NATURE'S VALUE IN THE SALISH SEA

NON-MARKET BENEFITS AND HUMAN WELLBEING

2022

EARTH ECONOMICS

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EARTH ECONOMICS

Executive Summary

The lands and waters of the Salish Sea Basin provide critical direct and indirect support for people's livelihoods and well-being. A source of food production, employment, disaster risk reduction, and recreational opportunities, the basin also provides indirect benefits such as water and air filtration, fish and wildlife habitat, and more. Yet these ecosystems—and the benefits they provide to people—are threatened by pollution, development pressures, and unsustainable land management.

To help stakeholders appreciate the value of protecting and restoring the Salish Sea, Earth Economics estimated the economic benefits that the basin's ecosystems provide to humans—known as *ecosystem goods and services*. When natural capital and ecosystem services are not quantified, they are effectively valued at zero in the decision-making process. This gap leads to inefficient investments based on incomplete information that translates to higher future costs and poor asset management strategies. Furthermore, when ecosystems are threatened with degradation (as the ecosystems of the Salish Sea are), we often fail to account for the indirect values of ecosystem goods and services that nature provides at no cost to society and must then replace them with more costly built alternatives.

Time is of the essence in addressing the problems the Sea faces: by using an accepted economic methodology[1] called benefit transfer method, estimates can be generated in a fraction of the time it would take to conduct a primary valuation study. Combining the extensive valuation literature with geospatial tools and the benefit transfer method allowed us to obtain a precise range of values for 47 ecosystem service-landcover combinations throughout the terrestrial and aquatic ecosystems of the greater basin.

The Salish Sea Basin provides an estimated US $124 billion in ecosystem services every year. Over a fifth of that value (22 percent) comes from water quality-related services, underscoring the need to protect both the Salish Sea and contributing inland watersheds. Water quality-related services include soil retention; water capture, conveyance, and supply; water quality (e.g., filtration); and water storage.

The values in this report reveal the breadth and magnitude of the economic benefits provided by ecosystem services in the Basin. The results offer a broad sense for and better understanding of the economic importance of these lands and waters, showing there are significant benefits to restoring natural capital in the Salish Sea. Proper consideration of ecosystem service values ultimately strengthens decision-making. Supported by the Environmental Protection Agency, Department of Ecology, and Puget Sound Partnership, this report should support stakeholders and decision makers in advancing cross-boundary solutions for an ecosystem in crisis.

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Introduction

The lands and waters of the Salish Sea Basin provide humans with multiple benefits (water and air filtration, disaster risk reduction, aesthetic beauty, and recreational opportunities, etc.) that can be quantified in economic terms. Yet these ecosystems are also threatened by development pressures, pollution, and unsustainable land management. To help stakeholders appreciate the value of protecting and restoring the Salish Sea, Earth Economics conducted an aquatic- and landcover-based Ecosystem Services Valuation (ESV) of the non-market value provided by ecosystems throughout the basin.

The Salish Sea Basin Background

The Salish Sea Basin spans from Olympia, Washington to Mt. Waddington, British Columbia, and from Neah Bay to the Cascade Range. The Salish Sea has only been recognized as one ecosystem relatively recently – the term first emerged in 1988 to describe U.S. and Canadian waterways, including the Puget Sound, Strait of Georgia, and Juan de Fuca ecosystems.

The sea gets its name from the Coast Salish peoples, the culturally diverse indigenous residents who inhabited the region for over 10,000 years.[2] Today, the basin remains rich with life, home to over eight million people and 3,400 marine species—including 126 threatened or endangered species.[3] By 2040, the region's human population is expected to rise to over 10.5 million, growth that will put additional pressure on the basin's ecosystems. For example, there is concern that the growing population will increase nutrient pollution in marine waters, and these impacts—like algal blooms that create low-oxygen areas in the sea—could be exacerbated by ocean acidification and rising sea surface temperatures.[3] Because the hydrological and biophysical nature of the basin transcends manmade political boundaries, minimizing human-caused degradation to this natural asset requires cooperation between governments.

Cross-boundary cooperation between the U.S. and Canada started in 2000. Recognizing the interconnectedness of the basin's ecosystems, the U.S. Environmental Protection Agency (EPA) and Environment and Climate Change Canada signed a *Joint Statement of Cooperation*. They agreed to collaboratively address the Salish Sea's environmental challenges through information sharing and periodic updates to action plans regarding the Salish Sea ecosystem's health.[4] Today, cross-boundary collaboration exists in international working groups like the Shared Water Alliance, an organization comprised of representatives from governments (federal and local), tribes and First Nations, and community groups from both countries. Their goal is to restore and protect the U.S.-Canadian shared waters of Boundary Bay.[5]

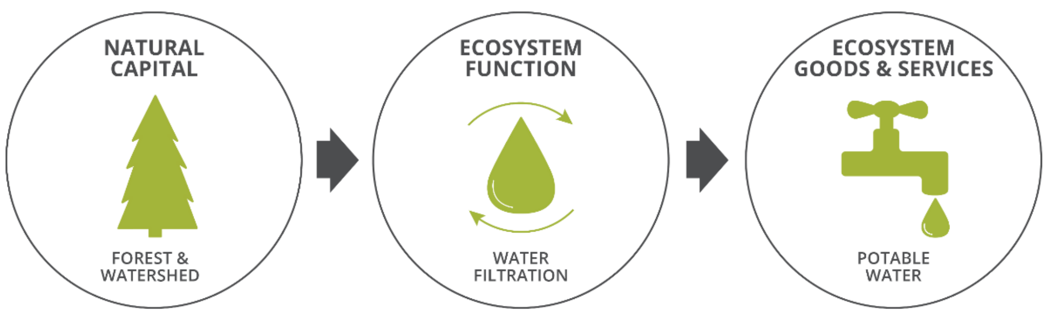
Because political boundaries do not limit the function of the Salish Sea Basin ecosystem or its provision of services to the surrounding area, we chose to broaden our study area beyond borders. Consequently, the total study area encompasses the entire Salish Sea Basin, including Canadian drainages.

Ecosystem Services Valuation

What are Ecosystem Services?

Natural capital refers to the planet's stock of natural resources, or assets. This includes Earth's geology, chemistry, soil, water, air, flora, fauna, bacteria, and fungi. Forests, watersheds, mountains, and shorelines represent natural capital assets. These assets contain multiple ecosystems that perform a variety of ecosystem functions. These functions in turn provide beneficial services that enrich the human experience, such as water filtration, raw material production, flood risk reduction, recreation, climate regulation, and more. As natural capital degrades, ecosystem functions are impaired and the value of ecosystem goods and services that humans receive decreases. Ecosystem services—breathable air, drinkable water, fertile soils, disaster resiliency, and the like—are critical to human survival. When these services are lost, the economic impacts can be measured in a variety of ways, including adverse health impacts, decreased productivity, and property loss. The flow of ecosystem goods and services from natural capital is illustrated in Figure 1.

Figure 1. Natural capital, ecosystem function, and economically valuable ecosystem goods and services



One distinguishing feature of most ecosystem services is that they are non-excludable, meaning that they can be used by multiple individuals. Upstream forested lands provide flood protection that benefits all downstream residents. One person benefitting from natural flood protection will not inhibit other community members from accessing the same service. In this example, nature provides a valuable service—flood protection—for free, and everyone downstream enjoys the benefit.

In recent decades, considerable progress has been made in systematically linking functioning ecosystems with human well-being. Typologies created by De Groot, Wilson, and Boumans,[6] the Millennium Ecosystem Assessment (MEA),[7] and The Economics of Ecosystems and Biodiversity (TEEB)[8] have all established conceptual models for valuing natural capital and ecosystem goods and services. These models have allowed decision makers to account for the cost of environmental impacts in more comprehensive and systematic terms. Earth Economics uses a hybrid model, based on these three sources, that counts 21 ecosystem service categories that can be translated to dollar values for economic analysis. Table 1 provides definitions of the ecosystem services considered in this report.

Table 1. Definitions of ecosystem services

Service	Economic Benefit to People
Provisioning	
Energy and Raw Materials	Providing fuel, fiber, fertilizer, minerals, and energy
Food	Producing crops, fish, game, and fruits
Medicinal Resources	Providing traditional medicines, pharmaceuticals, and assay organisms
Ornamental Resources	Providing resources for clothing, jewelry, handicraft, worship, and decoration
Water Storage	Providing long-term reserves of usable water via storage in lakes, ponds, aquifers, and soil moisture
Regulating	
Air Quality	Providing clean, breathable air
Biological Control	Providing pest, weed, and disease control
Climate Stability	Supporting a stable climate at global and local levels through carbon sequestration and other processes
Disaster Risk Reduction	Preventing and mitigating natural hazards such as floods, hurricanes, fires, and droughts
Pollination and Seed Dispersal	Pollinating wild and domestic plant species via wind, insects, birds, or other animals
Soil Formation	Accumulating soils (e.g. via plant matter decomposition or sediment deposition in riparian/coastal systems) for agricultural and ecosystem integrity
Soil Quality	Maintaining soil fertility and capacity to process waste inputs (bioremediation)
Soil Retention	Retaining arable land, slope stability, and coastal integrity
Water Quality	Removing water pollutants via soil filtration and transformation by vegetation and microbial communities
Water Capture, Conveyance, and Supply	Regulating the rate of water flow through an environment and ensuring adequate water availability for all water users
Navigation	Maintaining adequate depth in a water body to sustain traffic from recreational and commercial vessels
Supporting	
Habitat	Providing shelter, promoting growth of species, and maintaining biological diversity
Information	
Aesthetic Information	Enjoying and appreciating the scenery, sounds, and smells of nature
Cultural Value	Providing opportunities for communities to use lands with spiritual, religious, and historic importance
Science and Education	Using natural systems for education and scientific research
Recreation and Tourism	Experiencing the natural world and enjoying outdoor activities

Why Value Ecosystem Services?

Proper consideration of ecosystem service values ultimately strengthens decision-making. When natural capital and ecosystem services are not quantified, they are effectively valued at zero in the decision-making process. This omission leads to inefficient investments based on incomplete information that translates to higher future costs and poor asset management strategies. The dynamic complexity of most ecosystems—and the range of ecosystem goods and services they produce—makes it exceptionally difficult to substitute or replace these with human-made infrastructure and technology. The short-term gains from activities that degrade or destroy ecosystem function are often dwarfed by the lost long-term economic value of functional ecosystems.[9] One human activity in the basin that has impacted ecosystem services is logging of old growth forests. They are replaced with monocrop timber plantations, which reduce stream flows and degrade fish habitat—especially that of salmon.[10] Replacing natural functions with built infrastructure can incur significant costs, including maintenance, operations, and replacement costs not associated natural ecosystems.[11]

It is a growing best practice to translate the real-world benefits of ecosystems into dollars and ensure that these values are properly accounted for in planning decisions. This shift is perhaps best illustrated at the federal policy level, where ecosystem service values are increasingly being incorporated into benefit-cost analyses (BCA) as the understanding of the value of natural capital—and how to measure it—improves. In 2013, the Federal Emergency Management Agency (FEMA) announced a landmark policy change that allowed ecosystem services to be included in the formal BCA process for flood risk mitigation projects.[12] In 2017, FEMA released BCA Toolkit Version 5.3.0, which provided explicit guidance for including ecosystem service values in BCA, doubled the number of ecosystem service values from the prior version, and extended the application of ecosystem services beyond flood risk mitigation to all FEMA project types.[i] Subsequent guidance from FEMA updated the initial 2013 action to make it even easier to incorporate nature-based solutions for risk mitigation "… in recognition that the natural environment is an important component of a community's resilience strategy."[13]

Methodology and Assessment

Study Area

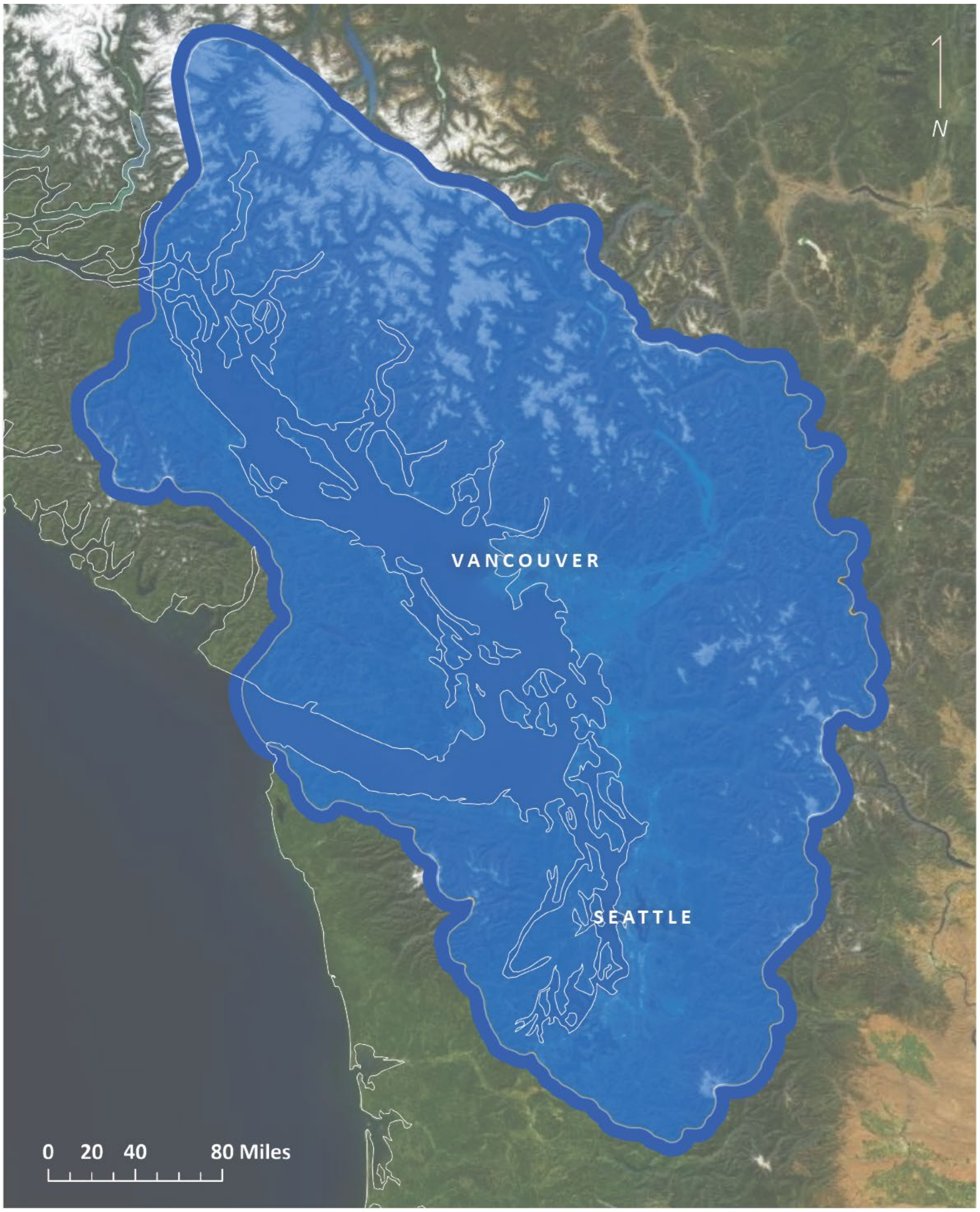
Because nature does not recognize political boundaries, our study area includes the entire Salish Sea Basin, incorporating drainages within Canada as well as the watersheds within the U.S. Valuing only the U.S. side of the Puget Sound Basin would exclude 60 percent of its lands and waters. Figure 2 illustrates the study area boundary, and Table 2 summarizes the extent of each landcover type in the basin by country. The basin extends across 26.8 million acres—an area just under the size of Tennessee—that are dominated by forests (50 percent) and estuaries (17 percent). Both ecosystem types face pressures from population growth, which is expected to rise further in the coming decades. These pressures include deforestation due to development and water quality degradation from urban waste and stormwater. The extent of urban landscapes on the U.S. side are already more than double that of Canada's.

Table 2. Summary of landcover extent and distribution in the Salish Sea Basin.

Landcover Type	Canada (*thousand acres*)	United States (*thousand acres*)	Salish Sea Basin (*% of total*)
Barren Land	1,333	282	6.0%
Beach	2	5	0.03%
Cropland	182	434	2.3%
Forest	7,833	5,426	49.5%
Estuary	2,623	1,825	16.6%
Grassland	593	297	3.3%
Lake	336	110	1.7%
River	99	29	0.5%
Shrubland	1,372	790	8.1%
Snow and Ice	1,278	48	5.0%
Urban and Built-up	452	1,102	5.8%
Wetland	49	269	1.2%
Total	**16,153**	**10,618**	**100%**

[i] FEMA's BCA Toolkit is currently in version 6.0, available at www.fema.gov/grants/tools/benefit-cost-analysis.

Figure 2. Study area boundary



Datasets Used

Geospatial Data

We sourced geospatial datasets for characterizing ecosystem and landcover types from the 2015 North American Land Change Monitoring System (NALCMS),[14] the most recent version of a dataset that categorizes landcover throughout the U.S., Canada, and Mexico. The NALCMS includes 19 landcover classes based on the Land Cover Classification System developed by the Food and Agriculture Organization of the United Nations.[15] We condensed these 19 landcover classes into larger groupings to facilitate the ecosystem services valuation (e.g., forest, shrubland, grassland).

To add nuance to these landcover categorizations, we assigned modifiers based on location or other contextual factors. These "spatial attributes" can support ecosystem services valuation estimates that are better aligned with the ecosystem descriptions in the supporting valuation literature.

For example, primary research may apply specifically to forested urban parks, but not forested rural parks. Applying an urban spatial attribute separates urban forests from other forested areas within the landcover data. In this way, urban value estimates are only applied to forested urban parks, and not rural forests. Without associating these distinct areas separately, values from the literature may be applied in instances where the key factors driving value (e.g., relative scarcity) are less prevalent, or where the specific ecosystem services produced vary (e.g., freshwater, brackish, or saline wetlands).

Valuations are considered to be more accurate when primary study site values are closely matched to transfer sites.[16] Applying spatial attributes and more focused study values is one way to increase the accuracy of benefit transfer analyses. We modified the NALCMS data with the following spatial attributes:

Table 3. Spatial attributes used in the valuation

Attribute	Spatial Extent	Sources Used
Climate zone	Extent of Koppen-Geiger climate classification types	Beck et al. (2018)[17]
Riparian	100-ft buffer around freshwater lakes, ponds, and waterways	USFWS National Wetlands Inventory, BC Freshwater Atlas
Urban	1-mile buffer around census-defined urban areas	US Census Bureau, Statistics Canada
Agricultural Border	1-acre buffer around farm lands	NALCMS
Upper Watershed	Areas above the mean elevation of 1st and 2nd order streams (mainland, Vancouver Island, all other islands)	USGS NHDPlus, SRTM Digital Elevation
Old Growth Forest	Occurrence	BC Vegetation Resource Inventory, LEMMA GNN Structure Maps
Shellfish Area	Shellfish beach (line features) intersection with barren land bordering Salish Sea and/or OpenStreetMap beaches	NALCMS, OpenStreetMap, Washington State Department of Health

Ecosystem Services Values

After identifying landcover, the next step is to identify the value of the ecosystem services produced by the landcover types present in the study area. This process is facilitated by Earth Economics' internal EVToolkit (EVT), a repository of over 2,500 individual ecosystem service value estimates drawn from peer-reviewed articles, government reports, and rigorous gray literature. EVT helps to construct appropriate comparisons between these studies and the area of interest by making it easy to select for characteristics such as climate type, ecosystem, and location. Using the benefit transfer method (see the following section), we queried EVT to isolate 47 value estimates that were appropriate to the study area. Appendix A shows the ecosystem services that could be valued for each landcover type. Appendix B lists the full references for the studies included in the data set.

Benefit Transfer Method

To value ecosystem goods and services, Earth Economics employs the benefit transfer method (BTM), in which economic value estimates are based on primary valuation studies of similar goods or services produced in comparable conditions (e.g., climate, terrain, soils, species).[18] BTM is often the only practical, cost-effective option for producing reasonable estimates of the wide range of services that ecosystems provide. In recent years, a substantial increase in publications on ecosystem services and valuations have supplied an abundance of values appropriate to the Salish Sea. Consequently, we were able to estimate values for a broad suite of ecosystems and ecosystem services.

The application of BTM begins with identifying critical attributes of a landscape that determine ecological productivity and expected benefits (see Geospatial Data previously). Primary valuations of similar ecosystems, geographies, and communities are then identified and assessed for their comparability with landcover types within the study area through a set of selection criteria for building a valuation data set (see Criteria for Values Used in this Study below). Estimates from primary studies are then standardized to ensure "apples-to-apples" comparisons (i.e., adjusted to common units, correcting for any inflation between the period of research and the present). In this sense, BTM is like a property appraisal, in which the features and pricing of similar nearby properties are used to estimate value prior to a sale. Although each process has its limitations, these are rapid, efficient approaches for generating reasonable values to inform investment and policy decisions.

Interest in certain ecosystem services and landcover types has generated a substantial body of research that offers multiple estimates for given combinations. In these instances, Earth Economics reports both low and high per-acre value estimates. Other ecosystem services and landcover types are less well-researched. For cases where Earth Economics was unable to identify a transferable study, no value is included. It is important to understand that this decision reflects the limitations of valuation research and does not reflect upon the value of those natural assets. Finally, all data is adjusted to 2021 USD using GDP deflator data estimated by the World Bank.[19]

Criteria for Values Used in This Study

The selection criteria for appropriate primary studies for the Salish Sea Basin include geographic location, the ecological and demographic characteristics of the original primary study sites, and study methodology. Only primary studies or meta-analyses were included in the dataset. Additionally, studies were first limited to Alberta, British Columbia, and the states of Washington, Oregon, and California. If no appropriate studies could be found from those areas, U.S.-wide or global meta-analyses were included.

Using these criteria, we created a data set that includes ecosystem service values for 47 ecosystem service-landcover combinations.

Table 4. Ecosystem service-landcover combinations analyzed

Ecosystem Service	Beach	Cropland	Estuary	Forest	Grassland	Lake	River	Seagrass	Shrubland	Wetland
Aesthetic Information	○		○	●	●	○	●		○	●
Air Quality				●	○				○	
Biological Control		●	○	○	●			○	○	○
Climate Stability			●	●	●			●	●	●
Existence Value	●	●	○	●	○	○	○	○	○	●
Disaster Risk Reduction				●	●				○	●
Food	●	○	●	●	○	○	○	●	○	○
Habitat	○		●	●	○	○	○	●	○	●
Pollination and Seed Dispersal		●	○	○	○		○		○	
Recreation and Tourism	●		●	●	●	●	●			●
Science and Education	○	○	○	●	○	○	○	○	○	○
Soil Retention		●		●	●				○	●
Water Capture, Conveyance, and Supply				●	○		○		○	●
Water Quality		○		●	●			○	○	●
Water Storage			○	○	○	○	○		○	●

Key

●	Produced by landcover, valued in report
○	Produced by landcover, not valued in report
	Not valued in report

Example of Benefit Transfer Method in Practice

The following example illustrates how dollar-per-acre estimates are obtained from a study in the data set; in this example, Walls (2011). See Appendix B for the full reference.

Walls (2011) provides an order-of-magnitude estimate of gains in returning salmon from the Smith Island Restoration Project, a component of the Snohomish River Basin Salmon Conservation Plan in Washington State. The author estimates a 31 percent increase in the returning adult spawning population over four years, relative to the average. This increase is valued using the average retail price per pound ($13.69 per pound), an average harvested weight at the site, and a projected increase in the number of returning Chinook, totaling $184,815 per year. The study's total restoration area is 440.28 acres. Dividing the annual benefit by the restoration area yields a per-acre annual estimate of $419.77 per acre per year. The study does not specify the dollar year, so it is assumed to be 2011 U.S. dollars. Using GDP deflator data from the World Bank, this value was inflated to 2021 U.S. dollars and then applied to the acreage of coastal wetland in the study area, along with values from one other study, Gregory and Wellman (2001; see Appendix B for full reference), to provide a range of values for coastal wetland habitats.

Nature's Value in the Salish Sea Basin

In addition to the results of our analysis outlined below, we have also created an interactive, publicly available web map[ii] that includes the total ecosystem services values at the country, county, watershed, and federally-recognized tribal land levels.

Ecosystem Services Values by Landcover

Overall, the terrestrial and aquatic ecosystems of the study area (as of 2015) are estimated to provide over US $123 billion in ecosystem goods and services each year (see Table 5). Broken out by country, the U.S. portion makes up about 52 percent of the total value but only 40 percent of the area. However, this does not necessarily mean the U.S. side of the basin provides more ecosystem services value—this could be the consequence of gaps in literature on ecosystem service-landcover combinations relevant to the Canadian study area. The total non-market value is further broken down by landcover type (Table 6) and ecosystem service (Table 7).

Table 5. Estimated total annual value of ecosystem services within the Salish Sea Basin, by boundary (millions 2021 USD per year)

Salish Sea Boundary	Low	High	Average
United States	52,508	79,281	63,871
Canada	43,792	82,599	52,709
Total	**96,300**	**161,880**	**123,580**

Forests

Over three quarters of the basin's value comes from the forests that dominate the landscape. Forests play a critical role in climate change mitigation by sequestering and storing carbon from the atmosphere. We estimated forest carbon sequestration using a study by Smith et al. (2006)[20] on the carbon stored throughout the lifetime of forests and forest products. The *Social Cost of Carbon* (SCC), estimated at US $51 per ton of CO_2, is a measure of the global impacts of every additional ton of atmospheric carbon, including damages to agriculture, public health, and property.[21] This means Salish Sea forests provide over US $17 billion in climate stability benefits each year. They also provide US $46 billion in aesthetic value—mostly from urban forests—and US $20 billion in water quality benefits.

Wetlands and Rivers

Although rivers and wetlands represent less than two percent of landcover in the study region, their combined value is 13 percent of the basin's total value. Rivers in urban areas provide US $1.8 billion in benefits in the form of increased value in homes with a view. Rivers in non-urban areas, however, provide nearly US $6 million in recreational opportunities for residents and tourists. These economic benefits are likely much larger when considering the ripple effect of recreational tourist spending that supports local jobs and wages.

Freshwater wetlands also provide considerable value—US $7.7 billion annually in total value throughout the Salish Sea Basin. Wetlands produce multiple ecosystem services benefits, most significantly flood risk reduction and water quality services.

[ii] Available at www.eartheconomics.org/salishsea.

Table 6. Estimated annual value produced by ecosystems within the Salish Sea Basin, by landcover type (millions 2021 USD per year)

Land Cover Type	Low	High	Average
Beach	259	259	259
Cropland	2,745	3,887	3,357
Estuary	4,542	4,547	4,544
Forest	72,157	132,134	96,819
Grassland	443	531	487
Lake	487	952	720
River	7,802	7,929	7,866
Seagrass	635	675	659
Shrubland	533	533	533
Wetland	6,697	10,433	8,336
Total	96,300	161,880	123,580

Table 7. Estimated annual value of ecosystem services within the Salish Sea Basin (millions 2021 USD per year)

Ecosystem Service	Low	High	Average
Aesthetic Information	52,903	53,173	53,037
Air Quality	828	828	828
Biological Control	2,688	2,689	2,688
Climate Stability	5,753	33,668	19,708
Cultural Value	985	985	985
Disaster Risk Reduction	2,514	5,336	3,784
Food	533	1,504	836
Habitat	5,590	5,739	5,668
Pollination and Seed Dispersal	70	1,207	679
Recreation and Tourism	6,714	8,386	7,464
Science and Education	124	124	124
Soil Retention	128	134	132
Water Capture, Conveyance, and Supply	2,156	9,523	3,768
Water Quality	15,294	38,384	23,767
Water Storage	20	201	110
Total	96,300	161,880	123,580

Other Landcovers

Seagrass

Seagrass generates energy through photosynthesis, removing carbon dioxide from the atmosphere in the process. This conversion of atmospheric carbon to biomass is called sequestration. Seagrass meadows are excellent at sequestering and storing carbon, burying carbon 35 times faster than tropical rainforests.[22] Yet only a portion of this carbon is effectively removed from the shorter-term carbon cycle as carbon storage; the remainder is re-released into the broader ecosystem as food for other marine life or decomposition in the coastal environment.[23] Because aquatic ecosystems can act as carbon sinks, we estimated seagrass in the Salish Sea provides US $28 million in climate stability benefits every year. Other benefits include food and aquatic habitat, for a total annual benefit of US $622 million.

Shellfish Beach

Shellfish harvest is a cornerstone of many Coast Salish Peoples' cultures and livelihoods, but shellfish bed closures have become more frequent in recent years due to increased pollution. Beyond their cultural significance to local tribes and First Nations, shellfish beaches also provide food and recreational opportunities for residents and visitors. We estimated shellfish beaches provide nearly US $700 thousand in benefits every year. Because public beach closures are generally due to water quality issues, this value demonstrates one of the many economic consequences should the Salish Sea water quality continue to decline.

Value of Water Quality-Related Services

The Salish Sea Basin provides US $27 billion in water quality-related benefits every year. Again, because of the interconnected nature of the basin as one ecosystem, water quality significantly influences many aspects of ecosystem function throughout the region, and thus other ecosystem services. We decided to break out water-quality related ecosystem services from the total valuation based on those services that directly affect the Salish Sea's water quality. Table 8 provides value estimates for water quality-related benefits by ecosystem service; Table 9 presents water quality-related benefits by landcover type. The service "Water Capture, Conveyance, and Supply" appears differently than in Table 7 because we removed a value for irrigation of agricultural lands as the original study was unrelated to water quality.

Table 8. Estimated annual value for water-quality related ecosystem services within the Salish Sea Basin (millions 2021 USD per year)

Ecosystem Service	Low	High	Average
Soil Retention	128	134	132
Water Capture, Conveyance, and Supply	2,129	9,496	3,741
Water Quality	15,294	38,384	23,767
Water Storage	20	201	110
Total	**17,570**	**48,216**	**27,750**

Table 9. Estimated annual value for water-quality related ecosystem services produced by ecosystems within the Salish Sea Basin, by landcover type (millions 2021 USD year)

Landcover Type	Low	High	Average
Cropland	-13	-8	-10
Forest	14,673	45,131	24,758
Grassland	47	47	47
Wetland	2,864	3,045	2,954
Total	**17,570**	**48,216**	**27,750**

Discussion

In this report, we demonstrate the immense economic value of the ecosystem services benefits provided by the lands and waters of the Salish Sea Basin.

- **On average, the basin provides residents with over US $123 billion in ecosystem services every year.** These economic benefits are likely much greater because this analysis was limited by data availability and relevant valuation literature.

- **The value of ecosystem services which impact Salish Sea water quality averages more than US $27 million.** Given that pollution and dissolved oxygen levels are a major concern in the Salish Sea region, it is important to highlight the benefits natural areas can have on both freshwater and marine water quality.

- **Cross-boundary collaboration and cooperation between U.S. and Canadian governments, NGO's, and tribes and First Nations are crucial to restoring and protecting the Salish Sea.** Threats to the ecological balance—like climate change and development pressure—endanger these sustainable, nature-based benefits and compromise the livelihoods and quality of life of all its residents.

Ecosystems—and the flow of ecosystem service benefits—rarely conform to manmade boundaries, and growing transboundary problems require transboundary solutions. As partnerships form across the border between various groups like tribes and NGOs, raising awareness among stakeholders of the economic value of nature's benefits in the Salish Sea Basin could push decision makers to take nature into account when developing land management policies, practices, and investment decisions.

We were able to complete this analysis largely due to spatial data sets like the NALCMS that go beyond political boundaries. The application of spatial attributes, a robust body of supporting valuation literature, and a rigorous application of best practices for benefit transfer method were crucial in obtaining a precise estimate.

Focusing on localized changes to landcovers can give important clues as to how policies are (or are not) preventing degradation of ecosystem services. It can also provide decision makers and stakeholders with transferable information for comparing land management policies. The values produced from this report on a county-basis served as the baseline for a case study in Island County on applying this framework at a local scale to understand how non-market value changes with landcover, over time. The results of that case study can be found in our companion report, *Nature's Value in Island County: Identifying the Economics Behind a Healthy Puget Sound*.

Nature and ecosystem functions provide considerable value that is not captured (or perhaps capturable) by markets. Improvements in water and air quality, aesthetic beauty, recreational opportunities, disaster mitigation, limiting the global impacts of climate change, and other non-market benefits not only improve quality of life, but also provide the basis for all social and economic activity. Because the estimates reported here are limited by both data availability and relevant valuation literature—and because important ecosystem goods and services such as cultural and existence value are difficult to value in monetary terms, the actual value of natural ecosystems within the study area is likely to be considerably greater. Successful stewardship of these ecosystems to maintain (and improve) these benefits is likely to require a combination of individual responsibility, public land use policies and zoning, regulation, and both public and private investment. The high quality of life enjoyed throughout the study area and beyond depends upon sustaining the quality and extent of these ecosystems.

Recommendations

Understanding the immense value of ecosystem services and how they shape the regional economy is a critical step in effective planning for policies, public investment, and decision-making regarding natural resource management and flood mitigation. With this in mind, we recommend the following:

- **Include Ecosystem Services Valuations (ESV) in Future Benefit-Cost Analyses (BCAs).** As government officials and Salish Sea stakeholders develop and implement plans for regional management, they should consider the costs and benefits of nature-based solutions and ecosystem services to address human needs. BCAs that incorporate ecosystem services can provide governments, organizations, and private landowners a means to calculate the full social return on conservation and restoration investments. Including ecosystem services values also allows for the full consideration of nature-based and built infrastructure solutions. A handful of state and federal agencies, including FEMA, already include ESV in their formal BCAs (Mitigation Policy FP-108-024-01, 2013). Governments throughout the basin should lead efforts to include the value of ecosystem goods and services in future BCAs.

- **Secure Funding to Scale ESV Research.** Both the U.S. and Canadian stakeholders should consider funding mechanisms to support additional ESV research throughout the basin. Additional studies will support the prioritization of ecosystem restoration projects by allowing decision makers to calculate the rate of return on various conservation efforts.

- **Protect and Restore Natural Capital.** Ecosystem degradation is happening faster than restoration and protection. Water quality improvement and protection; salmon habitat restoration; and forest conservation are priorities for U.S. and Canadian stakeholders. Collaborative private, tribal, and NGO partners can accelerate this work by advocating for ESV use in government planning processes. Including the value of ecosystem goods and services allows for the full consideration of nature-based alternatives to built infrastructure—like those likely to be planned soon with funding from the 2021 Infrastructure Investment Bill recently passed by Congress—which will support the region's long-term economic growth.

Appendix A: The Limits of Ecosystem Services Valuation

Given the scale and diversity of ecosystems throughout the study area, as well as limitations in the valuation literature, this analysis excludes some ecosystem services values likely to be produced throughout the study area. We identified multiple gaps in the supporting literature: for example, we had no studies of the air quality value of landcover types other than forests, or for water storage values for ecosystems other than wetlands. Although these services likely produce significant benefits, monetary estimates were not feasible without appropriate literature. Other ecosystem services, though widely recognized as valuable, are difficult to translate to monetary terms (e.g., cultural and existence value).

It is important to note that since BTM relies on published literature, some combinations of ecosystem service and landcover types cannot be valued. Some combinations have been studied more in-depth than others. The absence of a specific landcover-ecosystem service combination from this report does not necessarily mean that a landcover does not produce a given service or value, but rather reflects a lack of appropriate source studies and data relevant to that combination. For this reason, the reported values may in some cases be underestimates. Additionally, caution should be exercised when comparing total ecosystem services values across landcover types, as differences in total value may reflect information gaps, rather than real differences in benefit provisioning or the value of such services.

BTM, though pragmatic, is also limited. Some would argue that every ecosystem is unique and therefore has unique value. Though true, this statement implies that the only option for understanding the true value of a given ecosystem and ecosystem service is to fund resource-intensive primary studies. Yet benefit transfer—applying a study of one place to similar places—is widely accepted. State or county governments estimate property values to calculate property taxes by examining key variables known to influence property values—square footage, views, and more.

The baseline analysis was based on the 2015 North American Land Change Monitoring System (NALCMS) data set, which is produced at 30-meter resolution (approximately one-fifth of an acre). Changes in land cover since 2015, or higher-resolution variability (changes less than 900 m^2) may not be reflected in these data.

Appendix B: Annotated Bibliography of Ecosystem Services Literature

Citation	Annotation	Ecosystem Services Values Used
Adusumilli, N. 2015. Valuation of Ecosystem Services from Wetlands Mitigation in the United States. Mayer, Audrey L (ed.) Land 4: 182-196.	This paper presents a meta-analysis of ecosystem services provided by wetlands in order to understand the value of wetland mitigation in policy decisions. Results from the model show that the cumulative value across all wetland-based ecosystem services ranges from US $5,000 to US $70,000 per acre per year.	Wetlands - Water Storage
Anderson, L. E., Plummer, M. L. 2016. Recreational Demand for Shellfish Harvesting Under Environmental Closures. Marine Resource Economics 32(1): 43-57.	This study investigates the effect of beach closures on the value of recreational shellfishing in the Puget Sound. A travel cost model of recreational shellfish harvesters found that the average willingness-to-pay for a harvesting day to the beach most often used by a respondent was US $127.66.	Beach - Recreation and Tourism
Anielski, M., Wilson, S. J. 2005. Counting Canada's Natural Capital: Assessing the Real Value of Canada's Boreal Ecosystems.	The purpose of this study was to identify, inventory, and measure the economic value of ecosystem services provided by Canada's boreal region. The authors estimate both market and non-market values of natural capital. The market value of natural capital extraction (timber, mining, and hydroelectricity) is estimated to be US $37.8 billion in 2002, or 4.2 percent of Canada's GDP. Non-market ecosystem service value is estimated at US $93.2 billion in 2002, or 8.1 percent of Canada's GDP, with the highest values belonging to flood control, water purification, recreation, and carbon sequestration.	Wetlands - Habitat; Wetlands - Recreation and Tourism; Wetlands - Water Storage
Belcher, K., Edwards, C. K., Gray, B. 2001. Ecological Fiscal Reform and Agricultural Landscapes, Analysis of Economic Instruments: Conservation Cover Incentive Program. National Roundtable on the Economy and Environment.	This study evaluated an incentive program to promote conservation cover on agricultural landscapes in order to increase their ecological integrity in three different watersheds in Canada. Benefits and costs attributable to converting cropland to perennial vegetative cover are estimated, including private landowner benefits and public benefits to nearby communities. A mix of avoided cost, benefit transfer, and market values are used to characterize the program's ecosystem service benefits.	Grassland - Soil Retention
Bolitzer, B., Netusil, N.R. 2000. The Impact of Open Spaces on Property Values in Portland, Oregon. Journal of Environmental Management 59, 1-9.	The impact of open space on property value is assessed, with controls for home proximity and type of open space. The study uses a data set that includes sale prices for homes in Portland, Oregon, Geographic Information System data on each home's proximity to an open space and open space type, and neighborhood and home characteristics. Results show that proximity to an open space and open space type can have a statistically significant effect on a home's sale price.	Grassland - Aesthetic Information
Boxall, P. C. 1995. The Economic Value of Lottery-Rationed Recreational Hunting. Canadian Journal of Agricultural Economics-Revue Canadienne D'Economie Rurale 43, 119-131.	Lottery-rationed permits are used to allocate hunting opportunities where demand for permits exceeds sustainable levels. This paper uses a travel cost model and incorporates the expectation of receiving a permit, thereby finding the "expected value" of lottery-rationed permits. The authors focus on permits for antelope in Alberta.	Grassland - Recreation and Tourism

Citation	Annotation	Ecosystem Services Values Used
Boxall, P. C., McFarlane, B.L., Gartrell, M. 1996. An Aggregate Travel Cost Approach to Valuing Forest Recreation at Managed Sites. Forestry Chronicle 72, 615-621.	Travel cost models were estimated for camping trips in 1994 to designated recreation areas in Alberta's Rocky-Clearwater Forest. The authors aggregate trips by postal code and apply Poisson and binomial regressions. Aggregate non-market benefits provided by the Alberta Land and Forest Service recreation areas were about US $750,000.	Forest - Recreation and Tourism
Brander, L.M., Brouwer, R., Wagtendonk, A. 2013. Economic Valuation of Regulating Services Provided by Wetlands in Agricultural Landscapes: A meta-analysis. Ecological Engineering 56: 89-96.	This paper presents a meta-analysis of the economic valuation literature on ecosystem services provided by wetlands in agricultural landscapes. The study includes values from the United States and Europe with information on site attributes to improve transferability. A meta-regression is used to produce a value function for wetland regulating services that can be transferred based on site attributes. The authors focus on the value of flood control, water supply and nutrient cycling to create a database containing 66 value estimates standardized in USD per hectare per year.	Wetlands - Disaster Risk Reduction, Water Capture and Supply, Water Quality
Brander, L.M., Florax, R.J., Vermaat, J.E. 2006. The Empirics of Wetland Valuation: A Comprehensive Summary and a Meta-Analysis of the Literature. Environmental and Resource Economics 33: 223-250.	This meta-analysis examined 80 studies with sufficient information for statistical analysis to produce a comprehensive review of the valuation literature on wetlands. The authors include information on geography, climate, and socio-economic demographics for each study examined in the meta-analysis. The studies used avoided cost, hedonic pricing, contingent valuation, and market pricing to show the benefits of wetlands as an ecosystem service provider.	Wetlands - Disaster Risk Reduction, Recreation and Tourism, Water Quality
Bridgeham, S.D., Megonigal, J.P., Keller, J.K., Bliss, N.B., Trettin, C. 2006. The Carbon Balance of North American Wetlands. Wetlands 26(4): 889-916.	The authors examine the carbon balance of North American wetlands by reviewing and synthesizing the published literature and databases. Wetland loss has had the largest impact on carbon fluxes within Canada, the United States, and Mexico. The authors analyzed six wetland types, including peat, freshwater wetlands, saline wetlands, mangroves, and mudflats to estimate the carbon pool of North America and the annual sequestration rate of different wetland types. They estimate that North American wetlands emit 9 Tg methane (CH_4) yr-1. With the exception of estuarine wetlands, CH_4 emissions from wetlands may offset any positive benefits of carbon sequestration in soils and plants in terms of climate forcing. The authors conclude that they will not be able to accurately predict the role of wetlands as potential positive or negative feedbacks to anthropogenic global change without knowing the integrative effects of changes in several factors. These factors include temperature, precipitation, atmospheric CO_2 concentrations, and atmospheric deposition of nitrogen and sulfur on the carbon balance of North American wetlands.	Wetland - Climate Stability

Citation	Annotation	Ecosystem Services Values Used
Burke, S., Menzies, G. 2010. NMAI: WA Shellfish Production and Restoration – Environmental, Economic and Social Benefits and Costs Task 8b - Drayton Harbor Community Oyster Farm Community and Ecosystem Benefits. Pacific Shellfish Institute.	This report evaluates the benefits from shellfish in the Drayton Harbor Community Oyster Farm in Washington State. The author estimates values for commercial harvesting, subsistence harvesting, improvements to water quality, and social benefits of volunteering. In total, the farm provides US $14,000 annually in terms of food provisioning, US $48,000 from subsistence use, US $53,000 in improved water quality, and US $24,250 to US $41,500 in volunteer hours value.	Beach - Food
Cedar River Group, Mundy Associates LLC, Beyers, W.B. 2002. Evaluation of Blanchard Mountain Social, Ecological and Financial Values. Washington State Department of Natural Resources.	This report, prepared for the Washington State Department of Natural Resources, evaluates the social, ecological, and financial values of 4,827 acres of forest managed by the Skagit County Forest Board. The authors use contingent valuation to survey 200 local residents to value these attributes. Recreational and educational opportunities were valued at US $3.2 million, environmental resources at US $4.3 million, and land resources at US $730 to US $877 thousand.	Forest - Aesthetic Information, Cultural Value, Habitat, Recreation and Tourism, Science and Education, Soil Retention; Wetlands - Cultural Value, Water Capture and Supply
Clark, E. H. 1985. The Off-Site Costs of Soil Erosion. Journal of Soil and Water Conservation 40(1): 19-22.	Clark estimates economic damages caused by soil erosion. Instream (damages caused by erosion-related contaminants in water bodies and courses) and off-stream (damages caused before sediment gets into a waterway or after sediment-laden water is extracted) values are established using avoided costs. Total instream damages could be as much as US $2,100 to US $10,000 million. Total off-stream damages are estimated to be US $1,100 to US $3,100 million.	Cultivated - Soil Retention
Clucas, B., Rabotyagov, S., Marzluff, J. M. 2015. How Much is That Birdie in my Backyard? A Cross-Continental Economic Valuation of Native Urban Songbirds. Urban Ecosystems 18(1): 251-266.	The authors assess economic values placed on urban birding using a combined revealed preference and stated preference survey. In Seattle, the lower bound for the economic value of enjoying common native urban songbirds is estimated to be US $120 million per year.	Forest - Habitat
Cote, J., Domanski, A. 2019. Benefit Cost Analysis of Shore Friendly Practices in Island County. Island County Department of Natural Resources.	This study sought to determine the economic benefits and costs of different shoreline protection strategies in Island County, Washington. Methods used included hedonic analysis of property characteristics to determine direct effects to landowners and habitat equivalency analysis to estimate public economic benefits of habitat. The public value of shore-friendly practices could improve habitat by US $3.3 million each year.	Beach - Existence Value
Crooks, S., Rybczyk, J., O'Connell, K., Devier, D.L., Poppe, K., Emmett-Mattox, S. 2014. Coastal Blue Carbon Opportunity Assessment for the Snohomish Estuary: the Climate Benefits of Estuary Restoration. Report by Environmental Science Associates, Western Washington University, EarthCorps, and Restore America's Estuaries.	This study sought to estimate the scale of greenhouse gas emissions and removals associated with coastal wetland management in Washington State. The authors conducted a case study in Puget Sound's Snohomish Estuary, measuring carbon fluxes over multiple decades and management scenarios for a variety of wetland types. Full estuary restoration was estimated to rebuild soil carbon stocks of 1.2 Mt of carbon.	Wetland - Climate Stability

Citation	Annotation	Ecosystem Services Values Used
Donovan, G., Butry., D. 2010. Trees in the City: Valuing Street Trees in Portland, Oregon. Landscape and Urban Planning: 94(2): 77-83.	A hedonic model estimates the value street trees bring to sale prices of houses in Portland, Oregon. Street trees are shown to increase sales prices and also reduce the amount of time houses spend on the market. These benefits also spill over to neighboring houses.	Forest - Aesthetic Information
Duarte, C.M., Middelburg, J.J., Caraco, N. 2004. Major Role of Marine Vegetation on the Oceanic Carbon Cycle. Biogeosciences Discussions, European Geosciences Union 1 (1): 659-679.	This paper examined the carbon sequestration capabilities of global marine vegetation and soil. The analysis considers coastal ecosystems such as sea grass meadows, salt marshes, and mangrove forests along ocean coasts, which provide this regulating service. The report used biophysical data to show changes in sequestration rates across varying land covers. The results show that the total sequestration from underwater vegetation and soil sources could be double that of current global carbon sequestration estimates.	Open Water - Climate Stability; Seagrass - Climate Stability
Ehlers, T., Hobby, T. 2010. The Chanterelle Mushroom Harvest on Northern Vancouver Island, British Columbia: Factors Relating to Successful Commercial Development. BC Journal of Ecosystems and Management 11(1-2): 72-83.	The authors present an original case study investigating the social, economic, and ecological benefits of chanterelle harvests on Vancouver Island in British Columbia, Canada. They use a market pricing approach to value wild mushroom harvesting activity, finding that harvester income ranges from US $22.50 to US $135.00 per day, and that exports of chanterelles from Canada to other countries ranges from US $1 to US $5 million annually.	Forest - Food
Erckmann, J. 2000. Cedar River Watershed Habitat Conservation Plan. City of Seattle.	This plan was prepared to comply with the Endangered Species Act and address a variety of natural resource issues in the Cedar River Municipal Watershed, a 90-thousand-acre area that is Seattle's water supply. The plan includes a replacement cost estimate for the clean water supply that the natural watershed provides the city, savings that are more than US $100 million.	Forest - Water Capture and Supply
Garrard, S., Beaumont, N. 2014. The Effect of Ocean Acidification on Carbon Storage and Sequestration in Seagrass Beds; a Global and UK Context. Marine Pollution Bulletin 86: 138-146.	This study assesses the effect of ocean acidification on seagrasses and their ability to sequester carbon. Increasing seagrass above- and below-ground biomass would allow for significant increases in carbon sequestration, valued at 500 to 600 billion pounds globally over 90 years.	Seagrass - Climate Stability
Gregory, R., Wellman, K. F. 2001. Bringing Stakeholder Values into Environmental Policy Choices: a Community-Based Estuary Case Study. Ecological Economics 39: 37-52.	This paper presents a case study of a Natural Estuary Program planning effort in Tillamook Bay, OR. The project developed a community-based evaluation tool which considered trade-offs across multiple benefits, costs, and risks for taking restoration actions. Working with regional stakeholders, researchers estimate that beneficiaries are willing to pay US $2,000 to US $3,000 per acre to restore salmon habitat.	Wetlands - Habitat

Citation	Annotation	Ecosystem Services Values Used
Haener, M.K., Adamowicz, W.L. 2000. Regional Forest Resource Accounting: A Northern Alberta Case Study. Canadian Journal of Forest Research 30 264-273.	Haener and Adamowicz develop a resource accounting model for a region of public forestland in northern Alberta. Both market and non-market values are quantified, including those for forestry, trapping, fishing, recreation, subsistence, and ecosystem services. Several challenges with resource accounting are highlighted. The value of this forest ranges from a low of US $149 million to a high of US $316 million.	Forest- Habitat, Recreation and Tourism
Hill, B. H., Kolka, R. K., McCormick, F. H., Starry, M. A. 2014. A Ssynoptic Survey of Ecosystem Services from Headwater Catchments in the United States. Ecosystem Services 7: 106-115.	Water supply, climate regulation, and water purification are estimated for over 500 headwater stream catchments, using data derived from the National Hydrography Dataset for the lower 48 states. Production functions were created for water supply, climate regulation, and water purification and their results reported for nine ecoregions. The combined ecosystem services—valued at up to US $30 million per year overall—were presented in dollars per hectare per year.	Forest - Water Quality, Water Capture and Supply
Hovde, B., Leitch, J. A. 1994. Valuing Prairie Potholes: Five Case Studies. North Dakota State University.	The value of wetlands has increased in recent years, with people acknowledging their economic, social, and environmental benefits. Yet, wetland degradation remains an important problem in many areas, including the Prairie Pothole region. This report estimates dollar values for flood risk reduction, soil erosion prevention, and recreation, among others. Total annual values ranged from US $4 per acre to US $373 per acre.	Wetlands - Soil Retention
Hughes, Z. 2006. Ecological and Economics Assessment of Potential Eelgrass Expansion at Sucia Island, WA. University of Washington.	This paper assess the benefits of establishing a "no-anchor" zone off Sucia Island in the San Juan Archipelago in Washington State, which would prevent disturbances to existing eelgrass beds and improve salmon habitat. The economic value of potential eelgrass expansion resulting from this action is estimated at US $1712/ha/yr using estimates of the contribution this expansion would provide to the commercial fishery.	Seagrass - Food, Habitat
Kline, J. D., Alig, R. J., Johnson, R. L. 2000. Forest Owner Incentives to Protect Riparian Habitat. Ecological Economics 33: 29-43.	Non-Industrial Private Forest (NIPF) land accounts for 36 percent of private timberland in Western Oregon and plays a large role in Coho salmon populations and habitats in this area. This study models NIPF owners' willingness to forgo timber harvest near riparian zones for 10 years. The authors use cluster analysis to group owners based on their land-use and ownership objectives. The study site covered in this survey comprises 38 counties in Oregon and Washington, all west of the Cascades. Methodology used was a randomized telephone survey of the NIPF owners. The authors found that the incentive payments necessary ranged from US $38-$137/acre/year, and the probability that the NIPF owner would forgo harvest ranged from 32 percent to 91 percent.	Forest - Habitat

Citation	Annotation	Ecosystem Services Values Used
Knowler, D.J., MacGregor, B.W., Bradford, M.J., Peterman, R.M. 2003. Valuing Freshwater Salmon Habitat on the West Coast of Canada. Journal of Environmental Management 69 261–273.	In this paper, the authors present a framework for valuing benefits for fisheries from protecting areas from degradation, using the Strait of Georgia Coho salmon fishery in southern British Columbia, Canada. Specifically, they use a bioeconomic model of the Coho fishery to derive estimates of value consistent with economic theory. In addition, they estimate the value of changing the quality of fish habitat by using empirical analyses to link fish population dynamics with indices of land use in surrounding watersheds. The estimated value of protecting habitat ecosystem services is C $0.93 to C $2.63 per hectare of drainage basin, or about C $1322 to C $7010 per km of salmon stream length. At this time, C $1.00 was equivalent to US $0.71.	Forest - Habitat
Laffoley, D., Grimsditch, G. (eds). 2009. The Management of Natural Coastal Carbon Sinks. IUCN, Gland, Switzerland. 53 pp.	This report investigates management of coastal carbon sinks around the world, including marshes, mangroves, seagrass, and kelp. Estimates for carbon sequestration and storage are summarized from the literature, finding that the carbon management potential of these systems is at least comparable to carbon sinks on land.	Seagrass - Climate Stability
Leschine, T. M., Wellman, K.F., Green, T.H. 1997. Wetlands' Role in Flood Protection. October 1997. Report prepared for: Washington State Department of Ecology – Northwest Regional Office, Bellevue, Washington. Publication No. 97-100. www.ecy.wa.gov/pubs/97100.pdf	This study highlights the importance of flood-mitigating wetlands in Western Washington. Because flood risk reduction is a public good, this study sheds light on the private decisions developers take that negatively impact social welfare. Study sites include Scriber Creek in Lynwood, a 5.1-mile-long stream emptying into a wetland of about 6.8 square miles in a highly urbanized and developing community. Flooding along the lowlands rivers and streams of Western Washington has increased in frequency. The authors estimate that the benefits of wetlands—based on the costs to substitute engineered flood protection measures—ranges from US $36,000 to US $51,000 per acre.	Wetlands - Disaster Risk Reduction
Liu, S., Liu, J., Young, C.J., Werner, J.M., Wu, Y., Li, Z., Dahal, D., Oeding, J., Schmidt, G., Sohl, T.L., Hawbaker, T.J., Sleeter, B.M. 2012. Chapter 5: Baseline Carbon Storage, Carbon Sequestration, and Greenhouse-Gas Fluxes in Terrestrial Ecosystems of the Western United States. In: Zhu, Z. Reed, B.C. (eds). Baseline and Projected Future Carbon Storage and Greenhouse-Gas Fluxes in Ecosystems of the Western United States. USGS Professional Paper 1797.	This chapter describes the modeling and analysis of baseline carbon storage and carbon flux across various biomes and land types throughout all of California, Oregon, Washington, Idaho, Nevada, Utah, Arizona and parts of Montana, Wyoming, Colorado, New Mexico, and Texas. Land-use and landcover mapping and modeling results are used to assess carbon stock, carbon flux, and greenhouse gas (GHG) flux in live biomass, soil organic carbon, and dead biomass. Changing land use, landcover, and fire modeling were taken into account and reported as the total CO_2 sequestered by landcover. The types of land modeled, in increasing order of carbon sequestered, are agricultural lands (seven percent), grasslands/shrublands (30 percent), and forests (62 percent). The average net carbon flux in terrestrial ecosystems in the Western U.S. was estimated as -86.5 TgC/yr (a carbon sink). The western cordillera (Western US mountains), accounted for 59 percent of this storage.	Grassland - Climate Stability; Shrubland - Climate Stability; Wetland - Climate Stability

Citation	Annotation	Ecosystem Services Values Used
Loomis, J.B. 2002. Quantifying Recreation Use Values from Removing Dams and Restoring Free-Flowing Rivers: A Contingent Behavior Travel Cost Demand Model for the Lower Snake River. Water Resources Research 38.	The authors present a travel cost demand model, using intended trips contingent upon dam removal and river restoration. This model is used as a tool for evaluating the potential recreational benefits of dam removal. The model is applied to the Lower Snake River in Washington using data from mail surveys of households in the Pacific Northwest region. Five years after dam removal, about 1.5 million visitor days are estimated, with this number growing to 2.5 million annually during years 20 to 100. If four dams are removed and 225 km of river are restored, the annualized benefits at a 6.875 percent discount rate would be US $310 million.	Water - Recreation and Tourism
Losey, J., Vaughan, M. 2006. The Economic Value of Ecological Services Provided by Insects. American Institute of Biological Sciences 56(4): 311-323.	This study sought to highlight the value of four vital ecological services provided by wild insects: dung burial, pest control, pollination, and wildlife nutrition. Economic value for these services is based on projections of losses predicted to accrue in the absence of these insects. The annual value of these services in the U.S. is estimated to be at least US $57 billion.	Cultivated - Biological Control, Pollination; Grassland - Biological Control
Mahan, B. L. 1997. Valuing Urban Wetlands: A Property Pricing Approach. Portland, Oregon: U.S. Army Corps of Engineers. Institute for Water Resources.	This report, prepared for the U.S. Army Corps of Engineers, explores several central questions relating to wetlands policy, especially regarding differences among heterogeneous wetlands. The authors set out to value wetland environmental amenities in the Portland, Oregon metropolitan area using the hedonic model. The findings show that wetlands have a significant influence on nearby residential property values; different types of wetlands have significantly different marginal implicit prices; and wetlands and non-wetland greenspaces (e.g. public parks, lakes, or rivers) have significantly different marginal implicit prices.	Wetlands - Aesthetic Information
McKean, J. R., Johnson, D. M., Taylor, R. G. 2012. Three Approaches to Time Valuation in Recreation Demand: A Study of the Snake River Recreation Area in Eastern Washington. Journal of Environmental Management 112: 321-329.	This study uses three different approaches to the travel cost method to estimate non-fishing recreation value at Snake River reservoirs in Eastern Washington. Benefits per person per trip range from US $35 to US $90, depending on the method used.	Water - Recreation and Tourism
McPherson, E. G., Simpson, J. R., Peper, P. J., Maco, E., Xiao, Q. 2005. Municipal Forest Benefits and Costs in Five US Cities. Journal of Forestry 103(8): 411-416.	The authors estimate the benefits from community forests from cities in Colorado, Wyoming, North Dakota, California, and Arizona. The modeling tool STRATUM is used to estimate benefits of trees including energy savings, atmospheric carbon reduction, air quality improvement, stormwater runoff reduction, and aesthetics. These cities spent US $13 to US $65 annually per tree, but benefits gained range from US $31 to US $89 per tree.	Forest - Air Quality, Disaster Risk Reduction

Citation	Annotation	Ecosystem Services Values Used
Moore, R.G., McCarl, B.A. 1987. Off-Site Costs of Soil Erosion: A Case Study in the Willamette Valley. Western Agricultural Economics Association 12 (1): 42-49.	This study examined the marginal cost of sediment erosion in Oregon's Willamette Valley. Erosion costs related to water treatment, infrastructure maintenance, and hydroelectric generation were estimated at approximately US $5 million across the region. Infrastructure maintenance costs were highest, followed by water treatment costs.	Cultivated - Soil Retention; Forests - Soil Retention
Netusil, N. R. 2006. Economic Valuation of Riparian Corridors and Upland Wildlife Habitat in an Urban Watershed. Journal of Contemporary Water Research and Education 134(1): 39-45.	This study uses a hedonic model to estimate the value of wildlife habitat and riparian corridors to single-family residential properties in Portland, Oregon. Proximity to streams increased home sales values by US $6,526 to US $6,988, and US $8,581 to US $10,720 for improvements in the quality of adjacent riparian corridors.	Water - Aesthetic Information
Nowak, D. J., Hoehn, E., Crane, D. E., Stevens, C., Walton, T. 2007. Assessing Urban Forest Effects and Values. United States Forest Service (USFS).	This analysis focused on the benefits of tree cover in San Francisco, California. Ecosystem services valued include carbon storage, carbon sequestration, and air pollutant removal. The total value of these services is estimated at US $1.7 billion for the city.	Forests - Air Quality
Podolak, K., D. Edelson, S. Kruse, B. Aylward, M. Zimring, and N. Wobbrock. 2015. Estimating the Water Supply Benefits from Forest Restoration in the Northern Sierra Nevada. An Unpublished Report of The Nature Conservancy Prepared with Ecosystem Economics. San Francisco, CA.	This study explored whether increased investment in forest and meadow restoration in the Sierra Nevada mountains could increase and enhance California's water supply. The analysis synthesizes potential water yield impacts from forest thinning from over 150 studies, finding that a three-fold increase in forest restoration could yield up to six percent more in mean annual streamflows. Market rates are used to value these benefits. Depending on the watershed, benefits of increased water yield could be as much as US $415 million.	Forest - Water Capture and Supply
Poppe, K., Rybczyk, J. 2019. A Blue Carbon Assessment for the Stillaguamish River Estuary: Quantifying the Climate Benefits of Tidal Marsh Restoration.	This report summarizes a multi-year project funded by the Washington Sea Grant program assessing the carbon stock and sequestration potential of restored and natural salt marshes in the Stillaguamish River Delta and Estuary. Field measurements found that the mean rate of carbon sequestration for restored marshes was 230 grams of carbon per square meter per year.	Wetland - Climate Stability

Citation	Annotation	Ecosystem Services Values Used
Rein, F.A. 1999. An Economic Analysis of Vegetative Buffer Strip Implementation. Case study: Elkhorn Slough, Monterey Bay, California. Coastal Management 27(4): 377-390.	This study investigates the economics of implementing vegetative buffer strips as a tool to protect water quality from nonpoint pollution in Elkhorn Slough, California's first National Estuarine Research Reserve. It evaluates environmental costs and benefits of implementing vegetative buffer strips, both to the grower and to society as a whole, as a means of capturing non-market ecosystem values and informing decision making. Benefits evaluated include tourism, commercial fisheries, long-term road maintenance, and harbor protection, using replacement cost and market pricing methods. Results indicate a net economic benefit for growers to install vegetative buffer strips within the first year, when the costs of erosion are considered. Buffer strips also protect water quality and preserve soil fertility. A number of policy tools to encourage the implementation of vegetative buffer strips are discussed, including tax incentives and legislative policies. Government intervention through incentive-based programs is advocated due to the economic and ecologic benefits to society.	Grassland - Biological Control, Disaster Risk Reduction, Soil Retention, Water Quality
Shaikh, S., van Kooten, G. C. 2007. Are Agricultural Values a Reliable Guide in Determining Landowners' Decisions to Create Forest Carbon Sinks?. Canadian Journal of Agricultural Economics 55: 97-114.	This study investigated farmer participation in programs for agricultural tree plantations. A discrete choice survey determined the probability and willingness to accept compensation for participating in the program. The median one-time willingness to accept the program was about US $33 per acre.	Forest - Existence Value
Smith, J.E., Heath, L.S., Skog, K.E., Birdsey, R.A. 2006. Methods for Calculating Forest Ecosystem and Harvested Carbon with Standard Estimates for Forest Types of the United States. USDA Forest Service Northeastern Research Station, General technical report NE-343.	This study seeks to fully account for all carbon stored throughout the lifetime of forests and forest products in the US. The authors identified 10 regions, 51 forest types, and six forest ecosystem carbon pools. Two separate tables were developed for afforestation and reforestation. Multiple tables are presented estimating the carbon sequestration for forest ecosystems within the United States. Wood products are often considered to be an immediate carbon loss, but may in fact be kept out of the atmosphere for years, or even decades.	Forest - Climate Stability
TCW Economics. 2008. Economic Analysis of the Non-Treaty Commercial and Recreational Fisheries in Washington State. December 2008. Sacramento, CA. With technical assistance from The Research Group, Corvallis, OR.	This report highlights the economic importance of non-treaty commercial and recreational fisheries in Washington state. Conclusions are drawn from state databases on harvests and licenses. In total, non-treaty commercial fisheries and recreational fisheries contribute US $38 million and US $424 million in net economic values in the state.	Water - Food, Recreation and Tourism
Trust for Public Land. 2011. The Economic Benefits of Seattle's Park and Recreation System. Trust for Public Land, Seattle, WA. Available at: http://cloud.tpl.org/pubs/ccpe-seattle-park-benefits-report.pdf	This study assesses seven major factors to determine the value of Seattle's parks system, which includes more than 5,400 acres within city boundaries. The study assessed effects on nearby home prices, tourism, direct use, health, community cohesion, clean water, and clean air. Property tax and tourists' sales tax provide direct income to the city's treasury. Recreation on Seattle's public lands yields direct consumer surplus, and health benefits from recreation and cleaner air.	Grassland - Water Quality

Citation	Annotation	Ecosystem Services Values Used
van Kooten, G.C., Bulte, E.H. 1999. How Much Primary Coastal Temperate Rain Forest Should Society Retain? Carbon Uptake, Recreation, and Other Values. Canadian Journal of Soil Science 29(1): 1879-1890.	This study estimates the value of non-timber forest products, recreation, existence value, and carbon sequestration from preserving old growth forests in British Columbia, Canada. The authors infer values based on previously published studies and government reports, estimating that non-timber forest products provide an annual benefit of US $3.20 per hectare, recreation provides an annual benefit of US $105.51 per hectare, and annual carbon uptake benefits range from US $19.80 to US $244.80 per hectare.	Forest - Existence Value, Food
Wallmo, K., Lew, D. K. 2011. Valuing Improvements to Threatened and Endangered Marine Species: An Application of Stated Preference Choice Experiments. Journal of Environmental Management 92: 1793-1801.	The authors design a choice experiment to estimate willingness-to-pay values for improving the endangered species listing status of three Endangered Species Act-listed species in the United States. Results suggest that survey respondents had distinct preferences for each species as well as the level of improvement to their status. The willingness to pay for Puget Sound Chinook salmon recovery was used, estimated at US $46.95 per household per year.	Water - Habitat
Walls, T. 2011. Appendix C: Salmon Productivity Calculations for Smith Island Restoration Project. Snohomish County Public Works.	This report provides an order-of-magnitude estimate of gains in returning salmon from the Smith Island Restoration Project, a component of the Snohomish River Basin Salmon Conservation Plan in Washington State. The author estimates a 31 percent increase in the returning adult spawning population over four years, relative to the average. This increase is valued using the average retail price per pound, totaling US $184,815 per year.	Wetlands - Habitat
Wang, Y., Neupane, A., Vickers, A., Klavins, T., Bewer, R. 2011. Ecosystem Services Approach Pilot on Wetlands. Alberta Environment and Sustainable Resource Development.	The Ecosystem Services Approach Pilot on Wetlands was initiated as a short-term goal of the Alberta Environment and Sustainable Resource Development's strategy for integrating ecosystem services into governance, policy, and programs in Alberta. The project sought to document approaches and gaps for valuation of ecosystem services. Aesthetic value, recreation, carbon storage, water quality, and flood risk reduction were estimated for three different case studies in Alberta.	Wetlands - Aesthetic Information
Weinerman, M., Buckley, M., Reich, S. 2012. Socioeconomic Benefits of the Fisher Slough Restoration Project. ECONorthwest.	This report estimates the benefits of the Fisher Slough Tidal Marsh Restoration Project within the Skagit River Delta in northwestern Washington State. The project restored marshes, improved fish passage, and increased flood storage capacity to reduce flood damage. The authors quantified benefits by estimated avoided and replacement costs for the project benefits. Over 20 years, the project is estimated to produce US $6.4 million in benefits from improved natural capital.	Wetlands - Water Capture and Supply

Citation	Annotation	Ecosystem Services Values Used
Woodward, R., Wui, Y. 2001. The Economic Value of Wetland Services: A Meta-Analysis. Ecological Economics 37(2): 257-270	This meta-analysis of 39 studies evaluates the relative value of different wetland services, sources of bias in wetland valuation, and returns-to-scale for wetlands. The authors estimated per-acre benefits for flood risk reduction, water quality, recreation activities, commercial fishing, storm buffering, and habitat. They concluded that the value of wetlands is highly dependent on site-specific traits, and that estimates from one wetland valuation may not be applicable to another.	Wetlands - Recreation and Tourism
Yuan, Y., Boyle, K. J., You, W. 2015. Sample Selection, Individual Heterogeneity, and Regional Heterogeneity in Valuing Farmland Conservation Easements. Land Economics 91(4): 627-649.	This study investigates preferences for farmland conservation easements in the United States using a choice experiment. Results show that on a national scale, people are willing to pay 78.36 per household to preserve farmland with easements.	Cultivated - Existence Value

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