art, and building. Geological materials used for energy, construction, or other purposes.
	Genetic Resources	Genetic material and evolution in wild plants and animals.
	Medicinal Resources	Biological materials used for medicines.
	Ornamental Resources	Ornamental and companion uses (flowers, plants, pets, and other).
Regulating	Gas Regulation	Generation of atmospheric oxygen, regulation of sulfur dioxide, nitrogen carbon dioxide, and other gaseous atmospheric components.
	Climate Regulation	Regulation of global and local temperature, climate, and weather, including evapotranspiration, cloud formation, and rainfall.
	Disturbance Prevention	Protection from floods, storms, and drought.
	Soil Retention	Erosion protection provided by plant roots and tree cover.
	Water Regulation	Water absorption during rains and release in dry times, temperature and flow regulation for people, plants, and animals.
	Biological Control	Natural control of diseases and pest species.
	Waste Treatment	Absorption of organic waste, natural water filtration, pollution reduction.
	Soil Formation	Formation of sand and soil from decaying vegetation and erosion.
	Pollination	Fertilization of plants and crops through natural systems.
	Nutrient Regulation	Transfer of nutrients from one place to another; transformation of critical nutrients from unusable to usable forms.
Habitat	Habitat	Providing habitat for plants and animals and their full diversity.
	Nursery	Growth by plants provides basis for all terrestrial and most marine food chains.
Information	Aesthetic Information	The role which natural beauty plays in attracting people to live, work, and recreate in an area.
	Recreation and Tourism	The contribution of ecosystems and environments in attracting people to engage in recreational activities.
	Scientific and Educational Value	The value of natural systems for scientific research and education.
	Spiritual and Religious Experience	The use of nature for religious and spiritual purposes.
	Cultural and Artistic Information	The value of nature for cultural purposes.

Chapter 3- Related Policies: Shoreline Master Program (SMP) and No Net Loss Policy (NNL)

Clallam County, as well as many other counties in Washington State, has to update their SMP. This overall Plan is a state requirement for each city and county government to help protect their shoreline. Similar to other local policies required by the state, they are an opportunity to participate and voice the needs and suggestions of the communities directly involved with that ecosystem.

Shoreline Master Program

In recent years, shoreline and nearby wetlands have become critical areas that require conservation practices. For this reason, State requirements enable the creation of a local Shoreline Master Program. The SMP seeks to establish shoreline uses that will acknowledge present development, but regulate future development with the goal of serving the maximum public interest, rather than private interest. In doing so counties such as Clallam can specify practices and uses for their ecosystems.

Clallam County has a diverse shoreline that residents and visitors enjoy daily from the services provided by this ecosystem. From all over the nation visitors come to fish and boat in these waters, camp along them, or simply revel in the marine views. While tourism is a welcome ingredient of the County's economy, it is equally important to its residents that the County's shorelines be managed to the maximum benefit of those who live here now and will live here in the future.

The goal of the SMP is to conserve, to the fullest extent possible, the scenic, aesthetic and ecological qualities of the shorelines of Clallam County, in harmony with those uses, which are deemed essential to the life of its citizens. To achieve this goal, the past Master Program of 1992 took into account several general policies, that to this day are still applicable and serve as baseline information for the required update. Some of these policies include: the restriction of private and public development that further destroys the ecological state of the ecosystem; public access to certain areas is restricted and only permitted under specified terms; water quality is the prime goal of the shoreline management; conservation is succinct with development either by restrictions or mitigation efforts; among other general polices (Kramer *et al.,* 2010).

The 2012 update has many similar goals and will be a continuation of the efforts planned in the 1993 version. There are different policies that will include a quantification of ecological functions of the existing ecosystems. These requirements and goals are explained further in the No Net Loss Policy.

No Net Loss Policy

Almost 40 years ago the Washington State Legislature identified a "…clear and urgent demand for a planned, rational, and concerted effort, jointly performed by federal, state, and local governments, to prevent the inherent harm in an uncoordinated and piecemeal development of the state's shorelines" (Kramer *et al*., 2010 pg. 1). Since then, local governments have worked to put the broad policies of the Shoreline Management Act into practical terms through the development and implementation of Shoreline Master Programs. In 2003, the Department of Ecology specified that No Net Loss (NNL) of ecological function is the state standard for local Shoreline Master Program updates. The Department of Ecology recently updated their SMP Handbook to provide additional guidance on how to achieve NNL and now requires that each jurisdiction write a summary report describing how their SMP meets the state standard. On the surface, preparing a summary report is a relatively straightforward exercise, but achieving NNL of ecosystem functions in the face of continued growth and degradation continues to prove challenging (Kramer *et al*., 2010).

The SMP Guidelines, adopted in 2003, constitute the first actual rule of the Washington Administrative Code (WAC) to incorporate the NNL requirement. The concept of NNL in this State originated with earlier efforts to protect wetlands. In 1989, Governor Booth Gardner signed an Executive Order establishing a statewide goal regarding wetlands protection. The interim goal of the SMP is to reduce an overall net loss in acreage and function of Washington's remaining wetlands. It is further the long-term goal to increase the quantity and quality of these wetlands as a resource base.

Over time, the existing condition of shoreline ecological functions should remain the same as the SMP is implemented. Simply stated, the NNL standard is designed to halt the introduction of new impacts to shoreline ecological functions resulting from new development. Both protection and restoration are needed to achieve NNL. Restoration activities also may result in improvements to shoreline ecological functions over time.

Figure 1 is commonly used to explain how to achieve the NNL effort. Whether development will affect ecological functions or not, a mitigating effort must take place in order to permit new development.

Local governments must achieve this standard through both the SMP planning process and by appropriately regulating individual developments as they are proposed in the future. NNL should be achieved over time by establishing environment designations, implementing SMP policies and regulations that protect the shoreline, and restoring sections of the shoreline.

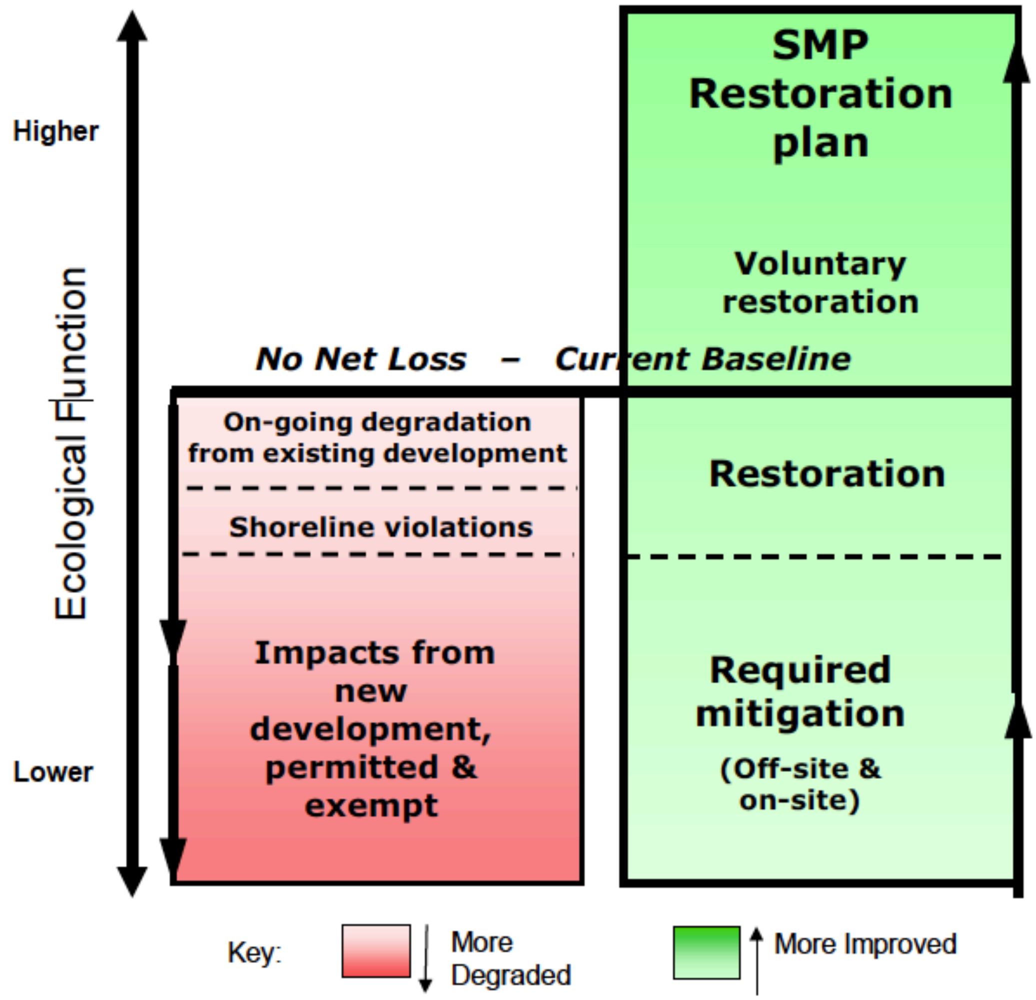

Figure 1. No Net Loss policy diagram-The red rectangle is representative of degradation or development. The green rectangle represents the mitigation efforts that are required in order to offset impacts caused by new development. The horizontal line indicates the minimum of efforts required while still allowing more mitigation actions to take place, if this limit is exceeded (SMP Handbook, 2010).

Based on past practice, current science tells us that most, if not all, shoreline development produces some impact to ecological functions. However, the recognition that future development will occur is basic to the NNL standard. The challenge is in maintaining shoreline ecological functions while allowing appropriate new development, ensuring adequate land for preferred shoreline uses and public access. With due diligence, local governments can properly locate and design development projects and require conditions to avoid or minimize impacts.

NNL incorporates the following concepts: existing ecological functions should not deteriorate due to permitted development; new adverse impacts to the shoreline environment that result from planned development should be avoided; mitigation for development projects alone cannot prevent all cumulative adverse impacts to the shoreline environment, so restoration is also needed (Kramer *et al*., 2010).

Local governments demonstrate NNL at two levels, through the comprehensive SMP update planning process and over time, during the project review and permitting processes. Local governments show that their updated SMP will result in a no net loss of ecological function by completing several tasks in the comprehensive SMP update process, including (from Kramer *et al*., 2010):

- Shoreline inventory and characterization;
- Shoreline use analysis estimating the future demand for shoreline space and potential use conflicts over a minimum 20-year planning period and projects future trends;
- Shoreline management recommendations that may translate the inventory and characterization findings into SMP policies, regulations, environment designations and protection strategies for each shoreline planning unit;
- Restoration plan, which includes restoration opportunities, priorities and timelines for shoreline restoration;
- Cumulative impacts analysis that will assesses the cumulative impacts on shoreline ecological functions.

Given these tasks each county, city and local government must have a preliminary evaluation of the ecosystem ecological functions and the requisites new development must follow.

Conclusion

The SMP, as a comprehensive plan that incudes many additional reports, enables the preservation of the shoreline. It is important for a County to identify and manage the ecological health of their ecosystems. Clallam County's income depends on functioning ecosystems. Local policies such as the SMP, Critical Areas Ordinance, and other Comprehensive Plans ultimately help prevent further unmanaged degradation.

Chapter 4- Clallam County: Site Description and Research Methods

To better illustrate the purpose of ecosystem service valuations and the benefits and utility these provide, this thesis uses Clallam County as an example. Many times counties, cities, and watersheds request valuations to support environmental policies and green agendas. This tool enhances communication between local governments, interested groups and community members bolstering environmental management and conservation.

Geography

Clallam County is located south of the San Juan Islands and is the County furthest to the north on Washington's Pacific Coast. Clallam County includes the western most point of the continental United States. The County is comprised of 254 miles of shoreline, which ranges the entire length of the Strait of Juan de Fuca to Discovery Bay and the Pacific Coast. With a population of approximately 71,000, Clallam County is predominantly rural land with its western border marked by the Olympic Coast National Marine Sanctuary and the Olympic National Park to the south. Of the total 2,670 square miles of Clallam County, 1,739 square miles is land while 931 square miles is water, composed of lakes, rivers and streams (Lear, 2011).

The Strait of Juan de Fuca shoreline is comprised of bluff backed beaches, feeder bluffs, barrier beaches (spits), rocky platforms, stream deltas, inlets, and embankments associated with protected lagoons and salt marshes. These features are continually evolving and changing in response to dynamic geographic and oceanographic processes such as sediment erosion and deposition, landslides, and bluff (Clallam County, 2011).

History

Clallam County takes its name from the Klallam or S'Klallam "strong people", the indigenous tribe who occupied the largest portion of what today is inland Clallam County. The Makah and the Quileute people occupied the coastal areas. Clallam County was one of the first regions of present day Washington to be explored by Europeans in 1778 and quickly became a prime resource for the fur trade. Despite its early European exploration and rich natural resources of marine and forest services, the region did not become a strong economic force until the early 1900s when the Elwha River dam introduced hydroelectric power. The result was an explosion in the lumber industry, which maintained its position as the primary employer of the region for the following several years. The lumber industry then created the pulp and paper industries, which continue to thrive in the region today. In 1915, a railroad was completed but transport remained dominated by water travel until the opening of the Olympic Loop Highway allowing the first convenient automobile access to the region (Clallam County, 2011).

Environmental regulations were revised and updated in the 1980s as a result of diminished forest ecosystems. Logging activities have declined from peaks but still remain a strong force. Other industries such as agriculture and services have also emerged as strong components of the Clallam County economy (Oldham, 2005).

Natural Resources Management

Water and lands of Clallam County are managed by the County's Department of Community Development who oversee committees on watershed planning, salmon recovery, Lake Ozette recovery, groundwater and other water quality, and natural resource planning and monitoring. The shoreline of Clallam County is regulated by the

Washington State Shoreline Management Act and the Clallam County Shoreline Master Program (SMP) in partnership with the cities in Clallam County. The SMP oversees the land use and development within 200 feet of rivers, lakes, streams and marine shores. The SMP was initially adopted in 1976; it was updated in 1992 and is currently undergoing updates and revisions (Clallam County, 2011).

Regional Biodiversity

Given Clallam County's numerous and diverse land covers, the County is rich in plant and animal biodiversity. The existence of dense forests containing douglas fir, western red cedar, western hemlock, sitka spruce, and other giant conifers made timber the County's economic core for most of its history (Clallam County, 2011). These forests provided healthy habitat for the presence of at least 7,013 species, including 4,248 animals, 1,504 plants, 851 fungi and 392 algae in the Puget Sound alone (Chapen *et al*., 2000). The North Olympic Land Trust is a local land conservancy that works to protect the biodiversity of the region.

Salmon

The numerous rivers and streams found throughout Clallam County- the Bogachiel, Dungeness, Elwha, Pysht, Lyre, Jimmycomelately, Morse, Sol Duc and Salt Creek, to name a few; have historically allowed for some of the most productive Pacific salmon runs in the world. Chinook, Coho, Chum, Sockeye, and Pink salmon return annually to the region (Ward *et al.*, 2008). Stories abound about tremendous runs of 100-pound salmon returning to the Elwha River prior to the construction of two dams at the turn of the century, which powered a growing Port Angeles but prevented the fish from accessing key upstream habitat.

These iconic fish are tremendously significant to local tribes and their members. They are an important food source, sought for commercial and subsistence harvest, and desired for their cultural significance. Salmon are also very important to the economy of this area, for commercial and individual harvest, and for recreational opportunities by sports and fly fisherman, both local and out-of-town (Clallam County, 2011).

Not to be forgotten is the significant role the Strait of Juan de Fuca nearshore, which plays as a major salmon migration corridor for Endangered Species Act (ESA) listed Puget Sound salmon, as well as ESA listed salmon from Klamath and Columbia River Regions. Nearby pocket estuaries and salt marshes are important breeding, rearing and feeding areas for juvenile salmon as they gain strength and size before their journey out to sea (Clallam County, 2011).

However, salmon stocks have significantly declined in the region, in part due to the effects of overharvest, extensive logging of local forests, as well as development, population growth, diking, damming and other human impacts to rivers, estuaries and streams. This has lead to listings under the Endangered Species Act for Puget Sound Chinook across much of the region, along with other listings for Eastern Strait of Juan de Fuca and Hood Canal Summer Chum along with bulltrout and steelhead (Clallam County, 2011).

Nearshore

Puget Sound nearshore is vital for the economic and recreational benefit of over 4 million citizens of the region. The nearshore zone ranges between the riparian forested land and extends to the photic zone where sunlight can no longer reach marine vegetation. As a result, the nearshore region is rich in a wide diversity of both terrestrial and aquatic plants and animals. From the shoreline bluffs, backshore, beach face, shallow tidal areas and subtidal zones, the health of this area is essential to maintaining the health of the entire region. Vegetation of the nearshore zone is crucial to providing soil stability, maintaining water quality, abating pollution and providing a protected habitat for migrating and permanent species (Clallam County, 2011).

Clallam's nearshore area along the Strait of Juan de Fuca is rich in aquatic vegetation and animals, which support many varieties of life. This area has been inhabited by human settlements for thousands of years and serves as the migratory path for a multitude of bird species, Fraser River Salmon, and marine mammals (Clallam County, 2011).

The temperate climate of the nearshore and the views that it has to offer make the area extremely desirable for development but the impacts of human activities can lead to the degradation of the essential components of the nearshore habitats. Shoreline armoring, a manmade practice, can disrupt the natural sedimentation process, also known as feeder bluffs. This term is specific to the Puget Sound area, where bluffs are common and the natural action of sediment disposition is a characteristic of these beaches. Bulkheads, aquaculture practices, and reduction of endemic vegetation not only harm natural ecosystems and animal species that depend on the health of the nearshore, it can also affect resource based industry and job creation in Clallam County (Clallam County, 2011).

Clallam County is an area with many natural resources and healthy ecosystems. The location of Clallam County on the Peninsula makes this area breathtaking and a popular tourist attraction. Regional healthy ecosystems provide more than beautiful sceneries, also numerous services that increase quality of life for residents and provide important economic opportunities.

Following are some detailed explanations of ecosystem services valued in this thesis. In Clallam County a total of 15 ecosystem services are present (details in Table 1). In the following section only five of the total ecosystem services present in Clallam County will be explained in great detail to exemplify the reasoning behind quantifying particular services. This section also lays out how each of these services are important to the study area.

Aesthetic and Recreational

Aesthetic value, as an ecosystem service, refers to the appreciation of natural land and seascapes. The existence of national parks and designated scenic areas attests to the social importance of this service. There is also substantial evidence demonstrating the economic value of environmental aesthetics through analysis of data on tourism, housing markets, wages, and relocation decisions. Degraded landscapes are frequently associated with economic decline and stagnation (Power *et al.*, 1996).

Clallam County Example

Activities such as sailing, rafting, skiing, kayaking, camping, hunting, hiking, bird watching and many more are a great source of income for Clallam County businesses throughout the year. Olympic National Park and Olympic National Forest attracts many visitors year round. Not only are the County's beautiful forest and rivers an aesthetic wonder, but the shoreline and beaches are also a great place for recreational activities such as hiking, fishing, surfing, tidepool exploration, and clamming. Clallam County has over fifteen parks, totaling approximately 735 acres, where residents and visitors enjoy interacting in unique natural surroundings providing important learning and bonding experiences.

Habitat and Nursery

Habitat is the biophysical space and process in which wild species meet their needs. Healthy ecosystems provide physical structure, adequate food availability, appropriate chemical and temperature regimes, and protection from predators. Habitat may also provide nursery functions; a nursery habitat refers specifically to where all the requirements for successful reproduction occur. Biodiversity provides the structure and complexity of ecosystems lending resiliency and producing provisioning, regulating, cultural and supporting ecosystem services. In addition to the physical structure provided to species, food/web relationships are important components of habitats that support all species (DeGroot *et al.,* 2002).

Clallam County Example

Ecosystem restoration and salmon recovery actions from the North Olympic Chapters of the Puget Sound Chinook Recovery Plan, the Eastern Strait of Juan de Fuca-Hood Canal Summer Chum, Lake Ozette Recovery Plan and draft WRIA 19 Recovery Plans are underway throughout Clallam County (Clallam County, 2011).

The plans include a comprehensive set of actions related to salmon recovery, such as harvest management, hatchery management, water diversions, or forest management. All of these actions help prioritize salmon recovery efforts led by the North Pacific Coast

Lead Entity in western Clallam County and the North Olympic Lead Entity for Salmon along the Strait. Other key partners include Tribes, Clallam County, cities, non-profits and citizens. The steps described in recovery strategies are necessary due to listings of five salmonid species as threatened under the Endangered Species Act. Salmon populations in many of Clallam County's watersheds have declined significantly. Preserving and restoring ecosystem health of Clallam County's many watersheds will help maintain the dwindling salmon populations. Some examples of this work includes the removal of two aging dams on the Elwha River lead by Olympic National Park in partnership with the Elwha Klallam Tribe, which is working on the revegetation and building large engineered log jams to maximize restoration efforts. As well as efforts to restore floodplain areas along the Dungeness by adding needed woody debris buffers along rivers.

Water Regulation

This category includes regulation of water flows through the ground and along terrestrial surfaces, as well as regulation of temperature, dissolved minerals, and oxygen. Ecosystems absorb water during rains and release it in dry times. They also regulate water temperature and flow for plant and animal species. Forest cover, riparian vegetation and wetlands all contribute to modulating the flow of water from upper portions of the watershed to streams and rivers in the lower watershed. When forested basins are heavily harvested, the remaining vegetation and litter layer on the forest floor absorbs less water. The elimination of the vegetation cover reduces water absorption increasing the flow of water onto land and bodies of water (Moore *et al.,* 2005).

Clallam County Example

The lack of water regulation in developed lands can be costly and problematic to local landowners. In Clallam County, drainage plans are used as a method for the control of stormwater runoff on individual properties. These plans are required to control increases in rainwater runoff resulting from development of the land. Every Clallam resident is responsible for damage caused by stormwater runoff due to their development. Maintaining natural pervious land cover can significantly reduce the mitigating efforts required by the county. This will save time and money required to build infrastructure to mitigate this water flow.

Erosion Control

Erosion is one of the most damaging outcomes of poor land development. Erosion strips the land of all nutrients and minerals that can prevent or significantly impact the ability for vegetative cover regeneration. This then creates a chain reaction where fauna is deprived of their natural habitats and land itself declines in value. Land erosion can sometimes pose real danger to landowners. Such is the case with shoreline erosion. The shoreline has been developed over many years. Natural factors like wind and storms cause accelerated impacts to developed lands, due to the lack of biological cover that serves as protection (Merrill *et al.,* 2002). Erosion control can be achieved through stormwater management; avoiding or limiting development in areas with a high risk to erosion due to slope, erodability of soil, and other factors; protection of endemic land covers and mitigating previous harmful activities.

Clallam County Example

Many shoreline and coastal bluff landowners have expressed interest in protecting the Nearshore environment. The conservation of this land will ensure their safety and will protect their property. The Shoreline Master Program deals with regulations that prevent further damage to the land and consequently will avoid erosion. With the No Net Loss policy new development is restricted and mitigation efforts are required either onsite or offsite. These mitigation efforts account for the impact development has on the land. It is monitored by maintaining the current state of ecological functions present in the area.

Food Provision

Providing food is one of the most important ecosystem functions. Agricultural lands are our primary source of food; farms are considered modified ecosystems, and food is considered an ecosystem good with labor and built capital inputs. Agricultural value is measured by the total market value of crops produced; however, market value is only a small portion of the total value agricultural lands provide through pollination, carbon sequestration, aesthetic value, and other services.

Clallam County Example

In Clallam County there are over 900 acres of agricultural land. Each farm has about 49 acres and the average value of agricultural products sold per farm is approximately $40,000 thousand per year. Agriculture contributes significantly to the local and regional economy, by producing high quality produce and jobs. Agricultural lands, especially organic farms, provide additional ecosystem services, such as pollination, habitat, flood protection and nutrient regulation. These services are considered “green infrastructure” and are critical to the local and regional economy.

Eventhough a wide variety of ecosystem services exist, they are limited to what is present in a certain area. All of the 15 services present in Clallam County were valued and provide a range of benefits. Services are particular to the area of study and their value may vary depending on geographical location, cultural and traditional activities, productivity, development, and many other aspects.

Methods: Land Cover Classification and Valuation Methodology

Land Cover in Clallam County

Clallam County, similar to other counties in Washington State is composed of many different geographically different land covers. The peninsula offers Clallam County a distinct terrain, increasing the ecosystem services pertinent to these land covers. Geographic Information Systems (GIS) data on land cover (forests, shoreline, rivers, pastures, etc.) is provided by satellite surveys. These land cover types provide suites of ecosystem services that may be valued. Although GIS has come a long way since this tool was first created, there are still limitations as to the accuracy of the distinct land cover types, in some cases the delimitation is nearly impossible. This is particularly true for Clallam County, where the shoreline was a challenge. Many geographical datasets combine shoreline with barren lands (over developed lands), which cannot be valued. For this project the acreage for unconsolidated shoreline was used as the area of beach valued. As for rivers and lakes they were included in the open water category, as well as riparian buffers. Combining certain land cover types is needed because of the shortage of exact data of the availability of GIS layers, time and personnel.

This thesis uses Coastal Change Analysis Program (C-CAP) a land classification by the National Oceanic and Atmospheric Administration (NOAA), which is a national effort to develop and distribute regional land cover and change analysis data for the coastal zone by using remote sensing technology. In addition to data development, C-CAP establishes guidelines and standards for developing digital, regional land cover and change data along the nation's coastal zone. The data used in this program is created from a combination of satellites and fieldwork. C-CAP classifies land cover types into 22 standardized classes that include forested areas, urban areas, and wetlands. C-CAP land cover change data is available in .img format and in Universal Transverse Mercator (UTM). Data coverage extends well inland from the coastlines, and includes most of the US shoreline. Typically, data is designated by state and is organized into three datasets per state: starting time land cover, ending time land cover, and land cover change. Table 2 categorizes and describes each GIS land cover type in the area.

Table 2. Land cover categories, C-CAP categories and a brief description of what each land cover type entails. Clallam County's land cover was divided into 11 types. Each land cover type provides different ecosystem services (C-CAP Classification, 2005).

Land Cover Type	C-CAP Classification	Description
Agricultural Land	Cultivated Crops	Areas used for the production of annual crops. Crop vegetation accounts for greater than 20 percent of total vegetation. This class also includes all land being actively tilled. Characteristic land cover features: Crops (corn, soybeans, vegetables, tobacco, and cotton), orchards, nurseries, and vineyards.
Beach	Unconsolidated Shore	Unconsolidated material such as silt, sand, or gravel that is subject to inundation and redistribution due to the action of water. Characterized by substrates lacking vegetation except for pioneering plants that become established during brief periods when growing conditions are favorable. Erosion and deposition by waves and currents produce a number of landforms representing this class. Characteristic land cover features: Beaches, bars, and flats.

Estuary	Estuarine Forested, Scrub/Shrub and Emergent Wetland	Includes all tidal wetlands dominated by woody vegetation and erect, rooted, herbaceous hydrophytes (excluding mosses and lichens). All such wetlands that occur in tidal areas in which salinity due to ocean is present. Characteristic species: Sea-myrtle (Baccharis halimifolia), Cordgrass (Spartina spp.), needlerush (Juncus roemerianus).
Forest	Deciduous, Evergreen and Mixed Forest	Areas dominated by trees generally greater than 5 meters tall and greater than 20 percent of total vegetation cover. More than 75 percent of the tree species shed foliage simultaneously in response to seasonal change or species that maintain their leaves all year. Canopy is never without green foliage. Characteristic species: Maples (Acer), hemlock (Tsuga canadensis), Douglas-fir (Pseudotsuga menziesii), ponderosa pine (Pinus monticola), Sitka spruce (Picea sitchensis).
Fresh Marsh	Palustrine Aquatic Bed	Includes tidal and non-tidal wetlands and deep water habitats in which salinity due to ocean-derived salts is below 0.5 percent and which are dominated by plants that grow and form a continuous cover principally on or at the surface of the water. These include algal mats, detached floating mats, and rooted vascular plant assemblages. Total vegetation cover is greater than 80 percent. Characteristic species: water lilies (Nymphea, Nuphar), water fern (Salvinia spp.), and Bladderworts (Utricularia)
Grassland	Grassland/Herbaceous	Areas dominated by grammanoid or herbaceous vegetation, generally greater than 80 percent of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing. Characteristic land cover features: Prairies, meadows, fallow fields, clear-cuts with natural grasses, and undeveloped lands with naturally occurring grasses.
Open Water Lakes and Rivers Riparian Buffer	Open Water	All areas of open water, generally with less than 25 percent cover of vegetation or soil. Characteristic land cover features: Lakes, rivers, reservoirs, streams, ponds, and ocean.
Pasture	Grassland/Herbaceous	Areas dominated by grammanoid or herbaceous vegetation, generally greater than 80 percent of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing. Characteristic land cover features: Prairies, meadows, fallow fields, clear-cuts with natural grasses, and undeveloped lands with naturally occurring grasses.

Salt Marsh Eel grass bed	Estuarine Aquatic Bed	Includes tidal wetlands and deep water habitats in which salinity due to ocean-derived salts is equal to or greater than 0.5 percent and which are dominated by plants that grow and form a continuous cover principally on or at the surface of the water. These include algal mats, kelp beds, and rooted vascular plant assemblages. Total vegetation cover is greater than 80 percent. Characteristic species: Kelp (Macrocystis and Laminaria), sea grasses (Halophila spp.)
Shrub	Scrub/Shrub	Areas dominated by shrubs less than 5 meters tall with shrub canopy typically greater than 20 percent of total vegetation. This class includes tree shrubs, young trees in an early successional stage, or trees stunted from environmental conditions. Characteristic species: scrub oak (Quercus beberidifolia), sagebrush (artemisia tridentate)
Wetland	Palustrine Forested, Scrub/Shrub and Emergent Wetland	Areas dominated by saturated soils and often standing water. Wetlands vegetation is adapted to withstand long-term immersion and saturated, oxygen-depleted soils. These are divided into two salinity regimes: Palustrine for freshwater wetlands and these are further divided into Forested, Shrub/Scrub, and Emergent wetlands.

Valuation Methodology

Since the 1940s, economists have been developing methods to place monetary value on the environment. One of the earliest instances was Hotelling's (1949) discussion on the value of parks as indicated by travel cost expenditures. The modern development of ecosystem services as a concept began with the "utilitarian framing" of ecosystem functions in the late 1970s, to demonstrate the importance of biodiversity conservation to human well being (Gomez-Baggethun *et al.,* 2010). Ecosystem services are generally defined as the benefits that people obtain from ecosystems. Ecosystem Service Valuation (ESV) achieved widespread mainstream interest following the publication of the Costanza *et al*. (1997) paper in Nature, which estimated the economic value of the world's ecosystem services at $33 trillion, almost double the value of global GNP at the time.

Ecosystem goods and services can be divided into two general categories: marketable and non-marketable goods and services. Measuring market values simply requires monitoring data for process and quantities sold. This production creates a flow of ecosystem goods that have a market-defined economic value over time. Some ecosystem services can be valued directly by using quantities and prices identified in a competitive market. Market analysis, in conjunction with factor input (initial input) or productivity analysis (end productive output) is useful in providing values in cases where services are priced by the market.

Non-market values of goods and services are difficult to measure. When there is no explicit market for services, more indirect means of assessing values must be used. Non-market measurement techniques can be further divided according to whether they measure use values, either for goods and services that are consumed or for goods and services. Bird watching is an example of this, where enjoyment does not involve "consumption" in the usual sense of the term, or non-use values, where there is no actual contact or encounter with the resource (Leschine *et al.,* 1997). The values associated with use are revealed through the behavior of individuals, while non-use values are such that economists tend to rely more on the stated preferences of individuals, such as can be established through surveys.

Economists may also use the results of previously completed resource valuation studies, conducted with any of the methods above, if there are enough similarities between cases to justify the inference that values obtained in one case also apply in another. This process is known as benefit transfer methodology (Leschine *et al.,* 1997). This thesis uses the benefit transfer methodology (BTM) for the values resulted in

Clallam County's ecosystem services. However, understanding the primary valuation methodologies is essential to understand the origin of the valuation process.

Table 3. Primary Valuation Methods-The valuation methods are separated into direct and indirect use values. With direct only a market price approach is used. Indirect uses include avoided cost, replacement cost, factor income, travel cost, hedonic pricing, contingent valuation and group valuation (Earth Economics, 1998).

Direct Use Values	
Market Price	Prices set in the marketplace appropriately reflect the value to the "marginal buyer." The price of a good tells us how much society would gain (or lose) if a little more (or less) of the good were made available. *Example: Rainforest products such as coffee and cacao.*
Indirect Use Values	
Avoided Cost	Value of costs avoided by ecosystem services that would have been incurred in the absence of those services. *Example: Hurricane protection provided by barrier islands avoids property damages along the coast.*
Replacement Cost	Cost of replacing ecosystem services with man-made systems. *Example: Natural water filtration replaced with costly man-made filtration plant.*
Factor Income	The enhancement of income by ecosystem service provision. *Example: Water quality improvements increase commercial fisheries catch and incomes of fishermen.*
Travel Cost	Cost of travel required to consume or enjoy ecosystem services. Travel costs can reflect the implied value of the service. *Example: Recreation areas attract tourists whose value placed on that area must be at least what they were willing to pay to travel to it.*
Hedonic Pricing	The reflection of service demand in the prices people will pay for associated goods. *Example: Housing prices along the coastline tend to exceed the prices of inland homes.*
Contingent Valuation	Value for service demand elicited by posing hypothetical scenarios that involve some valuation of land use alternatives. *Example: People would be willing to pay for increased preservation of beaches and shoreline.*
Group Valuation	Discourse-based contingent valuation, which is arrived at by bringing together a group of stakeholders to discuss values to depict society's willingness to pay. *Example: Government, citizen's groups, businesses come together to determine the value of an area and the services it provides.*

The valuation techniques that were used to derive the values in the database were developed within environmental and natural resource economics. These include market cost, avoided cost, replacement cost, factor income, travel cost, hedonic pricing, contingent valuation and group valuation. A short explanation of each technique is found in Table 3.

Benefit Transfer Methodology (BTM)

BTM provides a simple appraisal format that is inexpensive and can be performed quickly to affect decision-making. It involves obtaining an estimate for the value of ecosystem services through the analysis of a single study or group of studies that have been previously carried out to value similar goods or services in similar contexts. The "transfer" refers to the application of derived values and other information from the original study site to a new but sufficiently similar site (Brookshire and Neill, 1992; Desvousges *et al.,* 1992). As the *bedrock of practical policy analysis* (Desvouges *et al.,* 1998), BTM has gained popularity in the last several decades as decision-makers have sought timely and cost-effective ways to value ecosystem services and natural capital (Wilson and Hoehn, 2006).

Analysis using BTM estimates the economic value of a given ecosystem from prior studies of that ecosystem type. Like any economic analysis, this methodology has strengths and weaknesses. Limitations of BTM commonly cited include (from Batker *et al.*, 2010):

- Every ecosystem is unique, per-acre values derived from another location may be irrelevant to the ecosystems being studied.

- Even within a single ecosystem, the value per acre depends on the size of the ecosystem; in most cases, as the size decreases, the per acre value is expected to increase and vice versa.
- Gathering all the information needed to estimate the specific value for every ecosystem within the study area is not feasible. Therefore, the *true* value of all of the wetlands, forests, pasturelands, etc. in a large geographic area cannot be ascertained. In technical terms, we have far too few data points to construct a realistic demand curve or estimate a demand function.

Proponents of the above arguments often recommend an alternative valuation methodology that amounts to limiting valuation to a single ecosystem in a single location and only using data developed expressly for the unique ecosystem being studied. The size and landscape complexity of most ecosystems will make this approach to value extremely difficult, timely and costly. Oftentimes ecosystem assessments are needed within short time frames. In such cases primary valuations are not feasible due to expense and time limitations.

While every wetland, forest or other ecosystem is unique in some way, ecosystems of a given type, by their definition, have many things in common. The use of average values in ecosystem valuation is no more or less justified than their use in other macroeconomic contexts. An estimate of the aggregate value of a site's ecosystem services is a valid and useful basis for assessing and comparing these services with conventional economic goods and services.

As employed in most studies using BTM, the prior studies analyzed encompass a wide variety of time periods, geographic areas, investigators and analytic methods. Many of them provide a range of estimated values rather than single-point estimates.

As in any methodology there are many limitations and uncertainties. BTM as mentioned above provides effective values of ecosystem services in an efficient and quick manner. Other elements in this research may also have limitations. GIS data is frequently incomplete and imprecise, but today it is the best available science, therefore that is what is used. Other aspects that may vary and pose limitation to the overall research are:

- Increase in scarcity the economy is always changing;
- Values are not all inclusive, they do not include existing infrastructure for example;
- Incomplete study, not all ecosystem services that are present were valued;
- Study selection bias, studies were selected and not every study ever published was included;

BTM may have many limitations, but as an accepted economic methodology it also has many other benefits than the ones already discussed, more information on these may also be found in Appendix A.

Conclusion

The ecosystems present in Clallam County provide many benefits to residents. In identifying and analyzing these goods and services, an in depth knowledge of the study area is necessary. Every location is different and although natural resources throughout the world are similar, scarcity and abundance vary. An economic analysis not only identifies ecosystem services present but also values depending on necessity. The methodology used to value ecosystems will depend on human and financial resources and time. This thesis used BTM in valuing ecosystem services in Clallam County.

Chapter 5- Ecosystem Service Valuation: Clallam County

Identifying the ecosystem services present in Clallam County is the first step in order to estimate the value of these services. Working with Earth Economics, Clallam County's Department of Community Development, Washington State Department of Ecology, Coastal Watershed Institute, Washington State Department of Natural Resources, Peninsula College, and Friends of Dungeness Refuge this valuation was completed using Geographical Information Systems (GIS) land acreage. Not all ecosystem services are present in every land cover type.

An initial research goal is to determine the number ecosystem services present in Clallam County. The County was separated into land cover types determined by the GIS information provided by Clallam County Department of Planning. This study valued ecosystem services across 11 land cover types including: Agricultural lands, Beach, Estuary, Forest, Fresh Marsh, Grassland, Open Water, Pasture, Salt Marsh, Shrub, and Wetland (reference Table 2 on page 37). Depending on the primary values used, the presence of an ecosystem service across a specific land cover type is determined. Table 4 lists the land cover types in Clallam County (columns) and compares them with the ecosystem services evaluated in this study (rows). A total of 15 ecosystem services were valued: Aesthetic and Recreational, Biological Control, Disturbance Regulation, Erosion Control, Food Provision, Gas and Climate Regulation, Habitat and Nursery, Nutrient Cycling, Pollination, Raw Materials, Science and Education, Soil Formation, Waste Treatment, Water Regulation, and Water Supply.

Table 4. Ecosystem Services present in Clallam County. Ecosystem Services are categorized into present and valued; present but not valued and not present.

	Agricultural Land	Beach	Estuary	Forest	Fresh Marsh	Grassland	Open Water	Pasture	Salt Marsh	Shrub	Wetland
Aesthetic Recreational	X	X	X	X	X		X	X	X	X	X
Biological Control	X			X		X					
Disturbance Regulation	X	X		X	X		X				X
Erosion Control	X			X		X					
Food Provision			X			X	X				X
Gas and Climate Regulation	X			X	X	X	X		X	X	X
Habitat & Nursery			X	X			X		X	X	X
Nutrient Cycling	X		X	X			X		X		
Pollination	X			X		X		X			
Raw Materials				X	X						X
Science and Education				X						X	
Soil Formation	X					X		X			
Waste Treatment				X		X			X		X
Water Regulation				X		X					X
Water Supply			X	X	X		X				X

	Ecosystem service produced but not valued in this study
X	Ecosystem service produced and valued in this study
	Ecosystem service not produced by land cover type

Ecosystem services valued were determined by land cover types present in the County. Ecosystem services are categorized in the table as either produced by that land cover type and valued in this study; or produced by that land cover type but not valued in this study; or not produced by that land cover type. These categories help understand what values will be present in the economic analysis, as well as where these values originated. Many other ecosystem services may be present in Clallam County but because of limitations in primary studies used for BTM or inaccurate GIS data, they are not represented, analyzed nor valued. However, Table 4 illustrates in a quick manner the ecosystem services present and valued in this study, across the land cover types found in Clallam County.

A total of 15 ecosystem services were identified in Clallam County across 11 land covers. Valuation was possible in a range between 2 and 13 services on a given land cover, depending on the available studies with an economic value of an ecosystem service. Table 4 suggests that because a large number of ecosystem services (for most land covers) have yet to be valued in a primary study, this valuation provides a significant underestimate of the true value. As further primary studies are added to the database, the known value of ecosystem services in Clallam County will change.

Annual Value of Clallam County

The preliminary ecosystem service values for Clallam County were converted to 2010 US dollars per acre per year, representing the annual flow of value generated by a single ecosystem. Combining all the available ecosystem services for one land cover yield a total value in dollars per acre per year. For example, one peer reviewed scientific paper valued gas and climate regulation in agricultural land to have a minimum of $11.02

and maximum of $128.16 per acre per year. The low and high value, independently, is then combined with other values of ecosystem services present in agricultural land to produce a total low and high worth of that land cover type in Clallam County.

Tables 5-8 provide minimum and maximum valuation results per acre by land cover type. All values are adjusted for inflation dividing a monetary time series by a price index such as the Consumer Price Index determined by U.S. Department of Labor, Bureau of Labor Statistics, 2010.

Values are presented in a range. The range may vary in a large and small difference and this depends solely on the values used from primary sources, since these sources can vary in year and location of study, the values for a certain ecosystem service in a specific land cover type may also vary significantly. Even though the range may be wide, it is a better representation of the value of ecosystem services than a single number.

Table 5. Minimum and maximum $ value for agricultural land, beach, and estuary.

	Agricultural Land		Beach		Estuary	
Ecosystem Services	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
Aesthetic and Recreational	$2.06	$29.63	$151.06	$2,846.69	$5.76	$30.92
Biological Control	$14.18	$14.18				
Disturbance Regulation	$2.10	$2.10				
Erosion Control	$5.82	$5.82				
Food Provision					$21.70	$963.03
Gas and Climate Regulation	$11.02	$128.16				
Habitat Refugium and Nursery					$23.90	$2,001.04
Nutrient Cycling	$8.80	$22.32			$77.19	$7,710.95
Pollination	$2.59	$427.34				
Raw Materials						
Science and Education						
Soil Formation	$2.27	$5.82				
Waste Treatment						
Water Regulation						
Water Supply					$6.36	$24.32
Total	$48.84	$635.38	$151.06	$2,846.69	$134.90	$10,730.25

Table 6. Minimum and Maximum $ value for forest, fresh marsh, and grasslands

	Forest		Fresh Marsh		Grassland	
Ecosystem Services	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
Aesthetic and Recreational	$0.21	$2,174.80	$94.63	$863.50		
Biological Control	$9.69	$10.04			$13.09	$13.64
Disturbance Regulation	$1.40	$5.14	$2,051.93	$2,051.93		
Erosion Control	$112.58	$112.58			$17.94	$17.94
Food Provision					$33.02	$33.02
Gas and Climate Regulation	$14.55	$1,066.61	$47.10	$512.74	$0.08	$219.92
Habitat Refugium and Nursery	$1.22	$538.95				
Nutrient Cycling	$74.28	$1,135.64				
Pollination	$67.84	$413.73			$14.48	$427.34
Raw Materials	$1.87	$1.87	$6.37	$7.21		
Science and Education	$39.72	$68.37				
Soil Formation					$0.67	$0.67
Waste Treatment	$169.01	$169.01			$51.62	$51.62
Water Regulation	$10.35	$588.57			$1.59	$4.11
Water Supply	$1,395.98	$1,770.14	$62.56	$166.84		
Total	$1,898.70	$8,055.45	$2,262.60	$3,602.22	$132.48	$768.25

Table 7. Minimum and Maximum $ value for open water, pasture, and salt marsh

	Open Water		Pasture		Salt Marsh	
Ecosystem Services	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
Aesthetic and Recreational	$4.08	$2,475.18	$0.03	$0.03	$22.46	$203.28
Biological Control						
Disturbance Regulation	$8.15	$253.97				
Erosion Control						
Food Provision	$8.93	$24.40				
Gas and Climate Regulation	$0.35	$990.00			$4.46	$636.77
Habitat Refugium and Nursery	$0.55	$317.20			$6.78	$10,532.22
Nutrient Cycling	$36.92	$103.61				
Pollination			$2.60	$13.09		
Raw Materials						
Science and Education						
Soil Formation			$6.70	$6.70		
Waste Treatment					$118.28	$19,041.56
Water Regulation						
Water Supply	$5.16	$2,268.02				
Total	$64.14	$6,432.38	$9.33	$19.82	$151.97	$30,413.84

Table 8. Minimum and Maximum $ value for shrub and wetland

	Shrub		Wetland	
Ecosystem Services	**Min**	**Max**	**Min**	**Max**
Aesthetic and Recreational	$0.19	$2,174.80	$1.67	$4,641.41
Biological Control				
Disturbance Regulation			$18.35	$8,578.76
Erosion Control				
Food Provision			$65.71	$9,372.90
Gas and Climate Regulation	$6.68	$193.97	$1.79	$774.40
Habitat Refugium and Nursery	$1.33	$538.95	$99.76	$8,679.32
Nutrient Cycling				
Pollination				
Raw Materials			$2,816.44	$2,816.44
Science and Education	$39.72	$68.37		
Soil Formation				
Waste Treatment			$76.39	$435.98
Water Regulation			$148.48	$2,914.64
Water Supply			$10.01	$4,289.38
Total	$47.92	$2,976.10	$3,238.60	$42,503.23

Table 9. Total annual value in ecosystem services per acre and total annual values multiplied by acres present in Clallam County for each land cover type.

Land-cover Description	Acres	Low/acre	High/acre	Low/total acre	High/total acre
Agricultural lands	916	$49	$635	$44,735	$582,006
Beach	4,455	$151	$2,847	$672,974	$12,682,007
Estuary	916	$135	$10,730	$123,568	$9,828,913
Forest	859,741	$1,899	$8,055	$1,632,394,394	$6,925,599,844
Fresh Marsh	9	$2,263	$3,602	$20,363	$32,420
Grassland	31,703	$132	$768	$4,200,095	$24,355,975
Open Water	594,258	$64	$6,432	$38,117,949	$3,822,493,138
Pasture	22,675	$9	$20	$211,579	$449,508
Salt Marsh	1,306	$152	$30,414	$198,474	$39,720,471
Shrub	130,245	$48	$2,976	$6,241,332	$387,621,757
Wetland	26,353	$3,239	$42,503	$85,346,852	$1,120,087,585
Total	**1,672,577**			**$1,767,572,316**	**$12,343,453,624**

The combined ecosystem service values for each land cover were summed and the total value of that land cover type per acre per year is represented in Table 9, along with the number of acres of each land cover type present in Clallam County.

This baseline appraisal offers values for the benefits provided by nature in Clallam County annually. These valued services contribute in a number of ways: protection from storms both erosion and flood prevention, regulation of climate and gas emissions, provisioning food and pollination, sustaining habitat and soil formation, among other processes. Based on a total of 15 ecosystem services, Clallam County's ecosystem services contribute roughly $1 billion to $12 billion a year to the local and regional economy, in 2010 US dollars.

This total value of ecosystem services in Clallam County represents social, environmental and economic benefits to the County's residents. Defining and quantifying the County's natural capital is an important tool to inform public policy, including local land use planning. It also supports those efforts, which must incorporate state-mandated goals, and standards that involve protection and enhancement of water quality and important natural resources, and other quality of life factors.

In Clallam County, these values can be used to inform the update on their Shoreline Master Plan (SMP). This state mandated requirement obliges Counties to protect their shorelines at the standard of No Net Loss of ecosystem function, explained in Chapter 3. In Clallam County, fragile ecosystems such as shorelines are managed and protected under state law. Decisions by the County and the public on the level of protection to provide these ecosystems will determine the County's future sustainability and quality of life. Decisions could involve choices between development or conservation on the more ecologically important lands, and how development can occur in areas that are less important to avoid endangering these unique landscapes. Shorelines in Clallam County produce a number of ecosystem services that contribute between $670,000 and $12 million annually to the regional economy (as stated in Table 9). Regulatory efforts such as the SMP and Inventory Characterization Report (ICR) provide the opportunity to conserve larger areas of fragile ecosystems and produce noticeable economic benefits to County residents.

Total annual numbers can be used to inform the value of entire ecosystems or a specific land cover type or an individual ecosystem service. The ability to value one or many aspects of a region can inform management decisions and influence the creation or update of local policies, enabling prioritization of environmental issues.

Asset Value of Clallam County

An ecosystem produces a flow of valuable services across time, much like traditional capital assets. As long as the natural infrastructure of the present ecosystems are not degraded or depleted, this flow of value will likely continue into the future. This analogy can be extended by calculating the net present value of the future flows of ecosystem services, just as the asset value of a capital asset (infrastructure) can be calculated as the net present value of its future benefits. This calculation is no more than an economic exercise however, because in reality ecosystems are not bought and sold in this manner; its usefulness is to demonstrate their long-term economic worth.

Calculating the net present value of an asset requires the use of a discount rate. The net present value of Clallam County was calculated using two discount rates: nominal and 4%. Using a nominal rate assumes the regenerating nature of natural capital and, if maintained, people in the future will benefit from the same amount and quality of services as we enjoy currently. The 4% discount rate is established by the Army Corps of Engineers used in large projects, which discounts the value of benefits by 4% every year into the future. Discounting can be adjusted for different types of assets and is designed to control for the following:

- Pure time preference of money. This is the rate at which people value what they can have now, compared with putting off consumption or income until later.
- Opportunity cost of investment. A dollar in one year's time has a present value of less than a dollar today, because a dollar today can be invested for a return in one year.
- Depreciation. Built assets such as cars and levees tend to deteriorate and lose value due to wear and tear.

Using a discount rate assumes many things, for one, discounting assumes that the benefits humans enjoy in the present are more valuable than the benefits in future generations. Using a nominal rate in this thesis adds to the discussion that natural capital assets should apply lower discount rates than built capital assets because they tend to appreciate over time, rather than depreciate. Both natural and built capital assets are important to maintain a high quality of life, but each operates on a different time scale. For these reasons, a nominal discount rate best reflects the asset value of Clallam County's ecosystem services.

Calculations of the present value of the flow of ecosystem services demonstrate that intact natural systems provide enormous economic value to society in the short and long term. The present generation receives a relatively small amount of the total value provided by these services. If a total conservation of ecosystems is achieved in the present, future generations will receive huge economic benefits from healthy functioning ecosystems that have been accumulating over time. For Clallam County the net present value analysis over a 50-year period is in table 10.

More detailed information on the primary studies used in this benefit transfer are listed in Appendix B, they describe the land cover type, ecosystem service, reference of papers used in this study and the lowest and highest values known for each value utilized in this study. There is also a single value column where low and high values do not exist. More detail on study limitations and methodology used are explained in Appendix A.

Table 10. Net present value with a nominal and 4% discount rates over 50 years. This value attempts to demonstrate the value of services present in Clallam County in the future.

Discount Rate	Low Estimate	High Estimate	Mid point
Nominal (50 years)	$88,378,615,779	$617,172,681,182	$352,775,648,481
4% (50 years)	$37,971,314,807	$265,164,349,550	$151,567,832,179

Net present values are based on the assumption of today's economy, which can change significantly over time. The values in Table 10 suggest that natural capital, if maintained and conserved, could appreciate over time assuming a constant flow throughout the years. Also, using a 4% discount rate demonstrates that ecosystem services in 50 years, even with depreciation, are valued in billions of dollars. Similar to the asset values presented in Table 9, net present values could be used to inform current and future decisions concerning overall environmental health of ecosystems.

Conclusion

Ecosystem service valuation is primarily a communication tool. The values resulting from an economic analysis can be refined and used to compare with county and statewide expenditures, benefit cost analysis, job analysis, green infrastructure investments, funding mechanisms, and many more. The values determined by ESV, although a broad range, address the current initial problem, zero value for ecosystem services. Identifying and quantifying services present in an area is the first step for ecosystem conservation and protection.

Chapter 6- Conclusions and Future Suggestions

In order to achieve complete conservation an interdisciplinary approach is necessary. Economics must have a part in this process and it must be integral to societal needs, while still maintaining an ecological balance. An ecosystem produces a flow of valuable services across time, much like a traditional capital asset. As long as the ecosystems are maintained in their current state, the flow produced currently is likely continue into the future.

Overall Conclusions

The thesis explores different aspects of the relationship between economy and ecology. Conserving the environment has become an interdisciplinary effort. In conserving the environment habits have to change and society as a whole has to evolve. The transition of becoming a more conscientious community is bolstered by understanding the connection between environmental science to the rest of the sciences. Economics plays a significant role in ecosystem conservation.

Although there are many aspects of economics that are dependent on the environment, this thesis focuses on valuing services provided by ecosystems, also known as natural capital. Understanding the concept of natural capital entails comprehending the invaluable aspect of nature. Natural ecosystems are so complex that a complete valuation is not possible, but partial and baseline values serve the purpose of honing attention on environmental aspects that are typically overseen by current economic measurements.

This case study provides a baseline appraisal valuation of ecosystem services present in Clallam County, by quantifying the economic value of natural capital. Ecosystem services in Clallam County provide food, water, storm and flood protection, carbon intake, aesthetic beauty and recreational areas, and many more services. These services contribute approximately between $1 billion to $12 billion every year to the local economy. Land appraisal in Clallam County is estimated at 7.5 billion per year. This land property value includes land, improvement to land, structures and certain equipment affixed to structure; however it does not include the value of ecosystem services.

Ecosystem services can also be treated as assets, and their value over time can be calculated. Similar to built infrastructure, nature provides natural infrastructure that provides goods and services. These benefits over time are calculated using discount rates. Applying a 4% discount rate over 50 years, the net present value of ecosystem services in Clallam County has an asset value of between $37 billion to $265 billion dollars. This appraisal values are defendable and applicable to decision-making at every jurisdictional level. Investments many times require future assessments in value. The net present value in this thesis attempts to produce a number that can be reflected upon in 50 years. Cities, counties and states are increasingly dealing with land management conflicts and as urban areas grow, ecosystems may become threatened. The solution should be inclusive of new development, stipulating requirements and mitigation efforts in response to impacts that development activities cause.

Discovering and measuring the value of natural capital in Clallam County is essential to enhance effective and efficient natural resource management. The creation of macroeconomic measures in the 1930s, such as measures for the Gross Domestic Product now the Gross National Product, unemployment and inflation, transformed the United States because these measures enabled better economic decision-making. Built capital was scarce, and economic measures of built capital were essential to building a prosperous 20th century economy. Virtually all countries now utilize the same set of macroeconomic measures. Today, basing the country's economy on the ability to build capital might not be a complete representation of a country's wealth.

Valuation of natural benefits leads to their protection and provides measures to influence policy development and decision-making. While this thesis provides a valuation of ecosystem services in the County, it is only a first step in the process of developing policies, measures and indicators that support discussions about the tradeoffs in investments of public and private money that ultimately shape the regional economy for generations to come.

The values found in this case study will be used to inform local county environmental management policies. These legislative documents, as mentioned before, are required to be updated by the state every eight years. The economic value of Clallam's ecosystem services can be integrated into the Shoreline Master Program and specifically into the No Net Loss policy. The manner in which these values will help explain the value of conserving natural assets is still to be determined. An ongoing separate project in Clallam County will also provide primary valuations that will result in an economic value specific to the area and case study. These values will quantify fish abundance, invertebrate population, and feeder bluff erosion. The results of this scientific research and the economic analysis will produce a primary nearshore valuation for Clallam County.

Economic sustainability relies on a healthy, functioning environment. The loss of nature's bounties has monetary costs. Maintaining the health of ecosystems provide benefits for everyone. As demonstrated by this case study the different land cover types in Clallam provide goods and services across time and well beyond their boundaries. Conserving and protecting Clallam County's natural assets is critical to improving quality of life and securing sustainability, justice, and economic progress in the region.

Ecological economics provides essential tools to quantify natural capital and include ecosystem services into economic progress. Development will always be present, but conservation and preservation efforts can mitigate negative outcomes. Knowledge about environmental processes, what they provide, and quantifying their value is the first step in taking a holistic approach to manage natural resources while sustaining quality of life.

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Appendix A: Study Limitations

Other General Limitations of BTM

Increases in Scarcity- The original primary valuations may underestimate shifts in the relevant demand curves as the sources of ecosystem services become more limited. The values of many ecological services rapidly increase as they become increasingly scarce (Boumans *et al.,* 2002). If the ecosystem services of a study site are scarcer than assumed, their value will have been underestimated in this study. Such reductions in "supply" appear likely as land conversion and development proceed; climate change may also adversely affect the ecosystems, although the precise impacts are more difficult to predict.

Existence Value- The approach of BTM does not fully include the infrastructure or existence value of ecosystems. It is well known that people value the existence of certain ecosystems, even if they never plan to use or benefit from them in any direct way. Estimates of existence value are rare; including this service will obviously increase the total value of a study site.

Other Non-Economic Values- Economic and existence values are not the sole decision-making criteria. Techniques called multi-criteria decision analysis are available to formally incorporate economic values with other social and policy concerns. Having economic information on ecosystem services usually helps this process because traditionally, only opportunity costs of foregoing development or exploitation are counted against non-quantified environmental concerns.

Incomplete coverage- That not all types of ecosystems have been valued or studied well is perhaps the most serious issue, because it results in a significant underestimate of the value of ecosystem services. More complete coverage would almost certainly increase the values in a study, since no known valuation studies have reported estimated values of zero or less.

Selection Bias- Bias can be introduced in choosing the valuation studies, as in any appraisal methodology. The use of a range partially mitigates this problem.

Consumer Surplus- Because the benefit transfer method is based on average rather than marginal cost, it cannot provide estimates of consumer surplus. However, this means that valuations based on averages are more likely to underestimate total value.

Willingness-to-pay Limitations- Most value estimates in BTM datasets are based on current willingness to pay or proxies, which are limited by people's perceptions and knowledge. Improving people's knowledge about the contributions of ecosystem services to their welfare would almost certainly increase the values based on willingness to pay, as people would realize that ecosystems provided more services than they had previously known.

Price Distortions- Distortions in the current prices used to estimate ecosystem service values are carried through the analysis. These prices do not reflect environmental externalities and are therefore again likely to be underestimates of true values.

Non-linear/Threshold Effects- The valuations assume smooth responses to changes in ecosystem quantity with no thresholds or discontinuities. Assuming that such gaps or jumps in the demand curve would move demand to higher levels than a smooth curve, the presence of thresholds or discontinuities would likely produce higher values for affected services (Limburg *et al.,* 2002). Further, if a critical threshold is passed, valuation may leave the normal sphere of marginal change and larger-scale social and ethical considerations dominate, such as an endangered species listing.

Sustainable Use Levels- The value estimates of a BTM analysis are not necessarily based on sustainable use levels. Limiting use to sustainable levels would imply higher values for ecosystem services as the effective supply of such services is reduced.

Technical issues surrounding BTM also apply to primary studies, but are important to note:

GIS Data- Since this valuation approach involves using benefits transfer methods to assign values to land cover types based, in some cases, on their contextual surroundings, one of the most important issues with GIS quality assurance is reliability of the land cover maps used in the benefits transfer, both in terms of categorical precision and accuracy. The source GIS layers are assumed to be accurate but may contain minor inaccuracies due to land use change since the data was sourced, inaccurate satellite readings and other factors.

Ecosystem Health- There is the potential that ecosystems identified in the GIS analysis are fully functioning to the point where they are delivering higher values than those assumed in the original primary studies, which would result in an underestimate of current value. On the other hand, if ecosystems are less healthy than those in primary studies, this valuation will overestimate current value.

Spatial Effects- ESV using BTM assumes spatial homogeneity of services within ecosystems, i.e. that every acre of forest produces the same ecosystem services. This is clearly not the case. Whether this would increase or decrease valuations depends on the spatial patterns and services involved. Spatial dynamic analysis would be required to answer such questions. More elaborate systems dynamics studies of ecosystem services have shown that including interdependencies and dynamics leads to significantly higher values (Boumans *et al.,* 2002), as changes in ecosystem service levels ripple throughout the economy.

Potential Benefits of Conducting an ESV using Benefit Transfer Methodology

BTM Justifies Investment in Natural Capital- The outcome of estimating ecosystem services is to provide a better valuation than the implicit value of zero or infinity. What is not valued is often lost, and the advantage of a valued asset is that a sufficient budget for its operations and maintenance can be justified. A valuation of a natural asset may also enable or facilitate borrowing against the asset.

BTM Can be Used to Develop Funding Mechanisms- Identification, valuation and mapping of ecosystem services is used to develop sustainable, fair and efficient funding mechanisms for maintenance and restoration of natural capital, linking (often upstream) ecosystem service provisioners with (often downstream) ecosystem service users. Funding mechanisms can be developed based on the physical nature of the ecosystem service, and can include tax districts, payments for ecosystem services (PES), tradable credits, and fees and surcharges.

BTM Helps to Educate the Public- Providing transparent information to stakeholders is crucial to the operations of any public or private enterprise. In the case of a public utility for example, an ESV provides information to the public on the (often tremendous) asset value of their watershed. This provides an economic case for why the utility should continue to invest in the asset. Understanding the value of their shared asset, the public may also take greater interest in enjoying and enhancing the services it provides.

BTM Helps To Educate Decision Makers- An ESV captures the attention of decision-makers and helps to strengthen and communicate other important ecosystem service concepts, for example that natural capital tends to appreciate while built capital tends to depreciate. Ecosystem services concepts also provide a common language and framework in which to understand the contributions of green infrastructure to the economy (local, regional and national) and on quality of life, facilitating a conversation between policymakers, business, scientists, landowners and other stakeholders.

BTM is Cost Effective and Timely- A primary study generally looks at one or a few ecosystem services and takes up to two years, costing upwards of $100,000. A benefit transfer can now be completed in less than six weeks currently, assessing up to 23 ecosystem services, and at a fraction of the cost.

BTM Produces Defensible Results- The low valuation boundary is likely an underestimate of actual value, but can demonstrate that ecological services in an area are worth at least a certain dollar amount, which is usually sufficient to inform policy decisions such as restoring or maintaining those systems. A range of values also captures the uncertainty that is inherent in both ecology and economics. Economic values are volatile and decision-makers are accustomed to this, and like ESV, economic values are often presented in an appraisal format.

BTM shows Proven Results- ESV demonstrate the multiple benefits of ecosystems. They get the attention of decision-makers and move them more quickly toward conservation investments and permanent funding mechanisms for conservation.

Appendix B. Value Transfer Studies Used by Land Cover

			Data	
Land Cover	Ecosystem Service	Author(s)	Min	Max
Agricultural Lands	Biological Control	Wilson, S. J.	$14.18	$14.18
	Disturbance Regulation	Wilson, S. J.	$2.10	$2.10
	Erosion Control	Canadian Urban Institute.	$5.82	$5.82
	Nutrient Cycling	Canadian Urban Institute.	$22.32	$22.32
		Wilson, S. J.	$8.80	$8.80
	Pollination	Southwick, E. E. and Southwick, L.	$2.59	$2.59
		Wilson, S. J.	$427.34	$427.34
		Robinson, W. S., et al.	$13.04	$13.04
	Soil Formation	Canadian Urban Institute.	$5.82	$5.82
		Wilson, S. J.	$2.27	$2.27
		Sandhu, H.S., et al.	$5.82	$5.82
	Gas and Climate Regulation	Smith, W.N. et al.	$28.15	$28.15
		Wilson, S. J.	$11.02	$128.16
	Aesthetic and Recreational	Bergstrom, J., Dillman, B. L. and Stoll, J. R.	$29.63	$29.63
		Knoche and Lupi	$2.06	$4.78
Beach	Aesthetic and Recreational	Taylor, L. O. and Smith, V. K.	$451.00	$451.00
		Bell, F.W. and Leeworthy, V.R.	$2,571.82	$2,846.69
		Fankhauser, S. and Pearce, D.W.	$151.06	$151.06
Estuary	Nutrient Cycling	Newell et al.	$77.19	$77.19
		Costanza, R., et al.	$7,710.95	$7,710.95
	Water Supply	Whitehead, J. C., et al.	$6.36	$24.32
	Aesthetic and Recreational	Whitehead, J. C., et al.	$5.76	$30.92
	Habitat Refugium and Nursery	Farber, S. and Costanza, R.	$188.28	$2,001.04
		Armstrong	$23.90	$133.81
		De Groot, R.S.	$124.21	$124.21
	Food Provision	Costanza, R., et al.	$21.70	$963.03
Forest	Biological Control	Krieger, D.J.	$9.69	$9.69
		Wilson, S. J.	$10.04	$10.04
	Disturbance Regulation	Dodds, W.K., et al.	$1.40	$5.14
	Erosion Control	Dodds, W.K., et al.	$112.58	$112.58
	Nutrient Cycling	Dodds, W.K., et al.	$74.28	$1,135.64
	Pollination	Hougner, C.	$67.84	$304.71
		Wilson, S. J.	$191.49	$413.73
	Raw Materials	Dodds, W.K., et al.	$1.87	$1.87
	Waste Treatment	Wilson, S. J.	$169.01	$169.01
	Water Regulation	Olewiler, N.	$31.53	$31.53
		Loomis J.B.	$10.35	$10.35
		Wilson, S. J.	$588.57	$588.57
	Water Supply	Ribaudo, M. and Epp, D. J.	$1,395.98	$1,770.14
	Science and Education	Bishop, K.	$39.72	$68.37
	Gas and Climate Regulation	local estimate	$67.15	$1,066.61
		Pimentel et al.	$15.39	$15.39
		Mates. W., Reyes, J.	$57.52	$253.97
		Wilson, S. J.	$14.55	$637.67
	Aesthetic and Recreational	Bennett, R., et al.	$182.22	$182.22
		Bishop, K.	$1,940.39	$2,174.80

		Maxwell, S.	$12.69	$12.69
		Prince, R. and Ahmed, E.	$2.19	$2.80
		Willis, K. G. and Garrod, G. D.	$4.04	$4.04
		Willis, K.G.	$.42	$205.41
		Knowler, D. J. et al.	$30.57	$30.57
		Shafer, E. L., et al.	$112.25	$580.70
		Boxall, P. C., et al.	$.21	$.21
	Habitat Refugium and Nursery	Amigues, J. P., et al.	$73.92	$282.41
		Haener, M. K. and Adamowicz, W. L.	$1.52	$10.42
		Kenyon, W. and Nevin, C.	$538.95	$538.95
		Shafer, E. L. et al.	$2.98	$2.98
		Garber et al.	$290.73	$487.59
		Wilson, S. J.	$1.22	$1.22
Fresh Marsh	Disturbance Regulation	Roel/Ken	$2,051.93	$2,051.93
	Raw Materials	Roel/Ken	$6.37	$7.21
	Water Supply	Roel/Ken	$62.56	$166.84
	Gas and Climate Regulation	Roel/Ken	$47.10	$512.74
	Aesthetic and Recreational	Gund Database	$94.63	$302.68
		Roel/Ken	$275.78	$863.50
Grasslands	Biological Control	Pimentel et al.	$13.09	$13.64
	Erosion Control	Costanza, R., et al.	$17.94	$17.94
	Pollination	Pimentel et al.	$14.48	$14.84
		Wilson, S. J.	$427.34	$427.34
	Soil Formation	Sala, O.E., Paruelo. F.M.	$.67	$.67
	Waste Treatment	Pimentel et al.	$51.62	$51.62
	Water Regulation	Jones et al.	$4.11	$4.11
		Costanza, R., et al.	$1.59	$1.59
	Gas and Climate Regulation	Copeland et al.	$.08	$.08
		Wilson, S. J.	$10.62	$168.80
		Costanza, R., et al.	$3.85	
		Fankhauser, S. and Pearce, D.W.	$5.61	$5.61
		Salas OE and Paruelo JM	$87.97	$219.92
	Food Provision	Tyrvainen, L.	$33.02	$33.02
Open Water	Disturbance Regulation	Rein, F. A.	$8.15	$253.97
	Nutrient Cycling	Costanza, R., et al.	$36.92	$103.61
	Water Supply	Bouwes, N. W. and Scheider, R.	$665.24	$665.24
		Gramlich, F. W.	$221.01	$221.01
		Henry, R., Ley, R. and Welle, P.	$462.52	$462.52
		Ribaudo, M. and Epp, D. J.	$908.71	$908.71
		Rich, P. R. and Moffitt, L. J.	$5.16	$5.16
		Berrens, R. P., et al.	$2,268.02	$2,268.02
		Croke, K., et al.	$609.70	$609.70
	Gas and Climate Regulation	local estimate	$99.00	$990.00
		Costanza, R., et al.	$.35	$45.24
	Aesthetic and Recreational	Burt, O. R. and Brewer, D.	$497.56	$497.56
		Cordell, H. K. and Bergstrom, J. C.	$204.35	$858.14
		Kahn, J. R. and Buerger, R. B.	$4.08	$4.08
		Kealy, M. J. and Bishop, R. C.	$13.93	$13.93
		Piper, S.	$258.79	$258.79
		Shafer, E. L. et al.	$95.64	$1,186.64
		Young, C. E. and Shortle, J. S.	$88.18	$88.18

		Sanders, L. D., et al.	$2,475.18	$2,475.18
		Ward, F. A., et al.	$20.14	$2,067.09
	Habitat Refugium and Nursery	Kahn, J. R. and Buerger, R. B.	$2.33	$18.74
		Loomis J.B.	$17.13	$17.13
		Knowler, D. J. et al.	$11.24	$51.50
		Knowler, D.J., et al.	$.55	$2.95
		Streiner, C., Loomis, J.	$317.20	$317.20
	Food Provision	Costanza, R., et al.	$8.93	$24.40
		Postel and Carpenter	$22.54	$22.54
Pasture	Pollination	Costanza, R., et al.	$2.60	$13.09
	Soil Formation	Pimentel et al.	$6.70	$6.70
	Aesthetic and Recreational	Boxall, P. C.	$.03	$.03
Salt Marsh	Waste Treatment	Breaux, A., et al.	$118.28	$19,041.56
	Gas and Climate Regulation	Roel/Ken	$32.01	$348.48
		Stern and Boscolo	$4.46	$636.77
	Aesthetic and Recreational	Anderson, G. D. and Edwards, S. F.	$22.46	$203.28
	Habitat Refugium and Nursery	Batie, S. S. and Wilson, J. R.	$6.78	$848.14
		Johnston, R. J. et al.	$1,523.82	$1,523.82
		Mazzotta, M.	$10,532.22	$10,532.22
Shrub	Science and Education	Bishop, K.	$39.72	$68.37
	Gas and Climate Regulation	local estimate	$6.68	$193.97
	Aesthetic and Recreational	Bennett, R., et al.	$182.22	$182.22
		Bishop, K.	$1,940.39	$2,174.80
		Haener, M. K. and Adamowicz, W. L.	$.22	$.22
		Maxwell, S.	$12.69	$12.69
		Prince, R. and Ahmed, E.	$1.61	$2.01
		Willis, K.G.	$.45	$205.41
		Shafer, E. L., et al.	$580.70	$580.70
		Boxall, P. C., et al.	$.19	$.19
	Habitat Refugium and Nursery	Haener, M. K. and Adamowicz, W. L.	$1.33	$9.11
		Kenyon, W. and Nevin, C.	$538.95	$538.95
		Shafer, E. L. et al.	$3.21	$3.21
Wetland	Disturbance Regulation	Roel/Ken	$1,394.58	$1,394.58
		Leshcine et al.	$362.73	$2,366.79
		Wilson, S. J.	$560.43	$560.43
		Costanza, R., et al.	$280.89	$280.89
		Woodward, R., and Wui, Y.	$18.35	$8,578.76
	Raw Materials	Dodds, W.K., et al.	$2,816.44	$2,816.44
	Waste Treatment	Pate, J. and Loomis, J.	$76.39	$344.14
		Olewiler, N.	$155.17	$435.98
	Water Regulation	Woodward, R., and Wui, Y.	$148.48	$2,914.64
	Water Supply	Creel, M. and Loomis, J.	$584.64	$584.64
		Roel/Ken	$42.52	$113.39
		Hayes, K. M., et al.	$1,387.49	$2,156.77
		Wilson, S. J.		
		Brouwer, R., et al.	$21.77	$53.15
		Woodward, R., and Wui, Y.	$10.01	$4,289.38
	Gas and Climate Regulation	Roel calculation for LA	$43.30	$393.49
		Roel/Ken	$48.02	$774.40
		Wilson, S. J.	$1.79	$186.47

		Costanza, R., et al.	$178.88	$178.88
	Aesthetic and Recreational	Roel/Ken	$187.43	$586.87
		Whitehead, J. C.	$1,027.44	$2,262.93
		Hicks et al.	$157.32	$157.32
		Wilson, S. J.	$129.11	$129.11
		Cooper J. and Loomis, J.	$327.15	$1,284.80
		Costanza, R., et al.	$100.71	$396.27
		Whitehead, J. C., et al.	$237.71	$237.71
		Woodward, R., and Wui, Y.	$1.67	$4,641.41
	Habitat Refugium and Nursery	Pate, J. and Loomis, J.	$99.76	$317.15
		Mazzotta, M.	$8,679.32	$8,679.32
		Wilson, S. J.	$739.50	$739.50
		Kazmierczak, R.F.	$273.67	$530.31
		Streiner, C., Loomis, J.	$243.61	$243.61
		Woodward, R., and Wui, Y.	$158.50	$510.52
	Food Provision	Roel/Ken (for low value); Woodward and Wui, (for high value)	$65.71	$1,518.75
		Woodward, R., and Wui, Y.	$180.18	$9,372.90