Nature's Value in Island County

Identifying the Economics Behind a Healthy Puget Sound

Whidbey Basin | 2022

EARTH ECONOMICS

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Introduction

The lands and waters of Island County are important to food production, employment, and recreational opportunities, and they provide indirect benefits, such as water and air filtration; disaster risk reduction; and fish and wildlife habitat. These are referred to as ecosystem services.

To communicate the value of protecting and restoring Island County ecosystems, Earth Economics conducted an aquatic and landcover-based ecosystem services valuation (ESV) of the non-market value[i] provided by ecosystems throughout the county, as well as other watersheds known to impact water quality within Water Resource Inventory Area 6 (WRIA 6), whose boundaries coincide with Island County. We further estimated how landcover and land use changes between 1992 and 2016 may have affected the value provided by nature.

We chose WRIA 6 as a case study because much of it falls entirely within the Salish Sea itself, and because its water quality is affected not only by land use and practices within Island County, but also those of other upstream WRIAs, whose rivers, streams, and frontage drainages flow into the Whidbey Basin and Port Susan. Perhaps more than any other WRIA in the state, WRIA 6 exemplifies the challenges associated with transboundary resource management (see Table 1).

An initial goal was to assess the effect of land use policies—largely via the policies spurred by Washington State's adoption of the Growth Management Act (GMA) framework[ii]—on water quality in WRIA 6.

Unfortunately, while water quality within WRIA 6 (and Puget Sound overall) has been extensively studied and modelled, historical zoning records were not readily available. After several months of research, we determined that no clear, comprehensive record of historical zoning exists, and that constructing such a dataset would likely require years of focused archival research—far beyond the resources of this project.

Moreover, in reviewing recent zoning determinations, we learned that formal zoning rules are often a starting point for defining acceptable land uses. In practice, questions regarding accepted site-level land use appear to be resolved through the courts, where landowners often appeal initial zoning designations. Determining the magnitude and distribution of these negotiated land uses is likewise well beyond the scope of this project.

However, while it proved infeasible to attempt to link the GMA and zoning policies to actual land use, it is still possible to identify changes to landcover over time. Although research into the GMA's effects on landcover, land use, and environmental impacts is surprisingly limited, the somewhat extensive research on Puget Sound water quality allows us to infer major drivers of water quality change within WRIA 6. Unsurprisingly, transboundary factors end up significantly influencing water quality in both the Whidbey Basin and Port Susan estuaries.

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i Non-market goods and services are not traded directly in markets; their value must be estimated indirectly (e.g., what a person is willing to pay for the good or service).

ii The Growth Management Act (GMA) is a 1990 Washington State law requiring municipal and county governments to develop policies that identify and protect critical environments and natural resource lands, largely by delineating urban growth areas and developing comprehensive land use zoning policies. The Act is intended to protect quality of life throughout the state, promote sustainable economic development, and limit impacts on the natural environment. See https://apps.leg.wa.gov/rcw/default.aspx?cite=36.70a.

Defining the Study Area

We chose to expand the study area beyond the boundaries of WRIA 6 because there are significant areas of the mainland which contribute to water quality issues within the basin—inland watersheds that ultimately drain into WRIA 6 waters extend more than 6,000 square miles, over 17 times the total area of Island County. Transboundary contributions are even more considerable when looking at stream length. Island County represents barely over half of one percent of all rivers and streams contributing to WRIA 6 waters (see Table 1), with several inland rivers dwarfing Island County streams in total waterflow. The upper reaches of these inland waterways extend into Canada.

Table 1. Watersheds and streams contributing to WRIA 6 waters

WRIA	Basin	Area (mi^2)	% Area	Total Stream Length (mi)	% Total Stream Length
3	Lower Skagit and Samish	428	6.2%	1,131	3.6%
4	Upper Skagit and Sauk	2,445	35.6%	12,554	40.0%
5	Stillaguamish	720	10.5%	3,430	10.9%
7	Skykomish	832	12.1%	4,872	15.5%
	Snohomish	1,907	27.7%	8,835	28.2%
8	Cedar and Sammamish	42	0.6%	50	0.2%
9	Duwamish-Green	3	0.04%	0	0.0%
15	Kitsap	102	1.5%	243	0.8%
17	Quilcene-Snow	46	0.7%	69	0.2%
6	**Island**	**347**	**5.1%**	**198**	**0.6%**

Yet, including the full extent of the drainages or streams which contribute to WRIA 6 basins seems overly inclusive, given that some factors known to affect water quality are also known to be more localized due to a range of natural processes (e.g., filtration, sedimentation, dilution). In an attempt to account for such factors, we limited the inland streams to the east of WRIA 6 (e.g., those on the mainland of the state) to stream order eight[iii] and below, and then included only the sub-watersheds (HUC12-level[iv]) directly adjacent to those streams or WRIA 6 waters (i.e., drainages along Skagit Bay, Port Susan, or the section of Admiralty Inlet along Whidbey Island's western shore). Because Admiralty Inlet (the passage to the west of WRIA 6), the Strait of Juan de Fuca, and even the upper reaches of the Central Basin are both deeper than the semi-closed basins of WRIA 6 (Skagit Bay and Port Susan) and far more subject to tidal flushing,[1] we chose to omit the streams and sub-watersheds outside of WRIA 6 that contribute directly to its waters. Figure 1 shows the final boundaries of the study area, selected as the drainages and surface waters most likely to impact water quality within WRIA 6.

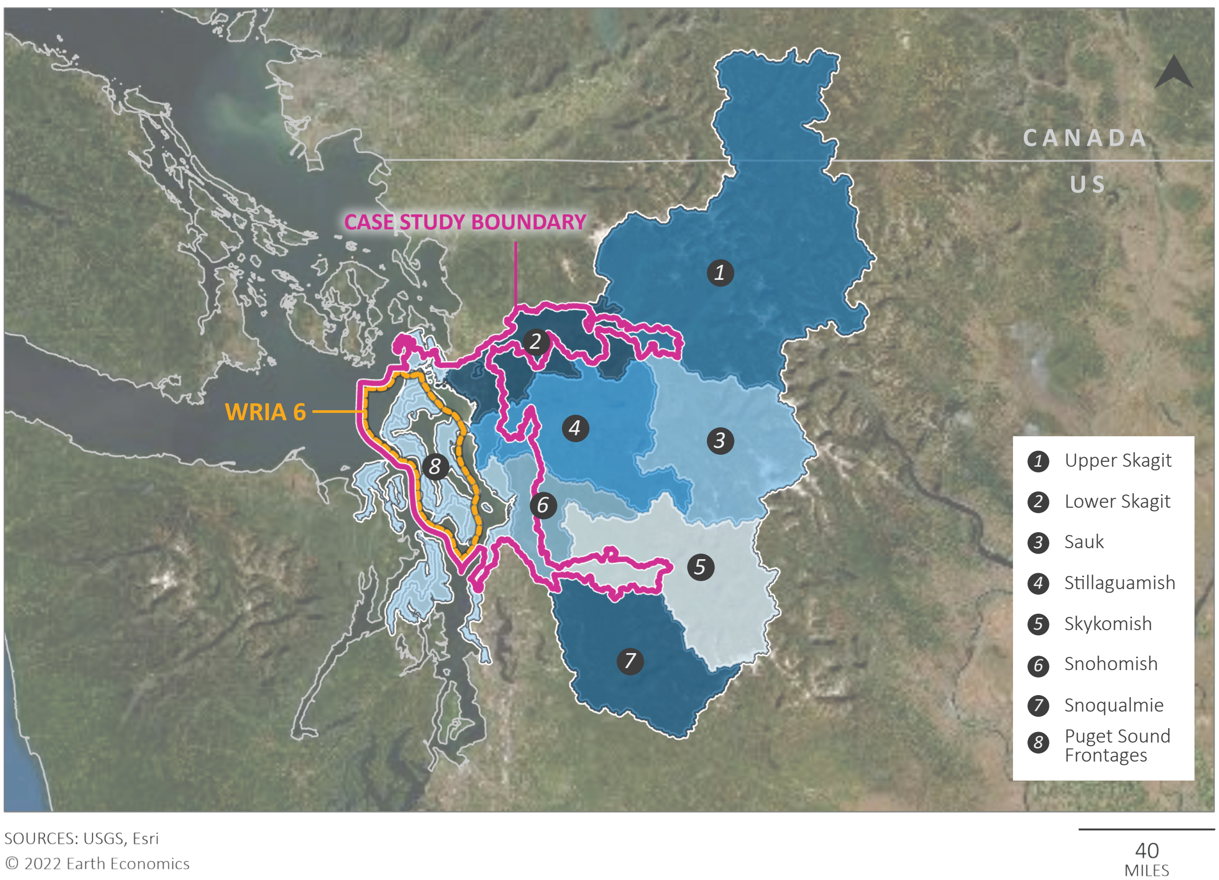
iii Stream order is a measure of classifying streams by their number of tributaries. First-order streams refer to small headwater streams which have no drainages into them, while larger order streams have many tributaries draining into them.

iv Within the National Hydrology Dataset, Hydrological Unit Codes (HUCs) refer to various scales of drainages into surface waters. The codes are nested, in that HUCs beginning with the same digits are part of the same drainage system. For example, the Bacon Creek sub-watershed (171100050903) falls within the sub-basin of the Upper Skagit (HUC 17110005) and contributes to the Puget Sound Basin (HUC 171100), which is part of the larger Pacific Northwest drainage region (HUC 17).

Table 2. Watersheds and streams within the study area

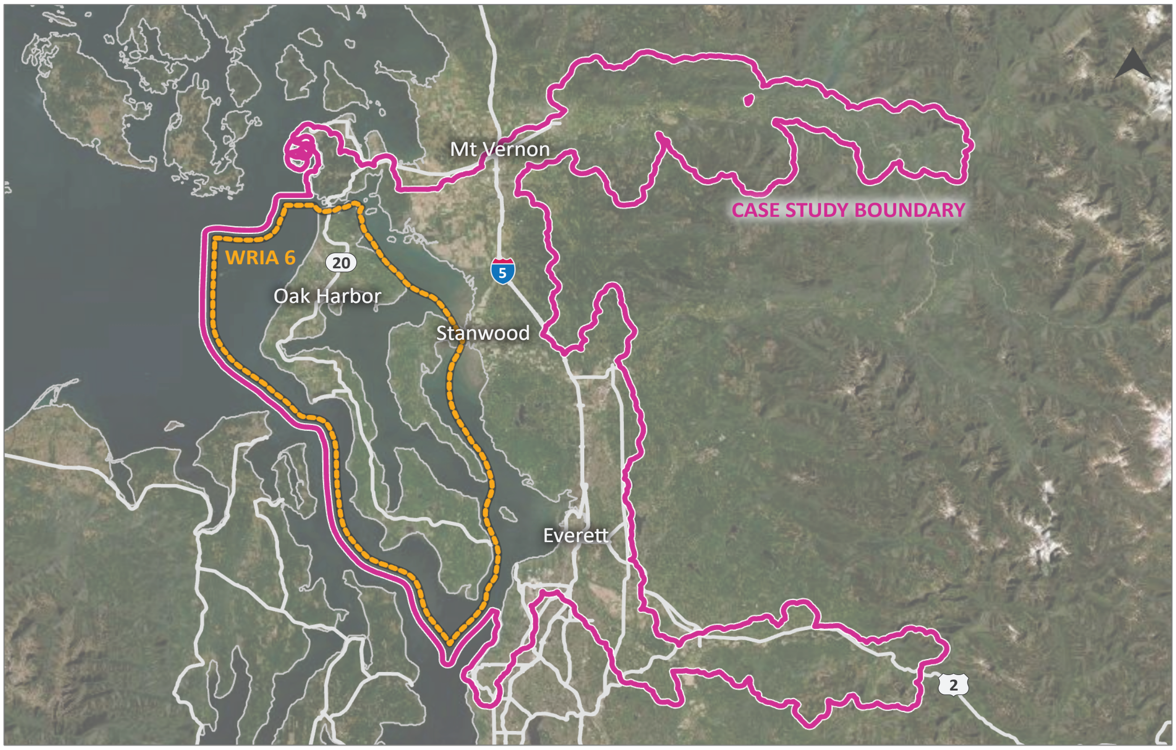
WRIA	Basin	Area (mi²)	% Area	Total Stream Length (mi)	% Total Stream Length
3	Lower Skagit	275	24.1%	1,469	37.5%
4	Upper Skagit	44	3.9%	511	13.0%
5	Stillaguamish	88	7.7%	366	9.3%
7	Skykomish	105	9.2%	405	10.3%
	Snohomish	131	11.5%	902	23.0%
	Puget Sound Drainages	152	13.3%	68	1.7%
6	Island	347	30.4%	198	5.0%

Figure 1. Drainages contributing to WRIA 6 waters vs the final ROI



SOURCES: USGS, Esri

Figure 2. Case study boundaries



We identified the type and extent of ecosystems within the study area using the landcover classifications of NOAA's Coastland Change Analysis Program (C-CAP) Regional Landcover and Change data set,[2] which offers 30-meter resolution (approximately 1/5th of an acre) data for five-year periods between 1992 and 2016. We applied a modified C-CAP classification framework (see Table 3) as a proxy for ecosystem types, function, and general productivity.

Table 3. Landcover categories and sources

Landcover Class	Description and Sources
Barren	C-CAP bare and unconsolidated shoreline that do not overlap Washington Department of Health (WDOH) shellfish beach data
Shellfish beaches	C-CAP bare and unconsolidated shore landcover classes that overlaps with WDOH shell-fish beach data
Cropland	Merges C-CAP cultivated and pasture/hay landcovers
Developed	C-CAP high, medium, and low-intensity developed areas
Estuary	C-CAP estuarine aquatic bed within the Salish Sea
Forests	C-CAP deciduous, evergreen, and mixed forests
Lake, River	C-CAP surface waters within lakes and ponds of the National Hydrology Dataset (USGS)
Grassland	C-CAP grasslands
Shrubland	C-CAP scrub/shrub
Wetlands	C-CAP wetland classes (all fresh and estuarine)

Even after limiting inland contributions to those watersheds and streams most likely to directly impact water quality in WRIA 6, inland drainages still form over 60 percent of the total study area. The inland basin is dominated by forests (41 percent), while the estuaries of Skagit Bay, Port Susan, and Admiralty Inlet cover over 54 percent of WRIA 6 (see Table 4).

Across the full study area, forests as defined by C-CAP cover nearly a third, and estuaries over a quarter. Urbanized and built-up areas are also a significant portion of both WRIA 6 and the inland basins, covering approximately 9.6 percent and 18.5 percent, respectively. Developed land does not produce ecosystem goods or services, and higher proportions of impervious surfaces are known to have a significant effect on water quality.[3] Croplands (not including commercial forestry) are also extensive, at just over 10 percent of the total study area.

Table 4. Landcover within the study area (acres)

CCAP Landcover[4]	Inland Basins	WRIA 6	Study Area
Bare	24,972	13,204	38,176
Beach	140	195	335
Beach (shellfish)	42	641	683
Cropland	74,085	16,557	90,642
Estuary	43,004	185,696	228,700
Forest, deciduous	36,670	9,354	46,024
Forest, evergreen	129,051	38,893	167,944
Forest, mixed	55,922	20,704	76,626
Grassland	7,804	3,269	11,073
Lake	2,234	912	3,145
River	9,716	339	10,055
Seagrass	0	11,183	11,183
Shrubland	27,832	4,232	32,064
Urban	99,939	32,932	132,870
Wetland, estuarine	4,199	457	4,656
Wetland, freshwater	23,683	4,957	28,640
Total	***539,292***	***343,525***	***882,816***

Ecosystem Goods and Services: Benefits Provided by Nature

Nature provides fish and wildlife habitat; natural resources such as wood, water, and minerals; medicines; protection from flooding and poor air quality; and a range of other benefits that also support human well-being. From an economic perspective, aquatic and terrestrial (land) ecosystems are often referred to as *natural capital*, and the benefits produced by ecosystem functions are known as *ecosystem goods and services*. Table 5 provides definitions of the ecosystem services considered in this report.

Table 5. Definitions of ecosystem services

Service	Economic Benefit to People
Provisioning	
Energy, 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, Seed Disper-sal	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, 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 commercial and recreational vessels

Service	Economic Benefit to People
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, Education	Using natural systems for education and scientific research
Recreation, Tourism	Experiencing the natural world and enjoying outdoor activities

While some ecosystem services are processed, packaged, and sold in markets, the full value of such benefits are rarely reflected in markets, if at all. Accordingly, they are often overlooked. Where such omissions lead to the degradation (or displacement) of whole ecosystems, the loss of ecological function may cause increased flooding, diminished aesthetics, or a need for technological replacements (e.g., water treatment plants) at far greater costs.[5]

A 2021 comparison of the costs of nature-based solutions and built infrastructure revealed that nature-based approaches returned $10 for every dollar invested, compared with $3.6 for built infrastructure. On average, nature-based solutions are half as expensive as built infrastructure, but provide 29 percent more value, largely as co-benefits (e.g., improvements to air and water quality, as well as fish and wildlife habitat). See Bassi et al., 2021.

Methodology for Estimating the Value of Non-Market Benefits

Discussions and analysis of land use and related decisions are framed and underpinned by budget, cost, and return-on-investment concepts. When non-market values are omitted, ecosystem goods and services are often treated as having little or no value, when in fact their value is significant. People have many ways for valuing nature, but economic assessments can be critical for including nature in decision-making processes in a meaningful way.

To estimate the value of non-market benefits of ecosystem goods and services, we applied the benefit transfer method (BTM), by which primary valuation research on goods and services provided by similar ecosystems in similar contexts (e.g., location, climate, proximity to coasts) are "transferred" to similar settings in the study area.[6]

This approach has the benefit of providing reasonable, broad-based estimates at a much lower cost than would be required to conduct primary research on multiple ecosystem services. In the simplest form of BTM, non-market benefits are regularized to per-acre, per-year estimates, which are then scaled by the extent of each ecosystem (including contextual variables) to generate an estimate of the total annual value of nature within the study area.

It is important to note that because 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. That a specific combination of landcover and ecosystem service value has not been included in this report does not necessarily mean such a landcover does not produce a given service—or that the service is not valuable—but rather reflects a lack of appropriate source studies and data relevant to that combination. For this reason, some values may be underestimates. Additionally, caution should be exercised when comparing total ecosystem service 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. See Appendix 1 for a matrix of the landcover types and ecosystem service combinations valued in this report.

Some key ecosystem services found within the study area could not be quantified in this report. For example, coastal bluffs in the region naturally erode, providing material that nourishes and maintains beaches and other nearshore habitats, including eelgrass beds and salt marshes that serve as habitat for forage fish and the larger species such as salmon and whales that feed on them.

- Rarely quantified in the literature, nature is a source of artistic inspiration. Whidbey Island hosts a lively art community and has twenty art galleries showcasing local artists' paintings, sculptures, glass, and more.
- Another rarely studied but well-recognized ecosystem service value is people's sense of place—their perceptions, attachment, and identity as relates to the environment. A recent report surveyed Island County residents and found residents had a strong sense of place connected to shorelines and strongly negative responses to shoreline change.[7]
- Shellfish provide many ecosystem services: food, recreational fishing opportunities, and water quality improvement as filter feeding removes nutrients.
- See Appendix 1 for further details.

Non-Market Benefits

Overall, the terrestrial and aquatic ecosystems of the study area (as of 2016) are estimated to provide over $6.5 billion in ecosystem goods and services each year (see Table 6). All values are reported in 2021 US dollars.

Forests—especially evergreen forests, given their predominance in the landscape—provide over $4.9 billion in ecosystem services benefits each year and represent nearly three-quarters of all ecosystem benefits within the study area. Most of that value is produced in the inland basins, with the greatest value associated with aesthetic beauty, followed by water quality (i.e., water filtration). Across the full study area, forests provide important flood risk reduction and carbon sequestration services, followed by water capture, air quality, and habitat.

Freshwater wetlands also provide considerable value—nearly seven percent of the total value each year throughout WRIA 6 and the inland basins. Over four-fifths of that value is produced in the inland basin. Wetlands' most economically significant ecosystem services benefits are reduced flood risk, water quality, and water storage. The aesthetic and recreational value of running streams are also considerable, providing just under eight percent of all ecosystem service benefits each year. Virtually all of these streams are associated with inland basin rivers, which represent nearly 95 percent of all surface streams within the study area.

Croplands also contribute non-market benefits, providing nearly $221 million each year across the study area. Although croplands also significantly erode soils (causing annual losses of nearly $647 thousand), this impact is more than offset by other valuable ecosystem services, primarily habitat for beneficial species (biological control), as well as pollination and seed dispersal.

Overall, though WRIA 6 extends over nearly 40 percent of the study area, it provides only about one-fifth of the annual ecosystem services—though this is still nearly $1.5 billion per year. Though WRIA 6 forests are less extensive than in the inland basins, they contribute nearly four-fifths of the ecosystem services benefits within WRIA 6 each year, at nearly $1.2 billion. Again, most of this is tied to aesthetic benefits, but water filtration, disaster risk reduction, carbon sequestration, water capture, and wildlife habitat also add value.

As with the inland basins, freshwater wetlands also provide considerable value within WRIA 6, most of which is associated with water quality improvement and flood risk reduction—nearly $78 million combined each year. Grasslands provide over $66 million in benefits, largely through water filtration. Croplands are also an important source of ecosystem services. In spite of losing over $118 thousand to soil erosion each year, they still net over $40 million in annual benefits. Unsurprisingly, the WRIA 6 estuary—including eelgrass beds—provides nearly $99 million in value, mostly as fish habitat and refugia, but also through food, carbon sequestration, and recreation.

Table 6. Annual value of ecosystem goods and services by landcover type in 2016 (thousands 2021 US$)

CCAP Landcover	Inland Basins	WRIA 6	Study Area
Beach	$2,207	$3,067	$5,273
Beach (shellfish)	$661	$10,133	$10,793
Cropland	$180,804	$40,407	$221,212
Estuary	$19,237	$83,067	$102,303
Forest, deciduous	$615,815	$157,079	$772,894
Forest, evergreen	$2,201,111	$663,366	$2,864,477
Forest, mixed	$946,460	$350,406	$1,296,866
Grassland	$158,358	$66,338	$224,696
Lake	$1,565	$639	$2,204
River	$502,682	$17,547	$520,229
Seagrass	$0	$15,540	$15,540
Shrubland	$3,000	$456	$3,456
Wetland, estuarine	$65,907	$7,166	$73,073
Wetland, freshwater	$371,720	$77,800	$449,519
Total	***$5,069,526***	***$1,493,011***	***$6,562,537***

Aesthetic value—especially that of the inland basins' forests and waterways—was the largest single source of benefits, providing more than $3.4 billion in value in the inland basins, and over $4.4 billion throughout the study area. Just under 11 percent of the total non-market benefits provided throughout the study area (nearly $659 million each year) can be attributed to water quality improvements by various landcover types (see Table 7). This is unsurprising, given that we prioritized those locations most likely tied to water-related factors as we defined the study area. Most of the water quality services are produced by forests, grasslands, and wetlands, which are also important for carbon sequestration. The biological control provided by beneficial insect habitat—chiefly on croplands—provides nearly $166 million in annual value.

Table 7. Annual value of water quality improvements from ecosystem goods and services (thousands 2021 US$)

Ecosystem Service	Inland Basins	WRIA 6	Study Area
Aesthetic Information	$3,179,218	$911,334	$4,090,551
Air Quality	$49,085	$15,271	$64,355
Biological Control	$134,914	$30,982	$165,895
Climate Stability	$123,786	$42,985	$166,770
Cultural Value	$8,594	$13,786	$22,379
Disaster Risk Reduction	$265,948	$73,881	$339,828
Food	$2,984	$12,103	$15,086
Habitat	$58,143	$83,481	$141,622
Pollination, Seed Dispersal	$33,872	$7,571	$41,441
Recreation, Tourism	$259,709	$14,436	$274,144
Science, Education	$1,096	$342	$1,436
Soil Retention	$5,409	$2,281	$7,689
Water Capture, Conveyance, Supply	$62,975	$18,619	$81,593
Water Quality	$504,236	$154,574	$658,809
Water Storage	$4,052	$788	$4,838
Total	***$4,694,007***	***$1,382,419***	***$6,076,424***

We have presented these estimates to provide context for the changes in ecosystem goods and services driven by landcover and land-use change since 1992. It is important to understand that the value of some ecosystem services changes by context; for example, disaster risk reduction is more important for lands adjacent to urbanized areas. As development displaces natural ecosystems, the total value of ecosystem services may decline, but we would also expect the unit value of those services (e.g., aesthetic value) to increase as that benefit becomes relatively scarcer. This analysis does not account for such dynamics.

Estimating Changes in Ecosystem Goods and Services

By comparing differences in the value of ecosystem services across landcover types (e.g., forest vs. agriculture, grasslands vs. developed areas), one can gain a sense of the gains and losses associated with landcover change. For example, the non-market benefits associated with converting a forest to cropland can be estimated as the non-market benefits produced by the new landcover (cropland) minus those produced by the former landcover (forest).

Where new landcover types are estimated to produce less ecosystem services value than those they displace, the net effect is a decline in non-market benefits that we can associate with landcover change. Landcover change analysis can support focused comparisons of landcover change, zoning policy, growth projections, and other factors at multiple scales. It is especially effective at communicating the less visible (i.e., non-market) tradeoffs between alternative landcovers, in both unit terms (per-acre conversions), and at the scale of observed or expected changes.

However, change from one landcover to another doesn't characterize all the effects humans have on the environment. Ecosystems may remain, but with reduced health and productivity (e.g., pest outbreaks, shifts in climate). For example, invasive species often crowd out native vegetation, while being recognized as the same landcover type (e.g., invasive and native grasses).

Based on C-CAP landcover change data, which is available from 1992 to 2016, we calculated total acreage change from one landcover to another across the full timespan, and step-wise between each 5-year period. This allows us to identify the magnitude of landcover changes overall, as well as any periods during which landcover change increased or decreased following the development and implementation of GMA-driven zoning policies.

We categorized the ecosystem services that would directly affect—or be directly affected by—changes in water quality as "water quality-related services" In order to highlight those that could be especially sensitive to changes from natural landcover types to those that are known to negatively impact water quality (developed and cropland). Again, to estimate the impacts of landcover change on ecosystem goods and services, we multiplied these $/acre/year values by the acreage which changed from one landcover type to another in each five-year period.

Landcover Change from 1992 to 2016

Landcover change within WRIA 6 (in-basin) and inland portions of the study area (out-of-basin) led to a net loss of ecosystem goods and services, mostly from the conversion of natural landcover types (e.g., forests, grasses, shrublands) to cropland or developed areas. Figure 3 shows the extent of conversion from one landcover type to another between 1992 and 2016.

Figure 3. Extent of landcover change from 1992 to 2016 (acres)

1992 \ 2016	Barren	Beach	Cropland	Developed	Estuary	Forest	Fresh Water	Grassland	Shrubland	Wetland	Grand Total
Barren			13	518	282	264	518	35	113	125	1,867
Beach				6			1	1		0	7
Cropland	55	1		1,957		272	17	97	96	7	2,501
Developed	1		0			1		0	1	0	4
Estuary	4,801	1		3			10	1		56	4,872
Forest	435	1	2,159	9,690			149	2,325	5,699	81	20,539
Fresh Water	378	2	14	24	8	8		21	6	141	602
Grassland	40	1	199	2,223		3,132	18		1,740	3	7,356
Shrubland	41	0	179	1,267		4,287	16	212		2	6,005
Wetland	93		58	116		10	151	35	16		480
Grand Total	5,845	6	2,623	15,804	289	7,973	879	2,727	7,671	416	44,233

Some of these longitudinal landcover changes are undoubtedly due to natural processes—areas of forests disturbed by wildfire or blow-down may be temporarily dominated by grasses or shrubs until successional processes return those areas to forest. Commercial forestry can generate similar dynamics, where areas harvested for pulp or timber are managed to maintain forest resources over time. We were unable to account for natural disturbances and also opted to exclude lands zoned for commercial forestry due to the longer time period required for this type of analysis.

Conversion to cropland or developed areas is a type of human intervention that is less likely to recover in similar ways—forests cleared for row crops or subdivisions are unlikely to return to forest. Unfortunately, this is exactly where most of the landcover change occurred across the study area between 1992 and 2016. Over 40 percent of the non-commercial forestry landcover change involved a transition to either cropland or developed areas, with the latter responsible for well over a third of all landcover change over that period. Most of this occurred between 1992 and 1996—before the GMA was fully implemented. Forest losses to development or croplands steadily diminished each period, falling nearly two-thirds between 1996 and 2001.

Land Conversion Leads to Loss of Ecosystem Services

Translating these conversions of natural lands to the net value of ecosystem services reveals losses to cropland of more than $1 million since 1992. Converting natural lands to development (both within WRIA 6 and other contributing basins) produced a net loss of ecosystem services more than an order of magnitude greater—over $10.3 million, over two-thirds of which came from converting forests to developed land. While these numbers pale in comparison to the total non-market value of ecosystem goods and services in 2016 (all ecosystem services losses to landcover conversion amount to 5.6 percent of the 2016 total), it is important to remember that losses to development are unlikely to be reversed, and reversing losses to cropland would require significant and sustained restoration efforts.

Landcover change also produced a net loss for water quality-related ecosystem services value between 1992 and 2016. More than $312 thousand was lost due to conversion of grasslands and forests to cropland, and nearly $2.9 million to development. Figures 2 and 3 show the loss of ecosystem services value in each 5-year span due to conversion to development and cropland. Inland basins lost nearly $2.5 million in water quality-related ecosystem services to development, while WRIA 6 lost nearly $395 thousand.

Conversion to cropland produced over $240 thousand in losses across the inland basins, and nearly $72 thousand within WRIA 6 between 1992 and 2016. The following figures below show the estimated change in ecosystem services benefits due to conversion of forests to cropland and developed landcover within Island County over time (Figure 4), and the locations where such losses occurred (Figure 5).

Again, our initial intent was to attempt to explicitly connect landcover changes, both by location (relative to GMA zoning) and rate. Although we are able to make limited inferences based on the relative rates of change period-over-period, historical data on zoning boundaries were exceedingly difficult to locate, especially in formats conducive to geospatial analysis—we have seen little evidence that deprecated zoning maps are maintained for archival purposes, especially for the years immediately following initial GMA implementation. Moreover, it is common for zoning designations to be renegotiated with landowners, who argue that zoning negatively impacts their property values. A parcel-by-parcel review of de facto zoning designations was beyond our resources, but should such data become available in the future, this analysis could be revisited.

On the other hand, period-over-period landcover changes appear to show a clear correlation with the implementation of the GMA (see Figures 4 and 5), with the loss of ecosystem services prior to 1996 being considerably higher than in later periods. Yet there are at least two factors which might also affect these rate differences. First, early losses of natural ecosystems may be more or less irreversible, reducing the extent of natural ecosystems (of any form) available for conversion. Second, larger economic and social dynamics affect demand for housing, cropland, etc., as well as the availability of financial capital. Because such factors may drive immediate or delayed effects, and because four to five years pass between C-CAP data updates, any assumptions about the effects of zoning (or the GMA generally) should be treated with caution.

Figure 4. Total change in ecosystem services benefits from conversion to developed and cropland over time

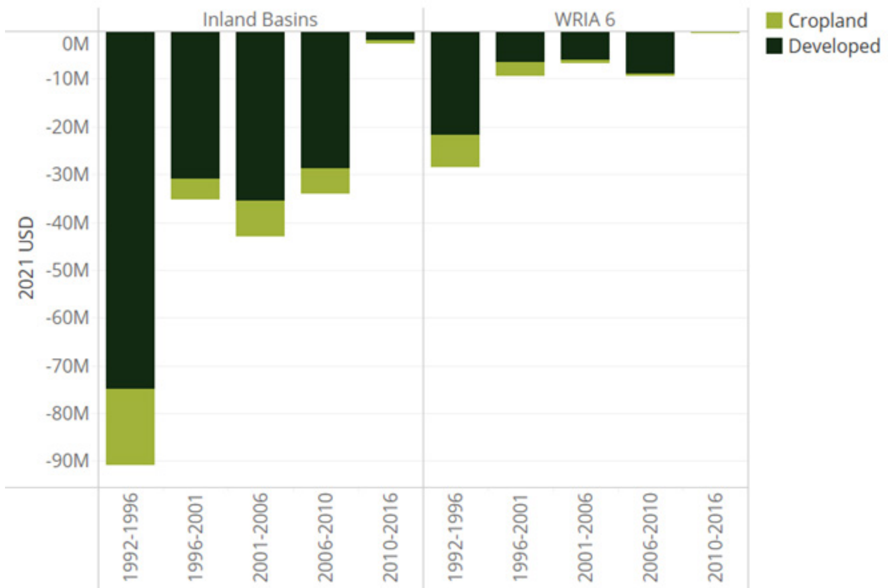
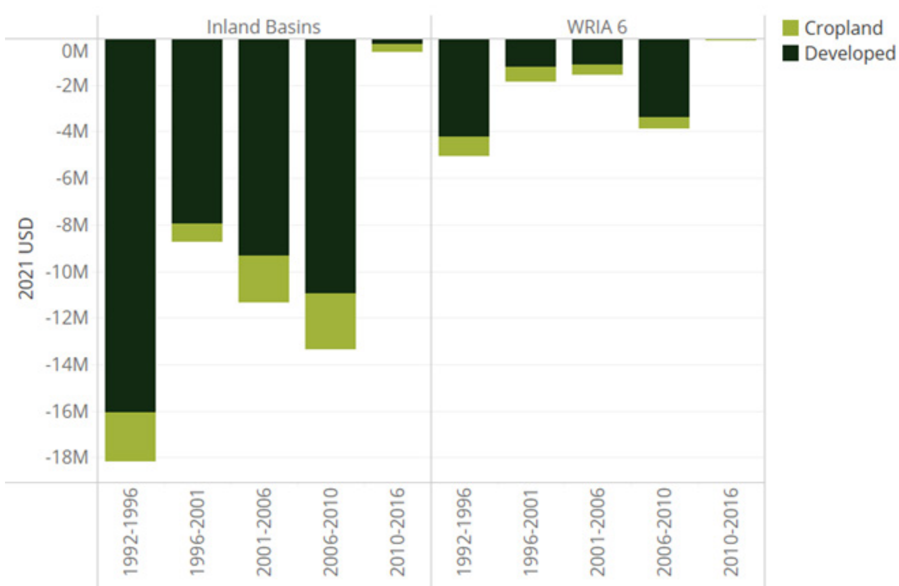


Figure 5. Total change in water quality-related ecosystem services value from conversion to developed and cropland over time



Tree Removal within Island County: A High-Resolution Analysis

To better understand the scale of forest-related ecosystem services due to conversion to other land uses, we analyzed the high-resolution change detection (HRCD) data set within Island County. At one meter resolution, this data set captures changes in tree cover and impervious surfaces—and the corresponding drivers of change, including development, commercial forestry, and natural causes—between 2006 and 2017.[8] We summarized the magnitude of these anthropogenic factors in Table 8. Locations where the driver of change has been identified as "tree removal" signify tree felling that could not be conclusively associated with commercial forestry, development, or similar activities.

Table 8. Acres of tree loss in Island County from 2006 to 2017, by change agent

Driver[v]	2006-2009	2009-2011	2011-2013	2013-2015	2015-2017	*Total*
Development	328	52	31	108	55	573
Forestry	125	0	463	239	0	827
Tree Removal	744	356	240	660	1,360	3,360
Total	***1,197***	***408***	***734***	***1,007***	***1,415***	***4,760***

Island County has over 140 thousand acres of forests—about 40 percent of all land within the county— that are both culturally and economically important to residents. Earlier, we estimated that Island County forests provided approximately $154 million in non-market benefits in 2016 (see Table 6). Almost a quarter of this value comes from the critical role forests play in climate change mitigation by sequestering and storing carbon from the atmosphere. We estimated carbon sequestration by WRIA 6 forests based on a study by Smith et al. (2006)[9] of the carbon stored throughout the lifetime of forests and forest products. The Social Cost of Carbon (SCC), estimated at $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.[10] Island County forests provide over $36 million in climate stability benefits each year.

When trees are removed and converted to housing, commercial development, or other impervious surfaces, it is reasonable to assume such changes are permanent. Even if these areas were replanted, it would take decades to regrow trees to the level of those removed, depending on the size and species of trees removed. Between 2006 and 2017, trees were removed from 573 acres in both urban and rural areas for development purposes—nearly 73 percent of which occurred in areas zoned as rural.

This still accounts for just 0.4 percent of all rural land in the county (about 108,000 acres), whereas urban tree removal accounted for 2 percent of all urban areas (about 6,400 acres). It is important to note that the ecosystem services provided by trees and forests tend to be valued higher when they are in close proximity to communities, both rural and urban.

While we were unable to account for this value difference in this study (due to the limited data available for the location of rural and urban areas from 1992 to the present), this difference in value is real. Accordingly, the loss of 573 acres of forests to development is likely to have resulted in ecosystem services losses of higher value than the baseline estimates presented in Table 6 suggest.

Forests across the county provide a broad range of benefits, supporting the economic and social well-being of both forest owners and communities nearby, downstream, and beyond. And while commercial forests are primarily managed for the production of wood and paper products, many owners of small, non-commercial forests manage for other ecosystem functions, as well. Over 60 percent of the forests throughout the study area are non-commercial; this proportion rises to 83 percent within WRIA 6. Only by understanding the

v The HRCD User Guide defines drivers as: 1) DEVELOPMENT: new impervious surface (e.g., buildings, paved roads, other permanent structures), or conversion to a well-defined compacted parking area or driveway (usually gravel), excluding non-permanent structures (e.g., greenhouses, RVs); 2) FORESTRY: removal of a large area of canopy for commercial use and determined not likely to be a precursor to development, using contextual clues (e.g., location relative to urban areas, forestry roads); 3) TREE REMOVAL: likely human removal of relatively small areas of canopy, excluding tree removal for obvious commercial use (e.g. forestry, timber sale). See WDFW 2017.

immense value of ecosystem services that these lands provide can landowners, elected officials, and other stakeholders manage and regulate the stewardship of the region's forests to maximize their economic, social, and environmental benefits—benefits on which everyone relies.

Conclusion

As of 2016, the ecosystems within the study area produced over $1.4 billion in non-market benefits each year. This is quite likely an underestimate, as the value of several ecosystem goods and services known to be produced by landcovers within the study area have not been reported in the valuation literature.

Moreover, most impacts on WRIA 6's water quality stem from land uses in the inland basins—80 percent of the lost value in water quality-related ecosystem services (over $48.6 million of nearly 60.8 million) was associated with landcover change in the inland basins between 1992 and 2016. Even though most WRIAs have been delineated based on river systems, water quality in Island County waters (coterminous with WRIA 6) depends in part on upstream land uses in other WRIAs. Accordingly, policy makers within Island County are somewhat limited in their ability to improve water quality in Skagit Bay and Port Susan and would need to collaborate with neighboring jurisdictions. This is a persistent challenge throughout Puget Sound and the Salish Sea, as political boundaries and policy jurisdictions rarely conform to ecological units.

That said, it appears that the GMA may have limited the conversion of natural lands to development throughout the study area, even accounting for larger social and economic dynamics. The largest loss of ecosystem services benefits occurred between 1992 and 1996, before the GMA was fully implemented.[vi] No period since has produced even half the losses of that initial period. Though some of this may be due to the reduced availability of natural lands for conversion in latter periods, and the larger social and economic dynamics that affect urban and rural growth, applying zoning at the county level is a plausible explanation for lower conversion rates.

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; mitigation of natural disaster risks; limiting the global impacts of climate change; and several 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 rely on a combination of individual responsibility, public land use policies and zoning, regulation, both public and private investment, and appropriate application and enforcement of existing laws, including state forest practices. Sustaining the high quality of life enjoyed throughout the study area and beyond will rely on sustaining the quality and extent of these ecosystems.

[vi] Freeland (Whidbey Island) was initially designated as a Rural Area of More Intensive Development (RAID), but that was appealed to the Western Washington Growth Management Hearings Board, which found the RAID designation did not comply with the GMA. In 2000, the County was ordered to reassess Freeland's zoning status; it was designated as Non-Municipal Urban Growth Area (NMUGA) in 2007. During 2016 Comprehensive plan update, the Freeland NMUGA was reduced by 78 percent, following a community request to shift growth from rural to urban areas. See www.islandcountywa.gov:443/Pages/Home.aspx.

Endnotes

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Appendix 1: 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 does not include the value of all ecosystem services likely to be produced throughout the study area. We identified multiple gaps in the supporting literature: for example, we had no studies of the value of air purification other than for forests. While we know other landcovers are likely to produce significant air purification benefits, we were unable to generate monetary estimates for these and other ecosystem services. Other ecosystem services, though widely recognized as valuable, are difficult to translate to monetary terms (e.g., cultural and existence value).

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 NOAA's Coastal Change Analysis Program (C-CAP) landcover data set, which is produced at 30-meter resolution (approximately one-fifth of an acre). Changes in landcover below that scale may not be reflected in such data. Moreover, because C-CAP (and similar) landcover data are updated once every five years, annual changes to landcover may not be fully apparent. The same could be said of the 1-meter HRCD dataset.

Table 9. Ecosystem services valued in this report

Ecosystem Service	Beach	Beach (Shellfish)	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, Seed Dispersal			■	▨	▨	▨		▨		▨	
Recreation and Tourism	▨	■		■	■	■	■	■			■
Science and Education	▨	▨	▨	▨	■	▨	▨	▨	▨	▨	▨
Soil Retention			■		■	■				▨	■
Water Capture, Conveyance, Supply					■	▨		▨		▨	■
Water Quality			▨		■	■			▨	▨	■
Water Storage				▨	▨	▨	▨	▨		▨	■

KEY

■	Produced by landcover, valued in this report
▨	Produced by landcover, not valued in this report
	Not valued in this report

Appendix 2: Landcover Changes and the Value of Ecosystem Services

Table 10. Net ecosystem services value from conversion of landcover types to cropland and urban/built landcover (2021 US$)

Location	Period	Change To	Change From	Net ESV	Period Effect
WRIA 6	1992-1996	Cropland	Barren	$2,689	0.01%
WRIA 6	1992-1996	Cropland	Forest	-$6,794,299	23.59%
WRIA 6	1992-1996	Cropland	Grassland	-$35,400	0.12%
WRIA 6	1992-1996	Cropland	Shrubland	$1,542	0.01%
WRIA 6	1992-1996	Developed	Estuary	-$98	0.00%
WRIA 6	1992-1996	Developed	Forest	-$18,373,297	63.79%
WRIA 6	1992-1996	Developed	Grassland	-$3,594,740	12.48%
WRIA 6	1992-1996	Developed	Shrubland	-$10,423	0.04%
WRIA 6	1996-2001	Cropland	Barren	$23,125	0.24%
WRIA 6	1996-2001	Cropland	Forest	-$2,540,283	26.57%
WRIA 6	1996-2001	Cropland	Grassland	-$468,060	4.90%
WRIA 6	1996-2001	Cropland	Shrubland	$28,269	0.30%
WRIA 6	1996-2001	Developed	Cropland	-$24,201	0.25%
WRIA 6	1996-2001	Developed	Forest	-$5,604,844	58.62%
WRIA 6	1996-2001	Developed	Grassland	-$970,223	10.15%
WRIA 6	1996-2001	Developed	Shrubland	-$5,616	0.06%
WRIA 6	2001-2006	Cropland	Barren	$1,075	0.02%
WRIA 6	2001-2006	Cropland	Forest	-$491,462	7.20%
WRIA 6	2001-2006	Cropland	Fresh Water	-$228,092	3.34%
WRIA 6	2001-2006	Cropland	Grassland	-$98,332	1.44%
WRIA 6	2001-2006	Cropland	Shrubland	$53,970	0.79%
WRIA 6	2001-2006	Cropland	Wetland	-$47,871	0.70%
WRIA 6	2001-2006	Developed	Cropland	-$358,171	5.25%
WRIA 6	2001-2006	Developed	Estuary	-$295	0.00%
WRIA 6	2001-2006	Developed	Forest	-$4,680,026	68.59%
WRIA 6	2001-2006	Developed	Fresh Water	-$57,151	0.84%
WRIA 6	2001-2006	Developed	Grassland	-$862,916	12.65%
WRIA 6	2001-2006	Developed	Shrubland	-$7,734	0.11%
WRIA 6	2001-2006	Developed	Wetland	-$45,886	0.67%
WRIA 6	2006-2010	Cropland	Barren	$28,503	0.30%
WRIA 6	2006-2010	Cropland	Forest	-$146,801	1.54%
WRIA 6	2006-2010	Cropland	Fresh Water	-$21,723	0.23%
WRIA 6	2006-2010	Cropland	Grassland	-$527,058	5.51%

Location	Period	Change To	Change From	Net ESV	Period Effect
WRIA 6	2006-2010	Cropland	Shrubland	$74,016	0.77%
WRIA 6	2006-2010	Cropland	Wetland	-$44,878	0.47%
WRIA 6	2006-2010	Developed	Cropland	-$666,865	6.98%
WRIA 6	2006-2010	Developed	Forest	-$4,068,452	42.57%
WRIA 6	2006-2010	Developed	Fresh Water	-$56,997	0.60%
WRIA 6	2006-2010	Developed	Grassland	-$3,268,352	34.20%
WRIA 6	2006-2010	Developed	Shrubland	-$11,303	0.12%
WRIA 6	2006-2010	Developed	Wetland	-$847,126	8.86%
WRIA 6	2010-2016	Cropland	Forest	-$73,400	27.21%
WRIA 6	2010-2016	Cropland	Grassland	-$7,867	2.92%
WRIA 6	2010-2016	Cropland	Shrubland	$6,682	2.48%
WRIA 6	2010-2016	Developed	Cropland	-$9,142	3.39%
WRIA 6	2010-2016	Developed	Forest	-$160,351	59.44%
WRIA 6	2010-2016	Developed	Grassland	-$4,472	1.66%
WRIA 6	2010-2016	Developed	Shrubland	-$24	0.01%
WRIA 6	2010-2016	Developed	Wetland	-$21,179	7.85%
Out-of-Basin	1992-1996	Cropland	Barren	$8,067	0.01%
Out-of-Basin	1992-1996	Cropland	Forest	-$15,975,697	17.41%
Out-of-Basin	1992-1996	Cropland	Fresh Water	-$21,723	0.02%
Out-of-Basin	1992-1996	Cropland	Grassland	-$86,532	0.09%
Out-of-Basin	1992-1996	Cropland	Shrubland	$6,682	0.01%
Out-of-Basin	1992-1996	Cropland	Wetland	-$35,903	0.04%
Out-of-Basin	1992-1996	Developed	Cropland	-$538	0.00%
Out-of-Basin	1992-1996	Developed	Forest	-$60,363,011	65.77%
Out-of-Basin	1992-1996	Developed	Grassland	-$15,264,234	16.63%
Out-of-Basin	1992-1996	Developed	Shrubland	-$36,860	0.04%
Out-of-Basin	1992-1996	Developed	Wetland	-$3,530	0.00%
Out-of-Basin	1996-2001	Cropland	Barren	$538	0.00%
Out-of-Basin	1996-2001	Cropland	Forest	-$4,037,007	11.36%
Out-of-Basin	1996-2001	Cropland	Grassland	-$373,661	1.05%
Out-of-Basin	1996-2001	Cropland	Shrubland	$64,250	0.18%
Out-of-Basin	1996-2001	Developed	Cropland	-$337,197	0.95%
Out-of-Basin	1996-2001	Developed	Forest	-$21,964,424	61.79%
Out-of-Basin	1996-2001	Developed	Fresh Water	-$68,397	0.19%
Out-of-Basin	1996-2001	Developed	Grassland	-$8,812,479	24.79%
Out-of-Basin	1996-2001	Developed	Shrubland	-$16,277	0.05%
Out-of-Basin	1996-2001	Developed	Wetland	-$3,530	0.01%
Out-of-Basin	2001-2006	Cropland	Barren	$5,916	0.01%

Location	Period	Change To	Change From	Net ESV	Period Effect
Out-of-Basin	2001-2006	Cropland	Developed	$538	0.00%
Out-of-Basin	2001-2006	Cropland	Estuary	$5,711	0.01%
Out-of-Basin	2001-2006	Cropland	Forest	-$6,385,811	14.71%
Out-of-Basin	2001-2006	Cropland	Fresh Water	-$206,370	0.48%
Out-of-Basin	2001-2006	Cropland	Grassland	-$688,324	1.59%
Out-of-Basin	2001-2006	Cropland	Shrubland	$76,072	0.18%
Out-of-Basin	2001-2006	Cropland	Wetland	-$415,874	0.96%
Out-of-Basin	2001-2006	Developed	Cropland	-$1,359,006	3.13%
Out-of-Basin	2001-2006	Developed	Estuary	-$1,281	0.00%
Out-of-Basin	2001-2006	Developed	Forest	-$23,851,351	54.95%
Out-of-Basin	2001-2006	Developed	Fresh Water	-$136,946	0.32%
Out-of-Basin	2001-2006	Developed	Grassland	-$10,167,214	23.42%
Out-of-Basin	2001-2006	Developed	Shrubland	-$33,219	0.08%
Out-of-Basin	2001-2006	Developed	Wetland	-$247,078	0.57%
Out-of-Basin	2006-2010	Cropland	Barren	$16,133	0.05%
Out-of-Basin	2006-2010	Cropland	Forest	-$3,679,580	10.68%
Out-of-Basin	2006-2010	Cropland	Fresh Water	-$282,400	0.82%
Out-of-Basin	2006-2010	Cropland	Grassland	-$1,242,915	3.61%
Out-of-Basin	2006-2010	Cropland	Shrubland	$375,219	1.09%
Out-of-Basin	2006-2010	Cropland	Wetland	-$649,242	1.88%
Out-of-Basin	2006-2010	Developed	Beach	-$87,023	0.25%
Out-of-Basin	2006-2010	Developed	Cropland	-$2,071,046	6.01%
Out-of-Basin	2006-2010	Developed	Estuary	-$1,576	0.00%
Out-of-Basin	2006-2010	Developed	Forest	-$12,686,413	36.82%
Out-of-Basin	2006-2010	Developed	Fresh Water	-$1,086,181	3.15%
Out-of-Basin	2006-2010	Developed	Grassland	-$12,174,724	35.34%
Out-of-Basin	2006-2010	Developed	Shrubland	-$41,097	0.12%
Out-of-Basin	2006-2010	Developed	Wetland	-$840,067	2.44%
Out-of-Basin	2010-2016	Cropland	Developed	$1,075	0.04%
Out-of-Basin	2010-2016	Cropland	Forest	-$268,070	10.29%
Out-of-Basin	2010-2016	Cropland	Fresh Water	-$54,308	2.09%
Out-of-Basin	2010-2016	Cropland	Grassland	-$338,261	12.99%
Out-of-Basin	2010-2016	Cropland	Shrubland	$44,717	1.72%
Out-of-Basin	2010-2016	Developed	Cropland	-$121,541	4.67%
Out-of-Basin	2010-2016	Developed	Forest	-$1,786,241	68.59%
Out-of-Basin	2010-2016	Developed	Grassland	-$67,067	2.58%
Out-of-Basin	2010-2016	Developed	Shrubland	-$500	0.02%
Out-of-Basin	2010-2016	Developed	Wetland	-$14,119	0.54%

Table 11. Change in water quality-related ecosystem services value from conversion of landcover types to cropland and urban/built landcover (2021 US$)

Location	Period	Change To	Change From	Net ESV	Period Effect
WRIA 6	1992-1996	Cropland	Barren	-$9	0.00%
WRIA 6	1992-1996	Cropland	Forest	-$847,578	16.52%
WRIA 6	1992-1996	Cropland	Grassland	-$25,809	0.50%
WRIA 6	1992-1996	Cropland	Shrubland	-$5	0.00%
WRIA 6	1992-1996	Developed	Estuary	-$98	0.00%
WRIA 6	1992-1996	Developed	Forest	-$1,953,284	38.07%
WRIA 6	1992-1996	Developed	Grassland	-$2,304,277	44.91%
WRIA 6	1996-2001	Cropland	Barren	-$72	0.00%
WRIA 6	1996-2001	Cropland	Forest	-$316,897	16.89%
WRIA 6	1996-2001	Cropland	Grassland	-$341,254	18.19%
WRIA 6	1996-2001	Cropland	Shrubland	-$92	0.00%
WRIA 6	1996-2001	Developed	Cropland	$75	0.00%
WRIA 6	1996-2001	Developed	Forest	-$595,856	31.76%
WRIA 6	1996-2001	Developed	Grassland	-$621,926	33.15%
WRIA 6	2001-2006	Cropland	Barren	-$3	0.00%
WRIA 6	2001-2006	Cropland	Forest	-$61,309	3.88%
WRIA 6	2001-2006	Cropland	Fresh Water	-$239,421	15.13%
WRIA 6	2001-2006	Cropland	Grassland	-$71,692	4.53%
WRIA 6	2001-2006	Cropland	Shrubland	-$174	0.01%
WRIA 6	2001-2006	Cropland	Wetland	-$56,501	3.57%
WRIA 6	2001-2006	Developed	Cropland	$1,110	0.07%
WRIA 6	2001-2006	Developed	Estuary	-$295	0.02%
WRIA 6	2001-2006	Developed	Forest	-$497,538	31.45%
WRIA 6	2001-2006	Developed	Fresh Water	-$57,151	3.61%
WRIA 6	2001-2006	Developed	Grassland	-$553,141	34.96%
WRIA 6	2001-2006	Developed	Wetland	-$45,886	2.90%
WRIA 6	2006-2010	Cropland	Barren	-$89	0.00%
WRIA 6	2006-2010	Cropland	Forest	-$18,313	0.47%
WRIA 6	2006-2010	Cropland	Fresh Water	-$22,802	0.58%
WRIA 6	2006-2010	Cropland	Grassland	-$384,269	9.83%
WRIA 6	2006-2010	Cropland	Shrubland	-$240	0.01%
WRIA 6	2006-2010	Cropland	Wetland	-$52,970	1.36%
WRIA 6	2006-2010	Developed	Cropland	$2,065	0.05%
WRIA 6	2006-2010	Developed	Forest	-$432,522	11.07%
WRIA 6	2006-2010	Developed	Fresh Water	-$56,997	1.46%
WRIA 6	2006-2010	Developed	Grassland	-$2,095,058	53.61%
WRIA 6	2006-2010	Developed	Wetland	-$847,126	21.67%

Location	Period	Change To	Change From	Net ESV	Period Effect
WRIA 6	2010-2016	Cropland	Forest	-$9,157	16.36%
WRIA 6	2010-2016	Cropland	Grassland	-$5,735	10.25%
WRIA 6	2010-2016	Cropland	Shrubland	-$21	0.04%
WRIA 6	2010-2016	Developed	Cropland	$28	0.05%
WRIA 6	2010-2016	Developed	Forest	-$17,047	30.45%
WRIA 6	2010-2016	Developed	Grassland	-$2,867	5.12%
WRIA 6	2010-2016	Developed	Wetland	-$21,179	37.83%
Out-of-Basin	1992-1996	Cropland	Barren	-$25	0.00%
Out-of-Basin	1992-1996	Cropland	Forest	-$1,992,941	10.87%
Out-of-Basin	1992-1996	Cropland	Fresh Water	-$22,802	0.12%
Out-of-Basin	1992-1996	Cropland	Grassland	-$63,089	0.34%
Out-of-Basin	1992-1996	Cropland	Shrubland	-$21	0.00%
Out-of-Basin	1992-1996	Cropland	Wetland	-$42,376	0.23%
Out-of-Basin	1992-1996	Developed	Cropland	$2	0.00%
Out-of-Basin	1992-1996	Developed	Forest	-$6,417,253	35.02%
Out-of-Basin	1992-1996	Developed	Grassland	-$9,784,578	53.39%
Out-of-Basin	1992-1996	Developed	Wetland	-$3,530	0.02%
Out-of-Basin	1996-2001	Cropland	Barren	-$2	0.00%
Out-of-Basin	1996-2001	Cropland	Forest	-$503,609	5.70%
Out-of-Basin	1996-2001	Cropland	Grassland	-$272,429	3.08%
Out-of-Basin	1996-2001	Cropland	Shrubland	-$209	0.00%
Out-of-Basin	1996-2001	Developed	Cropland	$1,044	0.01%
Out-of-Basin	1996-2001	Developed	Forest	-$2,335,060	26.44%
Out-of-Basin	1996-2001	Developed	Fresh Water	-$68,397	0.77%
Out-of-Basin	1996-2001	Developed	Grassland	-$5,648,917	63.97%
Out-of-Basin	1996-2001	Developed	Wetland	-$3,530	0.04%
Out-of-Basin	2001-2006	Cropland	Barren	-$18	0.00%
Out-of-Basin	2001-2006	Cropland	Developed	-$2	0.00%
Out-of-Basin	2001-2006	Cropland	Estuary	-$1,302	0.01%
Out-of-Basin	2001-2006	Cropland	Forest	-$796,619	6.96%
Out-of-Basin	2001-2006	Cropland	Fresh Water	-$216,619	1.89%
Out-of-Basin	2001-2006	Cropland	Grassland	-$501,844	4.39%
Out-of-Basin	2001-2006	Cropland	Shrubland	-$246	0.00%
Out-of-Basin	2001-2006	Cropland	Wetland	-$490,858	4.29%
Out-of-Basin	2001-2006	Developed	Cropland	$4,209	0.04%
Out-of-Basin	2001-2006	Developed	Estuary	-$1,281	0.01%
Out-of-Basin	2001-2006	Developed	Forest	-$2,535,661	22.16%
Out-of-Basin	2001-2006	Developed	Fresh Water	-$136,946	1.20%

Location	Period	Change To	Change From	Net ESV	Period Effect
Out-of-Basin	2001-2006	Developed	Grassland	-$6,517,320	56.96%
Out-of-Basin	2001-2006	Developed	Wetland	-$247,078	2.16%
Out-of-Basin	2006-2010	Cropland	Barren	-$50	0.00%
Out-of-Basin	2006-2010	Cropland	Forest	-$459,021	3.40%
Out-of-Basin	2006-2010	Cropland	Fresh Water	-$296,426	2.20%
Out-of-Basin	2006-2010	Cropland	Grassland	-$906,187	6.71%
Out-of-Basin	2006-2010	Cropland	Shrubland	-$1,216	0.01%
Out-of-Basin	2006-2010	Cropland	Wetland	-$766,305	5.67%
Out-of-Basin	2006-2010	Developed	Cropland	$6,415	0.05%
Out-of-Basin	2006-2010	Developed	Estuary	-$1,576	0.01%
Out-of-Basin	2006-2010	Developed	Forest	-$1,348,705	9.99%
Out-of-Basin	2006-2010	Developed	Fresh Water	-$1,086,181	8.04%
Out-of-Basin	2006-2010	Developed	Grassland	-$7,804,161	57.79%
Out-of-Basin	2006-2010	Developed	Wetland	-$840,067	6.22%
Out-of-Basin	2010-2016	Cropland	Developed	-$3	0.00%
Out-of-Basin	2010-2016	Cropland	Forest	-$33,442	5.73%
Out-of-Basin	2010-2016	Cropland	Fresh Water	-$57,005	9.76%
Out-of-Basin	2010-2016	Cropland	Grassland	-$246,621	42.24%
Out-of-Basin	2010-2016	Cropland	Shrubland	-$144	0.02%
Out-of-Basin	2010-2016	Developed	Cropland	$377	0.06%
Out-of-Basin	2010-2016	Developed	Forest	-$189,897	32.53%
Out-of-Basin	2010-2016	Developed	Grassland	-$42,990	7.36%
Out-of-Basin	2010-2016	Developed	Wetland	-$14,119	2.42%

Appendix 3: GIS Data Sources

GIS Data Reference	Annotation
Island County Planning Department, 2016. "Land Use Designations." Available at: www.islandcountywa.gov/maps/Pages/Data.aspx.	The layer shows the current Land Use Designations in the Comprehensive Plan, Zoning, and Rural Areas of more Intensive Development (RAID). Data year(s): 2016
Island County Planning Department. 2011. "UGA Boundaries." Available at: www.islandcountywa.gov/maps/Pages/Data.aspx.	The layer shows the current City Limits, Urban Growth Area (UGA) and Joint Planning Area (JPA) classifications for all of Island County. Data year(s): pre-2011
Washington Department of Fish and Wildlife, 2018. "Puget Sound High Resolution Change Detection 2006-2015." Available at: https://hrcd- wdfw.hub.arcgis.com/pages/data	The layer shows landcover changes in Western Washington State, specifically areas of tree loss and impervious surface increase. The changes include causes (e.g., forestry, development) and quantitative assessments of changes (e.g., percentage of tree loss in the polygon, percentage of impervious surface increase in the polygon). Data year(s): 2006, 2009, 2011, 2013, 2015 Resolution: 1m
National Oceanic and Atmospheric Administration, Office for Coastal Management. "C-CAP Regional Landcover and Change." Coastal Change Analysis Program (C-CAP) Regional Landcover. Charleston, SC: NOAA Office for Coastal Management. Available at www.coast.noaa.gov/htdata/raster1/land cover/bulkdownload/30m_lc/.	The layer shows landcover data from 1992 to 2016. Data year(s): 1992, 1996, 2001, 2006, 2010, 2016 Resolution: 30m

Appendix 4: Annotated Bibliography of Ecosystem Services Literature

Citation	Annotation	Ecosystem Services Values Used
Adusumilli, N. 2015. Valuation of Eco-system 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 under-stand the value of wetland mitigation in policy decisions. Results from the model show that the cumu-lative value across all wetland-based ecosystem services range 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 Bo-real 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 pro-mote 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 as-sessed, 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

Citation	Annotation	Ecosystem Services Values Used
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
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 transerability. 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 (CH4) yr-1. With the exception of estuarine wetlands, CH4 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 CO2 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

Citation	Annotation	Ecosystem Services Values Used
Crooks, S., Rybczyk, J., O'Connell, K., Devier, D.L., Poppe, K., Emmett- Mat-tox, 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
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 landcovers. 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 re-source 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 mil-lion.	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

Citation	Annotation	Ecosystem Services Values Used
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 tradeoffs 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
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 Synoptic 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 Eco-nomics 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 to US $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 CO2 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 US 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 dams 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 Wet-lands: 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 Wash-ington. 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
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

Citation	Annotation	Ecosystem Services Values Used
Netusil, N. R. 2006. Economic Valuation of Riparian Corridors and Upland Wild-life Habitat in an Urban Watershed. Journal of Contemporary Water Re-search 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 improve-ments 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 un-published report of The Nature Con-servancy 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 wa-ter 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 Car-bon 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 Stabil-ity
Rein, F.A. 1999. An Economic Analysis of Vegetative Buffer Strip Implemen-tation. Case study: Elkhorn Slough, Monterey Bay, California. Coastal Management 27(4): 377-390.	This study investigates the economics of implement-ing vegetative buffer strips as a tool to protect wa-ter quality from nonpoint pollution in Elkhorn Slough, California's first National Estuarine Research Reserve. It evaluates environmental costs and bene-fits 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 inform-ing decision making. Benefits evaluated include tour-ism, commercial fisheries, long-term road mainte-nance, and harbor protection, using replacement cost and market pricing methods. Results indicate a net economic benefit for growers to install vegeta-tive 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 incen-tive-based programs is advocated due to the eco-nomic and ecologic benefits to society.	Grassland - Biological Con-trol, Disaster Risk Reduc-tion, Soil Retention, Water Quality

Citation	Annotation	Ecosystem Services Values Used
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 pro-grams for agricultural tree plantations. A discrete choice survey determined the probability and willing-ness 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
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 govern-ment reports, estimating that nontimber 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

Citation	Annotation	Ecosystem Services Values Used
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
Woodward, R., Wui, Y. 2001. The Economic Value of Wetland Services: A Meta-Analysis. Ecological Economics 37(2): 257-270	A 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

EARTH ECONOMICS