VALUING THE AQUATIC BENEFITS OF BRITISH COLUMBIA'S LOWER MAINLAND

Nearshore Natural Capital Valuation

David Suzuki Foundation

EARTH ECONOMICS

VALUING THE AQUATIC BENEFITS OF BRITISH COLUMBIA'S LOWER MAINLAND: NEARSHORE NATURAL CAPITAL VALUATION

November 2012

David Suzuki Foundation and Earth Economics

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sitka foundation

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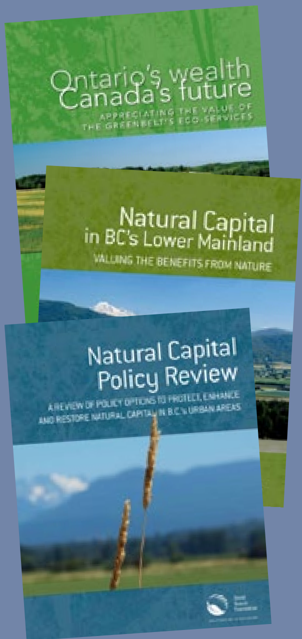

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STUDY ASSUMPTIONS

This report adopts an explicitly economic perspective on the links between economic development, natural resources and ecosystem services. This implies a focus on the value of functioning ecosystems *to people*, contrary to the intrinsic value of nature in its own right. This is not to suggest that nature's intrinsic biological, aesthetic, cultural, and evolutionary merits do not hold substantial and significant value. Such values are relevant and should be factored into decision-making.

An economic approach further implies that incentives matter. That is to say, that price signals, subsidies, taxes and property rights influence human behaviour and the use of natural capital. The lack of market incentives and public policy to indicate the full value of ecosystem services is a key contributor to the continued loss of natural resources and their associated ecosystem services. Although economic valuation cannot capture a comprehensive picture of nature's value, it is an important tool that can help decision-makers improve their ability to account for, conserve and secure nature and related ecosystem services.

Executive Summary

Our natural environment provides things we need to survive — breathable air, drinkable water, food for nourishment, security from flood and storm, and stable atmospheric conditions — to name a few ecosystem 'goods and services.' Natural systems also provide things essential for every economy to survive, such as oxygen, water and resources — indeed everything in the built environment originated from the natural environment. Natural systems are only now beginning to be viewed as economic assets, providing economically valuable goods and services.

Whereas 100 years ago the natural systems of British Columbia were conceived to be abundant and healthy relative to the demands made of them, today B.C.'s ecosystems are under stress. Rapid population growth and widespread development in the province's temperate southern region have contributed to its designation as a provincial 'hotspot' — a region of both high biodiversity and high risk. The continuing influx of people into the Lower Mainland will affect all aspects of sustainability (social, environmental, and economic) across a range of temporal and spatial scales. The region's natural resources will be drawn down to create more jobs, more housing and businesses, goods and services, transportation facilities, and recreational space. Unless these activities are significantly modified to mitigate their current impacts, they will cumulatively place an enormous burden on the land, species, and other natural resources. In turn, these activities will impact the ecological processes that support modern life.

Another path is to better design the economy to be more compatible with natural systems. The future of B.C.'s environment and economy are intricately intertwined. Careful choices must be made to ensure a healthy and sustainable future for natural systems, people and the economy.

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PHOTO COURTESY BEAUITIFUL BC/FLICKR

This study illuminates the connections between the economy and the aquatic ecosystems of B.C.'s Lower Mainland. By identifying and placing a value on the non-market goods and services sustained by these ecosystems and provided to 2.5 million residents, these connections are brought into the open. This is a vital step toward an informed discussion of how public and private decision-making can incorporate a wider range of interests into policies to improve prosperity for all.

In November 2010, the David Suzuki Foundation released *Natural Capital in BC's Lower Mainland: Valuing the Benefits from Nature*, which estimated the public value of land-based ecological services in the Lower Mainland. This report serves as a companion report in that it surveys the public value of aquatic-based ecological services to residents of the same region.

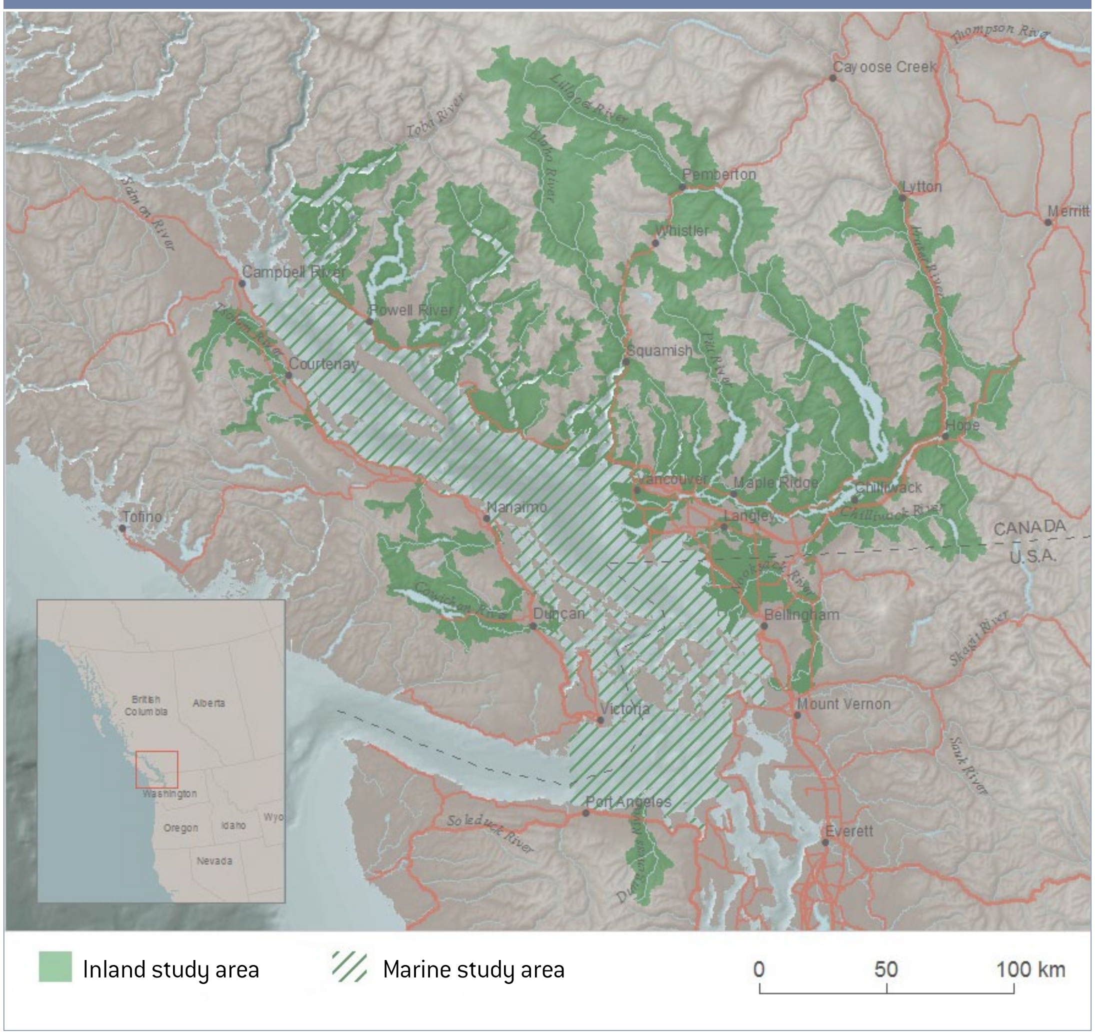
SCOPE OF REPORT

The study area includes the Georgia Strait and the major watersheds that empty into it, most notably the Fraser River Watershed.

FRASER RIVER PHOTO COURTESY TTCOPLEY/FLICKR

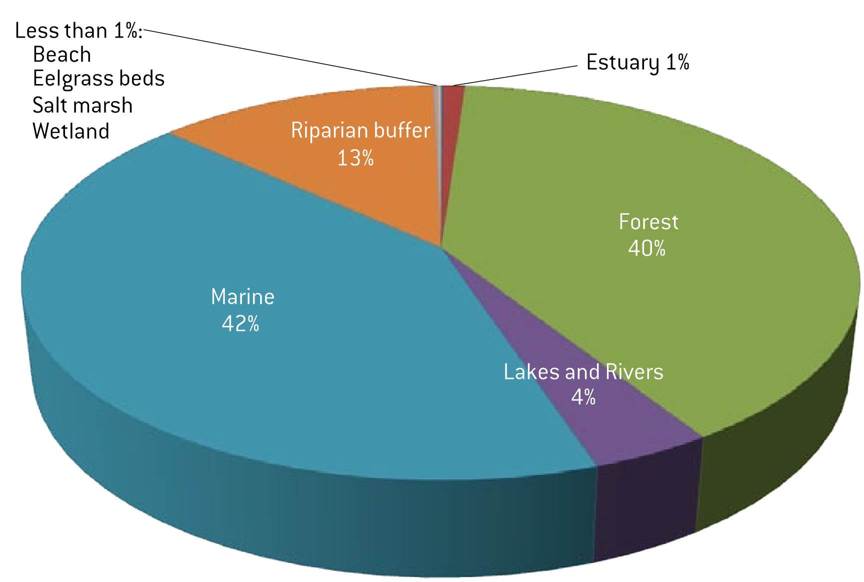
The study area for this report (shown below) extends beyond the political boundaries of the Lower Mainland, to represent boundaries that are ecologically appropriate for the ecosystem services addressed in this report. The region includes the Georgia Strait and the major watersheds that empty into it, most notably the Fraser River Watershed.

STUDY AREA FOR THE AQUATIC VALUATION



Our land cover analysis identified nine land cover classes, including beach, estuary, forest, lakes and rivers, marine, riparian buffer, salt marsh, wetland and eelgrass beds. This analysis indicates that in the entire study area, the dominant ecosystem type is marine at 42 per cent of land cover, followed by forest at 40 per cent, riparian buffer at 13 per cent of land cover, and lakes and rivers at 4 per cent of land cover. The remaining classes together represent less than 5 per cent of land cover (see below).

DISTRIBUTION OF LAND CLASSES



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TSAWWASSEN FERRY TERMINAL PHOTO COURTESY EVAN LEESON/FLICKR

METHODOLOGY

This study provides a structured understanding of nature's aquatic benefits in the Lower Mainland by introducing an ecosystem services framework.

The ecosystem services framework was developed within ecological economics as a tool for establishing nature's value into economic decision making. Although most often used in economic models (as opposed to other cultural or social value systems), the concept of ecosystem services has proven effective for understanding the linkages between ecosystems and human well-being.

The Economics of Ecosystems and Biodiversity (TEEB) classification system was adopted for this study. The table below provides a synopsis of this study's classification of services into four groups of services: provisioning, regulating, habitat, and cultural services.

In this study, services were classified into four groups: provisioning, regulating, habitat, and cultural services.

CLASSIFICATION OF ECOSYSTEM SERVICES IN THE AQUATIC VALUATION

Service	Definition
PROVISIONING	
Drinking Water	Water for human consumption
Food	Biomass for human consumption
Raw Materials	Biological materials used for fuel, art and building; geological materials used for construction or other purposes
Medicinal Resources	Biological materials used for medicines
REGULATING	
Gas and Climate Regulation	Regulation of greenhouse gases, absorption of carbon and sulfur dioxide, and creation of oxygen, evapotranspiration, cloud formation and rainfall provided by vegetated and oceanic areas
Disturbance Regulation	Protection from storms and flooding, drought recovery
Soil Erosion Control	Erosion protection provided by plant roots and tree cover
Water Regulation	Water absorption during rains and release in dry times, temperature and flow regulation for plant and animal species
Biological Control	Natural control of pest species
Water Quality and Waste Processing	Absorption of organic waste, filtration of pollution
Soil Formation	Formation of sand and soil through natural processes
Nutrient Cycling	Transfer of nutrients from one place to another, transformation of critical nutrients from unusable to usable forms
Pollination	Fertilization of plants and crops through natural systems
HABITAT	
Biodiversity and Habitat	Providing for the life history needs of plants and animals
Primary Productivity	Growth by plants provides basis for all terrestrial and most marine food chains
CULTURAL	
Aesthetic	The role natural beauty plays in attracting people to live, work and recreate in an area
Recreation and Tourism	The contribution of intact ecosystems and environments in attracting people to engage in recreational activities
Scientific and Educational	Value of natural resources for education and scientific research
Spiritual and Religious	Use of nature for religious or historic purposes (i.e., heritage value of natural ecosystems and features)

Ecological economists have developed a number of techniques for putting dollar values on the non-market goods and services provided by ecosystems. A combination of primary and transferred studies was used, due to the lack of primary valuation studies on aquatic ecosystem services in the study area. In addition, because ecosystem services are physically different and more or less amenable to markets, a variety of different valuation techniques are required. By utilizing an appraisal approach, great cost and time can be saved.

MAJOR FINDINGS

This report includes a valuation of eight ecosystem services across nine land classes in the Lower Mainland. The results are compelling (see table below): through benefits such as protecting against flooding, assuring water supply, buffering climate instability, supporting fisheries and food production, maintaining critical habit, providing waste treatment, and more, the Lower Mainland's aquatic ecosystems are providing $30 billion to $60 billion in benefits every year.

A large number of ecosystem services (for each land cover class) have yet to be valued in a primary study. We were able to value 30 per cent of known services. This suggests that the valuation is a significant underestimate of the true value, because many ecosystem services identified as valuable do not have an associated valuation study. As further primary studies are completed, the combined known value of aquatic ecosystem services in the Lower Mainland will rise.

The benefits of ecosystem services can be calculated by ecosystem service or land type. The top three ecosystem service values are aesthetic and recreation, estimated at $23 billion to $44 billion per year, water supply at $2.3 billion to $7 billion per year, and disturbance regulation at $2 billion to $5 billion per year. Top service values per hectare include disturbance regulation (up to $297,000/hectare/year), aesthetic and recreation (up to $283,000/hectare/year), and waste treatment (valued at a maximum of $115,000/hectare/year).

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FRASER RIVER PHOTO COURTESY EVAN LEESON/FLICKR

SUMMARY OF VALUE OF ECOSYSTEM SERVICES BY BENEFIT (2010 C$)

Ecosystem service		Total value/year (millions $/yr)		Value per hectare ($/ha)	
		Low	High	Low	High
Aesthetic and recreational		$22,612	$44,181	$18,854	$282,747
Disturbance regulation		$1,970	$5,032	$2,941	$296,886
Habitat refugium and nursery		$60	$773	$5,083	$62,633
Nutrient cycling		$130	$348	$17,249	$47,833
Waste treatment		$291	$1,052	$1,351	$115,089
Water supply		$2,656	$7,008	$3,932	$44,887
Food provisioning		$1.95	$1.95	$1.58	$1.58
Gas and climate regulation	Air pollution regulation	$642	$642	$539	$539
	Carbon sequestration	$52	$55	$122	$869
	Carbon storage	$2,238	$2,239	$3,480	$4,520
Total		$30,653	$61,331		

Net Present Value

An ecosystem produces a flow of valuable services across time. In this sense it can be thought of as a capital asset. This analogy can be extended by calculating the net present value of the future flows of ecosystem services, just as the asset value of a traditional capital asset (or large project) can be approximately calculated as the net present value of its future benefits. A range of discount rates has been applied to the results of this study. A zero per cent discount rate represents the view that natural capital does not depreciate over time; a 3 per cent discount rate represents the rate commonly used in socio-economic studies; and a 5 per cent discount rate represents a conventional rate used in net present value calculations. Over a 50-year period, the net present value is $1,533 billion–$3,067 billion at a 0 per cent discount rate, $789 billion–$1,578 billion at a 3 per cent, and $560 billion–$1,120 billion at a 5 per cent discount rate.

NET PRESENT VALUES FOR ECOSYSTEM BENEFITS (2010 C$)

Discount rate	Net present value (50-year period) billion $		Value per capita		Value per household	
	Low	High	Low	High	Low	High
0%	$1,533	$3,067	$613,060	$1,226,625	$1,532,650	$3,066,562
3%	$789	$1,578	$315,478	$631,215	$788,694	$1,578,038
5%	$560	$1,120	$223,840	$447,863	$559,599	$1,119,658

CONCLUSIONS AND NEXT STEPS

While this report provides a valuation of non-market aquatic ecosystem services in the Lower Mainland, it is only a first step.

PHOTO COURTESY ERIC EGGERTSON/FLICKR

While this report provides a valuation of non-market aquatic ecosystem services in the Lower Mainland, it is only a first step. The development of policies, measures, and indicators that highlight tradeoffs is needed, as investments of public and private money ultimately shape the regional economy for generations to come. The project team identified the following tasks as important next steps.

- Ongoing studies are critically needed to update valuations and further justify investment in natural capital.
- It is possible, in fact imperative, to identify specific providers of ecosystem services, the beneficiaries of those services and impediments to their continued supply.
- Further funding and research can play a key role in informing public and private investment.
- Achieving sustainability requires shifting investment from investments that damage ecosystem services to investments that improve and sustain them.
- Improving economic analysis to secure more productive and sustainable investment requires:
    - Accounting for natural capital;
    - Improving jobs analysis for restoration;
    - Adopting new industrial indicators;
    - Changing cost/benefit analysis;
    - Upgrading environmental impact assessments;
    - Including ecosystem service valuation in all watershed scale studies; and
    - Training government, private firm and non-profit staff in ecosystem services and the use of ecosystem service valuation tools.

REPORT OUTLINE

- Part 1: Introduction defines fundamental elements and definitions necessary to understanding natural capital valuation.
- Part 2: Overview of Study Area introduces the geography, population, ecology and economy of the Lower Mainland.
- Part 3: Study Approach describes the methodology followed throughout the study.
- Part 4: Identification of Aquatic Land Cover describes the process followed to identify the component land classes of the study region.
- Part 5: Identification of Ecosystem Services describes ecosystem services valued in this report with specific examples from the study region.
- Part 6: Case Studies provide an in-depth look at the emerging concept of blue carbon and a historical look at fishery productivity in the study area.
- Part 7: Summary of Values determines a range of study values for some non-market goods and services provided by the aquatic ecosystems of the Lower Mainland.
- Part 8: Conclusions and Recommendations discusses whole system economic analysis, with specific recommendations for decision makers.

ABBREVIATIONS

B.C.	British Columbia
CO_2	Carbon dioxide
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
DFO	Fisheries and Oceans Canada (also, Department of Fisheries and Oceans)
DSF	David Suzuki Foundation
EE	Earth Economics
EPA	U.S. Environmental Protection Agency
FAO	Food and Agricultural Organization of the United Nations
FTE	Full-time equivalent
FVRD	Fraser Valley Regional District
GDP	Gross domestic product
GIS	Geographic information system
GHGs	Greenhouse gases
ha	Hectare
NLCD	National Land Cover Database
No.	Number
TEEB	The Economics of Ecosystems and Biodiversity
WA	Washington state

PHOTO COURTESY
JEFFERY YOUNG

1.1 What is Natural Capital?

The collective benefits provided by the resources and processes supplied by natural capital are known as ecosystem goods and services.

GOSPEL ROCK/GIBSONS PHOTO COURTESY DANIEL PECKHAM/FLICKR

Natural capital refers to the planet's stocks of water, land, air, and renewable and non-renewable resources (such as plant and animal species, forests, and minerals). The term natural capital implies an extension of the economic notion of capital. Just as all forms of capital are capable of providing a flow of goods and services, components of natural capital interact to provide humans and other species with goods and services that are wide-ranging and diverse. The collective benefits provided by the resources and processes supplied by natural capital are known as ecosystem goods and services, or simply ecosystem services. These services are imperative for survival and well-being. They are also the basis for all economic activity.

Natural systems, such as forests, wetlands, rivers, and marine waters have a vast number of functions that maintain them. These functions utilize and regulate the flow of water, nutrients, materials and energy, as well as regulate the interactions between elements within these systems. Natural functions are dependent on natural infrastructure. For example, forest cover on slopes intercepts falling rainwater and facilitates greater infiltration and lower/slower peak flood flows. In comparison, if the forest cover is removed the result will be faster run-off, greater erosion, less infiltration and higher/faster peak flood flows. Natural systems have numerous functions, right down to the mechanics of microbes. Many of these functions are not well understood, and, for many others, there are no apparent links to human well-being. The ecological functions produced by natural systems that *do* provide very clear benefits to people come in two forms: ecosystem goods and ecosystem services.

1.2 Ecosystem Goods and Services

Ecosystem goods and services are the benefits that are provided by the earth's natural capital (e.g. land, air, water, and subsurface materials). Natural systems, such as forests, wetlands and riparian habitat, can be loosely compared to factories. Similar to a human-built assembly line, natural systems require a structure and inputs, from which they generate goods and services. Unlike a human-built factory, natural systems have evolved on their own to process inputs and provide services and do not require human intervention in order to work, although similar to factories, bad management can lead to disaster and destruction of capital.

ECOSYSTEM GOODS

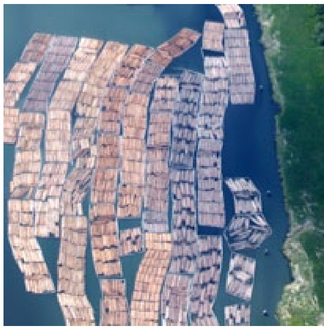
Goods are "things you drop on your toe" — physical objects created as a result of a process. Examples include drinking water, timber, fish, crops and wildlife. Ecosystem goods are typically tangible items quantifiable with flow, volume, weight, or quantity measures. The quantity of water produced per second, or board feet of timber cut in a 40-year rotation, can be measured by the physical quantity that an ecosystem produces over time. The current production of goods can be easily valued by multiplying the quantity produced by the current market price. Most goods are exclusive, which means that if one individual owns or uses a particular good, that individual can exclude others from owning or using the same good. For example, if one person eats an apple, another person cannot eat that same apple. Excludable goods can be traded and valued in markets.

The sustainable stream of goods provided by an ecosystem is a "flow of goods." These goods can provide enormous economic return. This revenue can be realized by a public agency such as Fisheries and Oceans Canada, or by a private corporation. However, the collection and sale of ecosystem goods can affect the ability of the remaining ecosystem to provide other goods and services, such as flood protection, clean drinking water or recreation. Good decisions require good information. Understanding the value of timber revenue and flood protection, clean water, recreation, and other goods and services is important, otherwise one action may inadvertently destroy more value (economic or otherwise) than it provides. For example, though timber harvest may be a privatized good, maximizing its value while ignoring the flood protection benefits of forests may result in flooding high value cities and lower the value of other public services and goods. By including the value of the entire suite of ecosystem goods and services, the economic relationships and tradeoffs can be better understood.

ECOSYSTEM SERVICES

Ecosystem services are the "benefits you can't drop on your toe," defined as "the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life." Unlike ecosystem goods, ecosystem services such as flood protection or drinking water filtration are not tangible items that you can hold. Flood protection, recreational value, aesthetic value, and water filtration are a few of the services that ecosystems provide. Because of their physical nature, no one can privately own them, and they cannot be traded in markets. An example would be flood protection. No one can own or trade natural flood protection, though built infrastructure that provides flood protection, like levees, *can* be owned. Ecosystem services are more difficult to value, yet they are very valuable and vital both for our quality of life and for economic production.

Many ecosystem services are non-excludable. When one person enjoys a view of the sunset, it does not prevent another person from enjoying the same sunset, unless congestion develops. Similarly, all downstream residents benefit from the flood protection provided by forested land or dams upstream. Many ecosystem services, such as oxygen production, soil regulation, and storm protection are not, or cannot, be sold in markets. However, markets for some ecosystem services are possible and slowly growing; water temperature trading and carbon sequestration markets are examples.



Understanding the value of timber revenue and flood protection, clean water, recreation, and other goods and services is important, otherwise one action may inadvertently destroy more value (economic or otherwise) than it provides.

FRASER RIVER LOG BOOMS PHOTO COURTESY TTCOPLEY/FLICKR

1.3 Why is it important to measure natural capital?

Our natural environment provides things we need to survive — breathable air, drinkable water, food for nourishment, security from flood and storm, and stable atmospheric conditions, to name a few ecosystem goods and services. Natural systems also provide things essential for every economy to survive, such as oxygen, water and resources, indeed everything in the built environment originated from the natural environment. Natural systems are only now beginning to be viewed as economic assets, providing economically valuable goods and services. If these valuable goods and services are lost, people sustain costs and a decline in their quality of life. Increased flooding is an example of a lost ecosystem service (flood risk reduction) that can destroy traditional economic capital. If lost, the service previously provided by natural systems for free must be replaced by costly, built structures that are primarily funded by taxes. Loss of flood protection, for instance, means replacing those lost benefits with pipes to do what nature once did for free. In some cases, however, no expenditure can replace lost ecosystem goods and services. Coral reefs damaged from ocean acidification may cease providing habitat for fish species, coastal storm protection, and tourism income, for instance.

Many economic measures were developed when natural capital was abundant and built capital scarce. With the goal of providing more manufactured goods and services, we developed a blind spot to the economic importance of natural systems. Labour with built and financial capital are typically considered as the primary "factors of production" for economic development. Land and natural systems, on the other hand, have seldom been included in economic analysis.

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FROM EAST VANCOUVER, PHOTO COURTESY TTCOPLEY/FLICKR

A small but growing number of economists are recognizing the many things important to human well-being beyond manufactured products. In fact, a great deal of research shows that things like leisure time, equality, and healthy relationships are far more important to people's happiness than greater consumption. In 2009, Elinor Ostrom, a founding member of the International Society for Ecological Economics, shared the Nobel Prize in Economics for her work on the economics of natural resources and the commons. This is changing our model of the economy. Figure 1 shows a typical 20th century view of the economy.

Built capital has often been considered a substitute for natural capital. For example, a filtration plant can substitute for the single forest service of water filtration. However, built and natural capital provide the best services to people when used in combination, as complements. Water pipes, for example, cannot substitute for water; it takes both to provide water at the spigot. In addition, all built capital requires natural capital inputs of material and energy. Natural capital and built capital are productively used as complements rather than substitutes. Figure 2 shows a 21st century scheme of the economy informed by modern science.

FIGURE 1: MODEL OF THE ECONOMY THAT EXCLUDES NATURAL CAPITAL

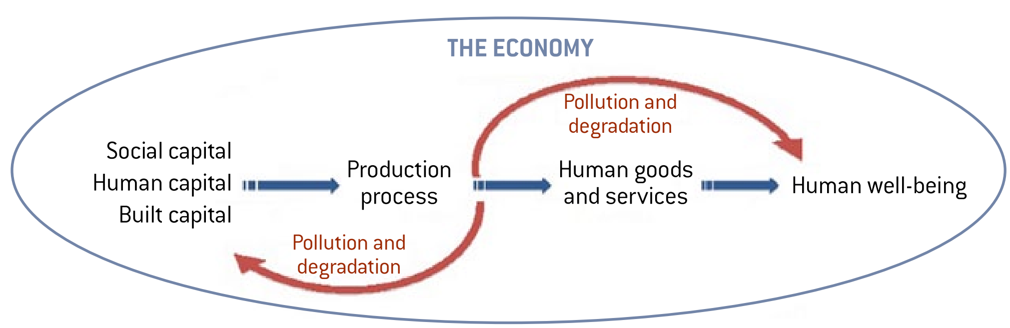
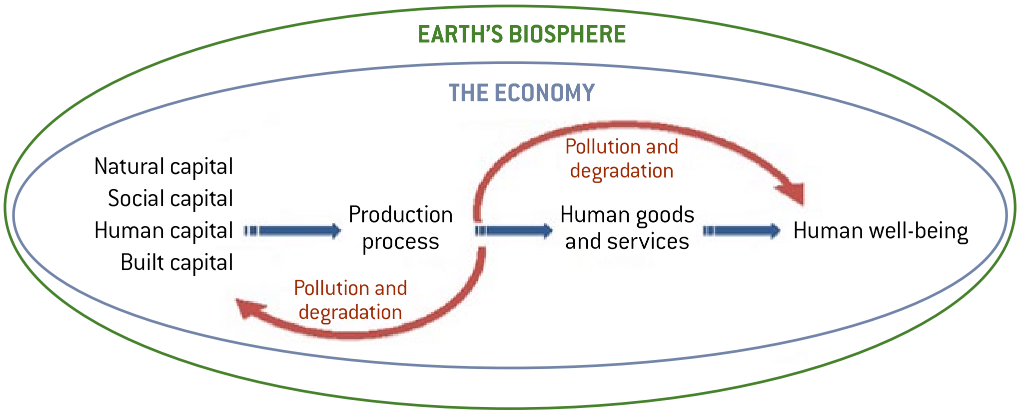


FIGURE 2: MODEL OF THE ECONOMY THAT INCLUDES NATURAL CAPITAL



1.4 Why do this study?

Natural systems are intrinsically valuable. In addition, economies need nature. Natural systems provide essential goods and services, required by all people (consider oxygenated air). Without understanding this value, critical natural systems could be lost at great cost to humanity today and into the future. This report assesses the value of benefits provided by the aquatic environment to the 2.5 million residents of British Columbia's Lower Mainland. It identifies water/land cover types and quantifies the non-market value of the services provided by the aquatic ecosystems of the Strait of Georgia and the main watersheds that drain into it.

In November 2010, the David Suzuki Foundation released *Natural Capital in BC's Lower Mainland: Valuing the Benefits from Nature* (hereinafter the 'Lower Mainland valuation'), which estimated the public value of land-based ecological services in the Lower Mainland. This report serves as a companion report in that it surveys the public value of aquatic-based ecological services to residents of the same region.

Whereas 100 years ago the natural systems of British Columbia were conceived to be abundant and healthy relative to the demand made of them, today B.C.'s ecosystems are under stress. Rapid population growth and widespread development in B.C.'s temperate southern region have contributed to its designation as a provincial 'hotspot' — a region of high biodiversity and high risk. The continuing influx of people into the Lower Mainland will affect all aspects of sustainability (social, environmental, and economic) across a range of temporal and spatial scales. The region's natural resources will be drawn down to create more jobs, more housing and built goods and services, transportation facilities, and recreational space. Unless these activities are significantly modified to mitigate their current impacts, they will cumulatively place an enormous burden on the land, species, and other natural resources. In turn, these activities will negatively impact the ecological processes that support modern life.

Another path is to better design the economy to be more compatible with natural systems. This would involve a transition from organizing our economy around expansion (and exhausting all that is truly useful to people), to an economy that maintains and cares for our world and what we've developed from it. The future of B.C.'s environment and economy are intricately intertwined. Careful choices must be made to ensure a healthy and sustainable future for natural systems and the economy.

This study aims to illuminate the connections between ecosystems and the economy of the aquatic ecosystems of B.C.'s Lower Mainland. By identifying and placing a value on the non-market goods and services sustained by these ecosystems, these connections are brought into the open. This is a vital step toward an informed discussion of how public and private decision-making can incorporate a wider range of interests into policies to improve prosperity for all.

Whereas 100 years ago the natural systems of British Columbia were conceived to be abundant and healthy relative to the demand made of them, today B.C.'s ecosystems are under stress.

GREAT BLUE HERON IN RICHMOND, PHOTO COURTESY DAN MOUTAL

PART 2

Overview of Study Area

2.1 Geography

The study area for this report includes the Georgia Strait and the major watersheds that empty into it, most notably, the Fraser River Watershed.

While the 'Lower Mainland' of B.C. has never been officially defined in legal terms, the moniker has been used for over a century to refer to the southwest corner of the mainland — a region that shares a similar climate, ecology, and geology. Covering 434,937 hectares, the region is bounded by two mountain ranges — the Coast Mountains to the north and the Cascade Mountains to the southeast — and an inland sea — the Strait of Georgia — to the west. In addition to including portions of three regional districts — Metro Vancouver, Fraser Valley, and Squamish-Lillooet — the Lower Mainland is the traditional territory of the Coast Salish First Nations. This group of First Nations in B.C., as well as Native Americans in Washington in the U.S., speak one of the Coast Salish languages. The study area covers the territory of more than 30 individual First Nations and Tribes. A complete list of Nations and Tribes in the study region is provided in Appendix A.

The study area for this report is shown in Figure 3. It includes the Georgia Strait and the major watersheds that empty into the Strait, most notably, the Fraser River Watershed. The Lower Mainland Valuation focused on the Lower Mainland eco-region and extended the study area up the coast from West Vancouver to Squamish. Figure 4 shows the boundaries of the Lower Mainland valuation in comparison to this valuation. Similar to the Lower Mainland valuation, this aquatic valuation extends the study area beyond the typical political boundaries of the Lower Mainland, to represent boundaries that are ecologically appropriate for the ecosystem services addressed throughout the report.

Where to draw study boundaries when analyzing any aquatic system is difficult. Aquatic ecosystems are fluid and highly connected. The scientific understanding of coastal ecosystem services is vast, yet has many gaps. The geographic data is sparse in comparison to terrestrial ecosystems. The primary commitment within this study was to reflect the ecological boundaries of the ecosystem as accurately as possible, and only then to adjust for other considerations, such as data deficiencies. This led to the inclusion of the bulk of the Georgia Strait, much of the Fraser River and other key watersheds that have a significant impact on aquatic environments. Refinements were based on the availability of mapping data, and the consistency of Canadian–U.S. data sets.

FIGURE 3: AQUATIC VALUATION STUDY AREA

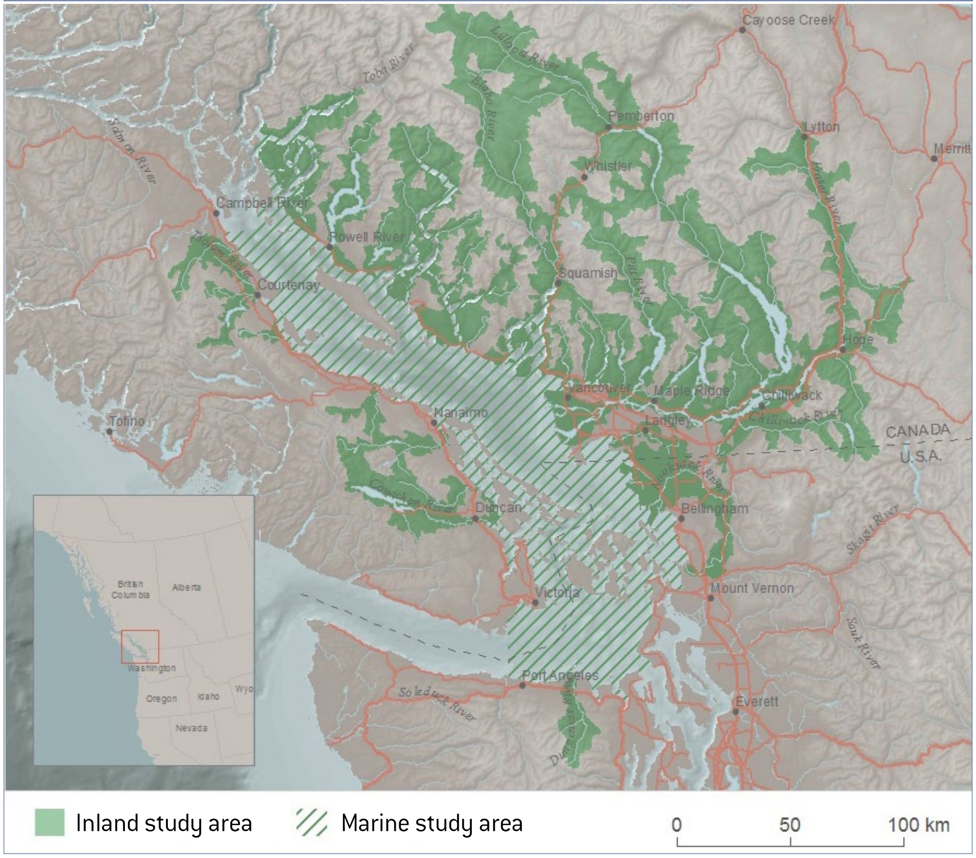
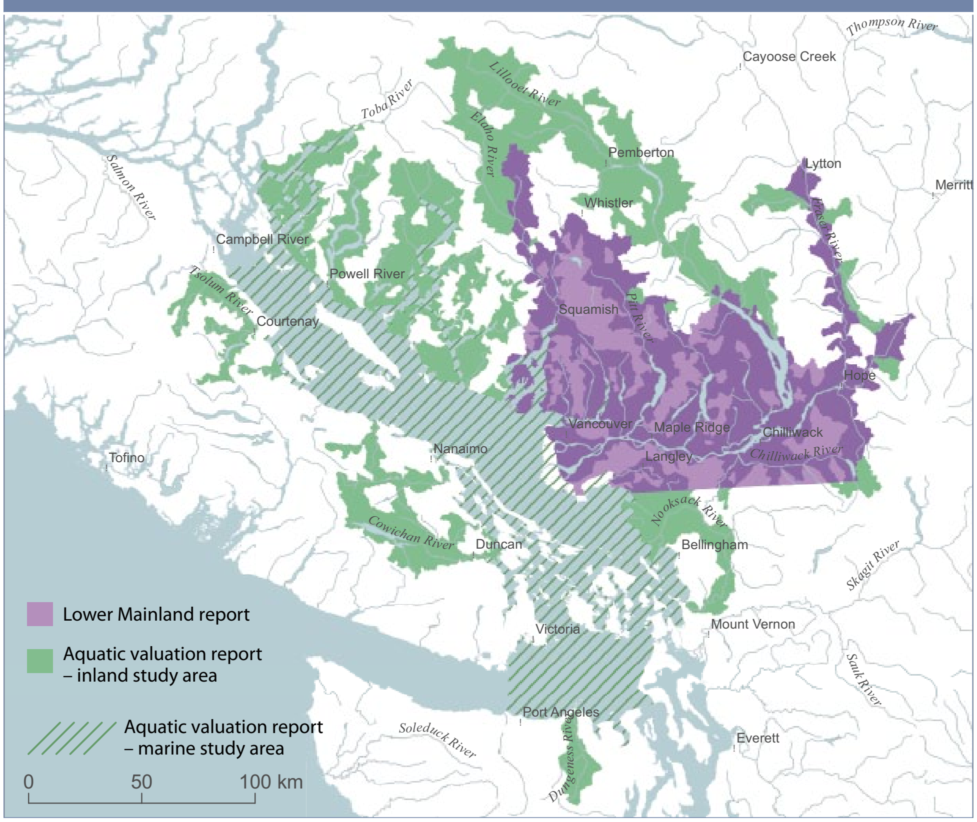


FIGURE 4: COMPARISON OF VALUATION REPORT BOUNDARIES



Where to draw study boundaries when analyzing any aquatic system is difficult. Aquatic ecosystems are fluid and highly connected.

PHOTO COURTESY EVAN LEESON/FLICKR

KEY WATER BODIES

The Fraser River cuts between the Coast and Cascade mountain ranges, separating a more continental climate from a milder coastal climate. It is the largest river system in the province, travelling southwest almost 1,400 kilometres before draining into the Strait of Georgia.[1] Within the study area, which is located in the lower reaches of the Fraser, the river is bordered by rich farmland in a floodplain covering over 3,000 square kilometres. The estuary at the river's mouth is part of the Western Hemisphere Shorebird Reserve Network, a site of staging, nesting and breeding grounds for over 500,000 shorebirds annually.[2] In addition to providing fertile soil for agriculture and habitat for wildlife, the area is heavily industrialized. According to the Fraser Basin Council, 80 per cent of B.C.'s economic production stems from the Fraser River Basin.[3]

The Georgia Strait is located between Vancouver Island and the mainland coast of B.C. It stretches 220 kilometres north from Canada's border with Washington State, to Campbell River and the Discovery Islands. The strait adjoins Puget Sound in Washington State, and together this body of water forms a huge estuary — a biologically rich and productive area where hundreds of rivers flow into the sea.[4] For residents of the Lower Mainland, the Georgia Strait provides outstanding scenery, a protected transportation corridor, and an accessible locale for swimming, surfing, boating, diving and fishing.

For residents of the Lower Mainland, the Georgia Strait provides outstanding scenery, a protected transportation corridor, and an accessible locale for swimming, surfing, boating, diving and fishing.

PHOTO COURTESY HEIDI HUDSON

2.2 Population and Economy

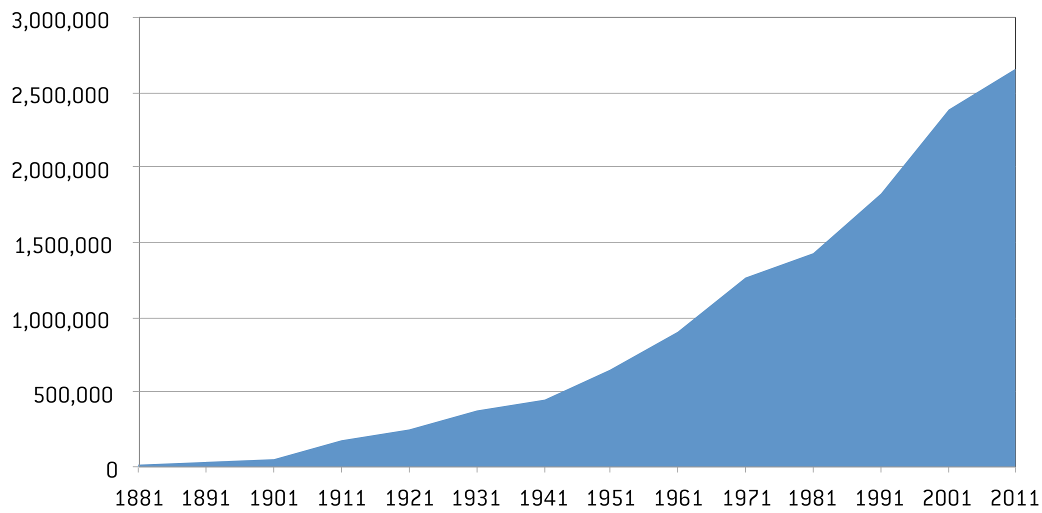
People are drawn to the Lower Mainland by its mild climate, natural beauty, healthy environment and vibrant economy. Almost 60 per cent of B.C.'s population is concentrated here, numbering approximately 2.5 million people.[5] The vast majority (87 per cent) reside in Metro Vancouver, followed by the Fraser Valley Regional District (FVRD) (11 per cent), and the Squamish-Lillooet Regional District (2 per cent).[6] The population of the Lower Mainland increased 23 per cent between 1995 and 2008, outstripping the provincial growth rate of 16 per cent, and placing the area among the highest growth rates on the continent.[7] Left unchecked, the population is anticipated to exceed 3 million by 2020, with the majority flowing into Metro Vancouver. Rapid growth of the region over the coming decades has prompted concerns about human-induced impacts on the rich ecosystems that sustain the population. Figure 5 depicts the growth rate of the Lower Mainland, with population on the vertical axis and time (years) on the horizontal axis.

The increasing population depicted in Figure 5 is an assumption based on the Regional Growth Strategies of Metro Vancouver and the FVRD. These strategies generally focus on how to best address and anticipate the needs of a growing population. They rarely ask if regional ecosystems can support the projected increase of people.

The economy of British Columbia was built upon the abundant natural resources of the land and sea. For thousands of years, the First Nations used these resources to supply their food, medicine, shelter and clothing. When European settlers arrived in the 1800s, the market for sea-otter pelts initiated the fur trade. By the start of the 1900s, the products derived from logging, mining, fishing and agriculture were being shipped across the country and in the case of salmon, around the world. Manufacturing activities centred on processing these natural resources, such as shoreline canneries for Fraser River salmon and pulp mills to produce paper from trees harvested in the coastal and interior forests.[8]

1 Hebert, 2008.
2 WHSRN, 2011.
3 Fraser Basin Council, 2004.
4 Georgia Strait Alliance, 2011.
5 BC Stats, 2009, *Municipal Population Estimates.*
6 Ibid.
7 BC Ministry of Regional Economic Skills Development and BC Stats, 2011.
8 BC Ministry of Regional Economic Skills Development and BC Stats, 2011.

FIGURE 5: GROWING POPULATION OF THE LOWER MAINLAND



Sources: Census of Canada (1951), table 6-84-88; (1971), table 8-92-96; BC Stats (2004b).

The economic role of the Lower Mainland has historically been as a service centre for B.C.'s resource economy. In addition to the processing activities listed above, the area has served as a transportation corridor to export goods. The country's largest and busiest deep-sea port, an international airport, and highways provide many commercial links to the rest of Canada, North America, Asia, and the world. Today, this region is the financial and business capital of the province.[9] High-tech and film industries, along with tourism, international banking, finance, insurance, and real estate are centred here.[10] Forestry, fishing, and agriculture continue as important sources of employment, particularly in rural areas. Shoreline businesses include bulk-loading terminals, a sugar refinery, a sodium chlorate plant, a chlor-alkali plant, and oil depots. Key industries associated with the study area are discussed below and summarized in Table 1. All data comes from GSGislason & Associates Ltd., 2007.

The country's largest and busiest deep-sea port, an international airport, and highways provide many commercial links to the rest of Canada, North America, Asia, and the world

YVR PHOTO COURTESY EVAN LEESON/FLICKR

SEAFOOD SECTOR

The B.C. seafood industry produces, processes, and distributes seafood for consumption locally, nationally, and internationally. Production includes the harvesting of fish and shellfish through a variety of methods (nets, hooks and lines, traps, diving, etc.). Processing activities transform the raw product into steaks, fillets, canned, smoked, roe, and other products. Distribution involves the delivery of the product to wholesale and retail food channels. In 2005 the industry contributed $790 million to provincial GDP, reported labour income of $475 million, and employed 12,900 FTE (full-time equivalent) employees. Approximately 35 per cent of total provincial seafood employment occurs in the Lower Mainland. Indirect supplier and induced consumer spending impacts add approximately 70 per cent to the direct provincial GDP, labour income and employment figures. Seafood is widely recognized as an ecosystem good.

9 Ibid.

10 Ibid.

OCEAN TRANSPORTATION/SHIPPING

The network of ports is important for the delivery of goods to a number of B.C. communities. The ocean transport industry includes the shipping of freight and associated support services, including freight forwarding, import/export, bunker fuel sales, marine engineering and others. It also includes B.C.'s supplier role for cruise ships operating from B.C. ports, but it excludes ferry services, as these are included under recreation. More than 70 ports along the B.C. coast handle over 120 million tonnes of cargo each year, including grains, forest products, minerals, coal, seafood, and automobiles. Port Metro Vancouver is the largest and handles over half of all provincial traffic. In 2005, this industry contributed over $1.5 billion to provincial GDP, $1.2 billion in labour income, and employed 20,700 FTEs.

The conveyance of cargo on marine waters is an ecosystem service. When this same cargo is transported across road or rail, shippers must pay for either road construction via taxes or transportation charges on rail. These payments are justified to maintain the capital assets (roads and rails) required. Conveyance across marine ecosystems is free. Yet, just as the weight of cargo degrades roads, bilge water, noise and other impacts of shipping degrade natural systems. No charge for maintaining marine systems is brought back to those traversing marine shipping lanes. Conveyance across marine systems has not generally been perceived as one of nature's services.

Conveyance across marine ecosystems is free. Yet, just as the weight of cargo degrades roads, bilge water, noise and other impacts of shipping degrade natural systems.

PHOTO COURTESY PORT OF VANCOUVER

SHIP AND BOAT BUILDING

The ship and boat building industry includes both building and repair. The nature of this industry is that it has spikes in activity (i.e., a few large orders), followed by lulls. In 2005, the industry contributed $398 million to provincial GDP, $175 million in labour income, and 2,490 FTEs, with 64 per cent of regional employment occurring in the Lower Mainland. To these values can be added a contract awarded by the federal government in October 2011 to Seaspan (owner of Victoria Shipyards in Esquimalt and Vancouver Shipyards in Vancouver).[11] The contract secured the construction of $8 billion worth of federal non-combat ships, and is expected to create about 4,000 direct and indirect jobs.[12] As in the case of many other ecosystem services (e.g., seafood served in restaurants), the benefits of nature's systems reverberate back into manufacturing and other sectors of the economy.

OCEAN RECREATION

The ocean recreation industry includes saltwater angling (including fishing lodges and charters, as well as shellfish harvesting), cruise ship visitation, ferry travelers, whale watching, boating and sailing, and guided kayak trips. Both tourist and non-tourist activities are included. In 2005, the ocean recreation industry contributed $3.8 billion to provincial GDP, $1.2 billion to labour income, and employed 32,200 FTEs. It is difficult to say what proportion of these figures can be attributed to the Lower Mainland, although it is fair to say that a considerable portion of tourist-associated expenditures occurs here. Recreation in coastal waters and shorelines is widely recognized as an ecosystem service.

Table 1 provides a snapshot of these ocean-based industries in terms of their contribution to provincial GDP, labour income, and the estimated number of full-time employees. Of the key industries reviewed for the region, ocean recreation stands apart. The industry provides more jobs and contributes more to provincial GDP than the ocean shipping industry, which contains Canada's busiest port.

11 Public Works and Government Services Canada, 2011.

12 Wilson, 2012.

TABLE 1: B.C. CENSUS DATA OF MARINE-RELATED INDUSTRIES IN THE LOWER MAINLAND			
Sector	FTEs	Contribution to provincial GDP ($ millions)	Labour income ($ millions)
Seafood	12,900	$790	$475
Ocean Transportation/Shipping	20,700	$1,500	$1,180
Ship and Boat Building	2,490	$398	$175
Ocean Recreation	32,200	$3,800	$1,200
Total	68,290	$6,488	$3,030
Source: Compiled from GSGislason & Associates Ltd., 2007			

2.3 Regional Biodiversity

B.C. is Canada's most ecologically and biologically diverse province. Clues to the abundance of biodiversity (i.e., the diversity within species, among species and of ecosystems) prior to Europeans arriving at the end of the 18th century can be found in First Nations stories as well as the journals of European explorers, which include accounts of herds of mountain caribou 2,000 strong and salmon runs exceeding 50 million fish.[13] Although 14 species have disappeared from the province since this time — including the passenger pigeon, western pond turtle, sea mink and viceroy butterfly — almost all the native species and ecosystems remain intact.[14] However, the past two decades have witnessed changes in the abundance and distribution of multiple species and ecosystems.

The study region falls within three terrestrial biogeoclimatic zones and one marine ecoregion. Both classification systems were developed in B.C. and are biogeographic classifications of patterns of biodiversity. The terrestrial biogeoclimatic zones include Coastal Douglas Fir, Coastal Western Hemlock, and Mountain Hemlock. The marine ecoregion is the Strait of Georgia. The health of these regions and the species that reside in them varies widely. However, in some cases, this information is simply unknown.

While almost all B.C. native species and ecosystems remain intact, the past two decades have witnessed changes in the abundance and distribution of multiple species and ecosystems.

VICEROY BUTTERFLY PHOTO COURTESY PICCOLO NAMEK

TERRESTRIAL AND FRESHWATER BIODIVERSITY

Our knowledge about terrestrial and freshwater biodiversity in B.C. is limited. Baseline information on the historic extent of ecosystems is incomplete and limited to a few ecosystems. As such, we know little about ecosystem trends over time. With respect to the current status of ecosystems, the vast majority of terrestrial mapping and classification is complete, but freshwater ecosystem mapping and classification is far less advanced. In addition, the data available on species richness and genetic diversity is biased because surveys and incidental observations often occur close to roads and areas of higher human population.[15] As such, the majority of B.C. species — 46,200 out of 50,000 — have not had their conservation status assessed.[16]

Table 2 provides a snapshot of the health of the three terrestrial biogeoclimatic zones. It provides the provincial extent of the zone in square kilometers, the conservation status, which is based on criteria that includes rarity, trends and the level of threat from human activity,[17] the number of species of global conservation

13 Ricker, 1987.
14 Austin et al., 2008.
15 Ibid.
16 Austin et al., 2008.
17 Austin et al., 2008.

concern, and provincial conservation concern. Lastly, the conservation status of ecological communities provides a finer level of detail, through the classification of ecosystems contained within a zone.

The Coastal Western Hemlock zone covers over 100,000 square kilometers of B.C. and is the most common biogeoclimatic zone in the study area. Its conservation status is "apparently secure," which indicates some cause for long-term concern; the zone is uncommon but not rare, and widespread where it is found. Although it contains the highest number of species of conservation concern, and lists over 80 per cent of its ecological communities of provincial concern, the shear extent of the zone prevents it from receiving a listing of higher conservation concern.

The Lower Fraser Valley has been heavily impacted by human use over the past century. Conversion of ecosystems has caused significant damage to streams and wetlands.

ABBOTSFORD PHOTO COURTESY JOSH MCCULLOCH/PICTUREBC

The Coastal Douglas-Fir zone occurs primarily along the southern portions of the east coast of Vancouver Island, and in the most southwest corner of the Lower Mainland. Its conservation status is "imperiled," indicating the zone is at high risk of extinction. This is reflected in the conservation status of its component ecological communities, 97 per cent of which are of concern.

The Mountain Hemlock zone occurs sporadically throughout the study region, primarily inland and at higher elevations of the Lower Mainland. It is listed as "apparently secure," yet only half of the ecological communities within the zone have been assessed. Although the number of species of conservation concern are relatively low, it is likely that many of the species of the zone have not been assessed.

TABLE 2: STATUS OF BIOGEOCLIMATIC ZONES WITHIN THE STUDY REGION

Biogeoclimatic zones	Area (km^2)	Conservation Status	Number of species of conservation concern		Status of ecological communities
			Global	Provincial	
Coastal Western Hemlock	102,253	Apparently secure	40	242	100% assessed, of which 83% are of provincial concern
Coastal Douglas-Fir	1,310	Imperiled	24	170	100% assessed, 97% of which are of provincial conservation concern
Mountain Hemlock	36,572	Apparently secure	13	45	51% assessed, of which 19% are of provincial concern

Source: Adapted from Austin et al., 2008

Threatened freshwater ecosystems of the study area include streams and wetlands. The Lower Fraser Valley has been heavily impacted by human use over the past century. Large areas of land have been converted to agriculture, settlement, and urbanization. This conversion of ecosystems has caused significant damage to streams and wetlands. A 1997 survey of classified streams in the Lower Mainland found 85 per cent were either no longer waterways or were threatened of becoming this way.[18] Likewise, a wetland study conducted in the Fraser Valley between 1989 and 1999 found a 20 per cent loss of wetland ecosystems over the decade due to urbanization or agriculture.[19]

18 Ibid.

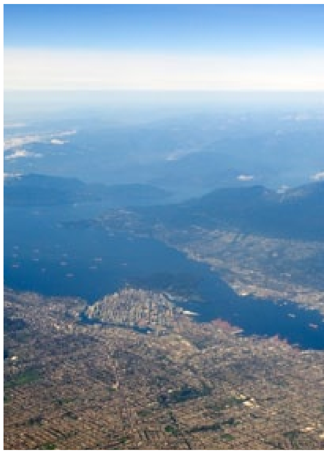
19 Ibid.

MARINE AND COASTAL BIODIVERSITY

The Strait of Georgia is considered one marine ecoregion. Our knowledge of marine ecosystems is considerably more limited than terrestrial and freshwater ecosystems. For instance, Mora et al. (2011) estimate that approximately 90 per cent of marine species have yet to be examined. The taxonomic groups for which we have a reasonable level of knowledge include marine fishes, birds and mammals. In general, we know more about vertebrates than invertebrates, about large more than small organisms, and about swimming than burrowing species.[20] With respect to habitats, little is known about biodiversity in the midwater and deeper parts of the ocean.[21]

Trends in marine biodiversity can be assessed by examining the number of marine species assessed as being at risk by the Committee on the Status of Endangered Wildlife (COSEWIC). A review of the past half century reveals that the status of most marine mammals has increased after past over-exploitation, that the status of marine fishes has stabilized after a sharp decline in abundance between 1970 and 1995, that the majority of fished stocks are well below target levels, and that seabirds show mixed results.[22]

The coastal zone, where the Fraser River and hundreds of smaller watercourses flow into the sea, is among the most productive of ecosystems. The mix of fresh and saltwater, along with the upwelling that occurs offshore, combine to make the Georgia Strait a nutrient rich habitat for a staggering number of fish, marine mammals, invertebrates, shorebirds and marine plants. The waters of the Strait support at least 200 species of fish, including five species of wild salmon, over 1,500 invertebrate species, hundreds of seabirds and shorebirds, and approximately 500 species of marine plants.[23] Intertidal zones are also important to a number of terrestrial species due to their relative ease of access to a vast diet of aquatic organisms. For example, coastal bears feast on shore crabs, porcelain crabs, mussels, barnacles, isopods and sea stars in intertidal zones.[24] The loss of species habitat is threatening the health of these species.



The waters of the Strait support at least 200 species of fish, including five species of wild salmon, over 1,500 invertebrate species, hundreds of seabirds and shorebirds, and approximately 500 species of marine plants.

GEORGIA STRAIGHT PHOTO COURTESY JEFF GUNN/FLICKR

THREATS TO REGIONAL BIODIVERSITY

The limited supply of low elevation areas and grassland habitats has simultaneously drawn a high level of biodiversity and human settlement to these regions. The explosive population growth in the Lower Mainland of has contributed many threats to aquatic habitat and wildlife. Ecosystem conversion and degradation due to urban sprawl, toxic chemicals, sewage and stormwater pollution, invasive species, the mismanagement of fisheries and marine resources, and the impacts of net cage salmon farming have cumulative impacts that can have cascading effects,[25] which result when multiple factors combine to create unexpected and often snowballing negative impacts. A 2003 provincial survey of approximately 300 biodiversity experts identified the human activities considered to have the greatest impact on broad ecosystem types. In terrestrial and freshwater ecosystems, climate change topped the list, whereas in the marine realm overfishing was found to have the greatest impact.

20 Austin et al., 2008.
21 Webb et al., 2010.
22 Cote et al., 2012.
23 Georgia Strait Alliance, 2011.
24 Ibid.
25 Georgia Strait Alliance, 2011; Austin et al., 2008.

PART 3

Study Approach

TURTLES AT LOST LAKE IN COQUITLAM, COURTESY NEIL VANDERWOLF/PICTUREBC

3.1 Natural Capital Valuation Framework

Within the past decade, considerable progress has been made to systematically link functioning ecosystems with human well-being.

Within the past decade, considerable progress has been made to systematically link functioning ecosystems with human well-being. Work completed by de Groot et al. (2002), the Millennium Ecosystem Assessment (MA, 2005) and The Economics of Ecosystems and Biodiversity (TEEB, 2010) have marked key advancements in this task. Although all recognize the linkages are a simplification of reality and consequently the need for further research and refinement, their studies have provided a conceptual framework for valuing natural capital and its related (ecosystem) goods and services.

Recognizing the lack of a standardized framework for the growing amount of information being collected on the value of ecosystem goods and services, de Groot, Wilson, and Boumans were among the first to present a conceptual framework and typology for describing, classifying and valuing ecosystem functions, goods and services in a consistent manner. As such, the authors took on the initial step of translating the complexity of ecological structures and processes into a limited number of ecosystem functions. From there, they identified how these functions provide goods and services of value to people. This led to the creation of four primary categories of ecosystem functions: regulating functions, habitat functions, production functions and information functions.

In 2001, an international coalition of scientists within the World Bank, the United Nations Environmental Program, the World Resources Institute, and others initiated an assessment of the effects of ecosystem change on human well-being. The product of this collaboration was the Millennium Ecosystem Assessment (MA), which refined the framework of the de Groot et al. study and provided an assessment of the state of ecosystem goods and services. The Assessment classified ecosystem services (as opposed to ecological functions) into four broad categories: provisioning services, regulating services, supporting services and cultural services.

The conceptual framework initiated by de Groot et al. and developed through the MA provided the impetus for several subsequent initiatives and programs, most notably The Economics of Ecosystems and Biodiversity (TEEB). Given that the MA intentionally did not focus much attention to the economics of ecosystem change, a

framework was proposed for the ecological and economic aspects necessary for the valuation of ecosystem goods and services. The revised typology classifies ecosystem goods and services into four groups:

- PROVISIONING SERVICES provide basic materials; mostly ecosystem service goods. Forests grow trees that can be used for lumber and paper, berries and mushrooms for food, and other plants for medicinal purposes. Rivers provide fresh water for drinking and fish for food. The waters of the Georgia Strait provide fish, shellfish, and seaweed. Provisioning of these goods is a familiar service provided by nature, and is easiest to quantify in monetary terms.
- REGULATING SERVICES are benefits obtained from the natural control of ecosystem processes. Intact ecosystems provide regulation of climate, water, soil, and keep disease organisms in check. Degraded systems propagate disease organisms to the detriment of human health.
- HABITAT SERVICES relate to the refuge and reproductive habitat ecosystems provide to wild plants and animals. Intact ecosystems provide commercially harvested species, and the maintenance of biological and genetic diversity.
- CULTURAL SERVICES are those that provide humans with meaningful interaction with nature. These services include spiritually significant species and natural areas, enjoying natural places for recreation, and learning about the planet through science and education.

The TEEB classification system has been adopted for this study, and is presented in Table 3 on the following page. These are the primary categories of ecosystem services, and are discussed in more detail in Section 5. It should be kept in mind that these can be further broken down into sub-categories; for example, recreation contains boating, fishing, birding, hiking, swimming and other activities. Every year, ecosystem services are added to the more detailed categories.

Identification of ecosystem services and goods provides a basis for estimating the value that these goods and services provide.

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TABLE 3: REVISED TYPOLOGY FOR ECOSYSTEM SERVICES

Service	Definition
PROVISIONING	
Drinking Water	Water for human consumption
Food	Biomass for human consumption
Raw Materials	Biological materials used for fuel, art and building; geological materials used for construction or other purposes
Medicinal Resources	Biological materials used for medicines
REGULATING	
Gas and Climate Regulation	Regulation of greenhouse gases, absorption of carbon and sulfur dioxide, and creation of oxygen, evapotranspiration, cloud formation and rainfall provided by vegetated and oceanic areas
Disturbance Regulation	Protection from storms and flooding, drought recovery
Soil Erosion Control	Erosion protection provided by plant roots and tree cover
Water Regulation	Water absorption during rains and release in dry times, temperature and flow regulation for plant and animal species
Biological Control	Natural control of pest species
Water Quality and Waste Processing	Absorption of organic waste, filtration of pollution
Soil Formation	Formation of sand and soil through natural processes
Nutrient Cycling	Transfer of nutrients from one place to another, transformation of critical nutrients from unusable to usable forms
Pollination	Fertilization of plants and crops through natural systems
HABITAT	
Biodiversity and Habitat	Providing for the life history needs of plants and animals
Primary Productivity	Growth by plants provides basis for all terrestrial and most marine food chains
CULTURAL	
Aesthetic	The role natural beauty plays in attracting people to live, work and recreate in an area
Recreation and Tourism	The contribution of intact ecosystems and environments in attracting people to engage in recreational activities
Scientific and Educational	Value of natural resources for education and scientific research
Spiritual and Religious	Use of nature for religious or historic purposes (i.e., heritage value of natural ecosystems and features)

Source: Compiled from Daly and Farley 2004, de Groot 2002, and TEEB 2009

3.2 Non-Market Ecosystem Valuation

While certain goods are explicitly accounted for in the market — goods that are perceived as important and of limited supply — the services underpinning the production of such goods are usually absent in the market. For example, food, fibre, and fuel have been valued in markets for centuries, while climate regulation and air quality do not garner the market signals that would alert society to changes in their supply or deterioration in the underlying ecosystems that support them. Determining the value of ecosystem goods and values is straightforward when they are traded in the market. Depending on the information available, measuring the value of a specific non-market good or service can range from easy, to possible but difficult, to impossible.

Economists have developed a number of techniques for putting dollar values on the non-market goods and services provided by ecosystems. These can be grouped into three broad categories: 1) direct market valuation approaches; 2) revealed preference approaches; and 3) stated preference approaches.[26] Direct market valuation methods derive estimates of ecosystem goods and services from related market data. Revealed preference methods estimate economic values for ecosystem goods and services that directly affect the market prices of some related good, and stated preference methods obtain economic values by asking people to make trade-offs among sets of ecosystem or environmental services or characteristics.[27]

It should be noted that these valuation methods differ in the welfare measures they estimate. While some methods measure the benefits consumers derive from the exchange of goods and services (i.e., consumer surplus), other methods measure the benefits producers derive from the exchange of goods and services (i.e., producer surplus), while others value components of total revenue. This source of heterogeneity in the meta-data raises the issue of non-comparability between estimated values.[28] In addition, willingness-to-pay measures generally exclude *ability* to pay constraints from the analysis. Recognizing that we need to be wary of comparing differing concepts of economic value, this study provides a range of values for most ecosystem service being measured (see Appendix B for a more detailed discussion of the strengths and weaknesses of non-market valuation). Table 4 provides descriptions of accepted techniques and the welfare values measured.

Determining the value of ecosystem goods and values is straightforward when they are traded in the market. Depending on the information available, measuring the value of a specific non-market good or service can range from easy, to possible but difficult, to impossible.

FRASER VALLEY DELTA PHOTO COURTESY EVEN LEESON/FLICKR

26 Pascual and Muradian, 2010.

27 Daly and Farley, 2004.

28 Brander et al., 2006.

TABLE 4: VALUATION METHODS AND ASSOCIATED WELFARE MEASURES USED TO VALUE ECOSYSTEM SERVICES IN PRIMARY STUDIES

Valuation Method	Description	Welfare Measures
DIRECT MARKET VALUATION APPROACHES		
Market prices	Assigns value equal to the total market revenue of goods/services.	Total revenue
Replacement cost	Services can be replaced with man-made systems; for example waste treatment provided by wetlands can be replaced with costly built treatment systems.	Value larger than the current cost of supply
Avoided cost	Services allow society to avoid costs that would have been incurred in the absence of those services; for example storm protection provided by barrier islands avoids property damages along the coast.	Value larger than the current cost of supply
Production approaches	Services provide for the enhancement of incomes; for example water quality improvements increase commercial fisheries catch and therefore fishing incomes.	Consumer surplus, producer surplus,
REVEALED PREFERENCE APPROACHES		
Opportunity cost	Value of the next best alternative use of resources; for example, travel time is an opportunity cost of travel because this time cannot be spent on other pursuits. The travel cost method is a well accepted application of the opportunity cost approach.	Consumer surplus, producer surplus, or total revenue for next best alternative
Travel cost	Service demand may require travel, which have costs that can reflect the implied value of the service; recreation areas can be valued at least by what visitors are willing to pay to travel to it, including the imputed value of their time.	Consumer surplus
Hedonic pricing	Service demand may be reflected in the prices people will pay for associated goods; for example housing prices along the coastline tend to exceed the prices of inland homes.	Consumer surplus
STATED PREFERENCE APPROACHES		
Contingent valuation	Service demand may be elicited by posing hypothetical scenarios that involve some valuation of alternatives; for instance, people generally state that they are willing to pay for increased preservation of beaches and shoreline.	Compensating or equivalent surplus

Economists have developed a number of techniques for putting dollar values on the non-market goods and services provided by ecosystems.

FRASER RIVER DELTA PHOTO COURTESY TTCOPLEY/FLICKR

BENEFIT TRANSFER

Ideally, a valuation of the aquatic ecosystem services of the Lower Mainland would involve detailed ecological and economic studies of each ecosystem of interest for each land cover type, utilizing one or more of the above valuation techniques. Unfortunately, undertaking such studies is expensive and time consuming — it would require over 100 primary valuation studies. This is a similar problem to the valuation of a business or house, and the reason why an appraisal approach provides a less costly valuation method. In natural resource analysis, this is analogous to the benefit transfer method. As such, the benefit transfer approach was used for valuing a range of services in this study. Benefit transfer can be used to evaluate non-market ecosystem services by transferring existing benefit estimates from primary studies already completed for another study


PHOTO COURTESY EVAN LEESON/FLICKR

area.[29] When using this method, care must be taken to ensure values being transferred exhibit similarities within the specific ecosystem good or service characteristics.

A combination of in-house calculations and transferred studies has been used in this report. This combination of studies was necessary due to the lack of primary valuation studies on aquatic ecosystem services in the study area. In addition, because ecosystem services are physically different and more or less amenable to markets, a variety of different valuation techniques are required. By utilizing an appraisal approach, great cost and time can be saved. Existing studies were required to meet a set of three criteria to be included in this valuation.

- ALL PRIMARY STUDIES INCLUDED A PEER-REVIEW PROCESS. The vast majority of primary studies were drawn from academic journals, but we also include commissioned reports for governments and non-profit organizations, and graduate dissertations.
- PRIMARY STUDY LOCATIONS WERE RESTRICTED TO NORTH AMERICA. This ensured similar demographics and ecosystem characteristics. We made two exceptions: we included studies that adopted global-averages for nutrient cycling and gas and climate regulation, since both of these processes occur on a global scale.
- PRIMARY STUDIES MET METHODOLOGY RECOMMENDATIONS. We based our methodology recommendations upon Farber et al., 2006, but made adjustments for those services not included (e.g., habitat refugium and nursery), valuation methods not considered (e.g., opportunity cost), and valuation methods that are gaining wider acceptance.

Table 5 on page 30 provides the valuation approach used for each service in this study, the accepted valuation methods and degree of transferability. For example, waste processing was valued using the benefit transfer approach. When choosing primary studies, only those that followed the replacement cost, avoided cost, or contingent valuation methods were included in our study. Lastly, the ability to transfer the service of waste processing from one context to another is medium to high.

29 Daly and Farley, 2004.

TABLE 5: VALUATION METHOD USED BY BENEFIT TYPE

Ecosystem service	Valuation approach	Recommended valuation method	Transferability across sites
Aesthetic and Recreational	Benefit transfer	TC, CV, H, **OC**	Low
Disturbance Regulation	Benefit transfer	AC, **RC, H**	Medium
Gas and Climate Regulation	In house calculation and benefit transfer	CV, AC, RC	High
Habitat Refugium and Nursery	Benefit transfer	CV, P, AC, H, OC	
Nutrient Cycling	Benefit transfer	CV, AC, **RC, P**	Medium
Raw Materials	Benefit transfer	M, P	High
Soil Erosion Control	Benefit transfer	AC, RC, H	Medium
Waste Processing	Benefit transfer	RC, AC, CV	Medium — High
Water Regulation	Benefit transfer	M, AC, RC, H, P, CV	Medium
Water Supply	Benefit transfer	AC, RC, M, TC, **CV,OC**	Medium
Food Provisioning	In house calculation	M, P	High

Note: AC = avoided cost; CV = contingent valuation; H = hedonic pricing; M = market pricing; P = production approach; RC = replacement cost; TC = travel cost; OC = opportunity cost. **Green** = Valuation method added by Earth Economics

Source: Adapted from Farber, et al., 2006.

3.3 Study Limitations

Valuation exercises have limitations that must be noted, although these limitations should not detract from the core finding that ecosystems produce a significant economic value to society. These concerns can be grouped into general limitations; arguments against benefit transfer, including database limitations; GIS limitations; and primary study limitations. Here, we address the key general limitations of natural capital valuation and benefit transfer. However, each class of limitations is addressed in detail in Appendix B.

GENERAL LIMITATIONS

STATIC ANALYSIS. This analysis is a static, partial equilibrium framework that ignores interdependencies and dynamics, though new dynamic models are being developed. The effect of this omission on valuations is difficult to assess.

INCREASES IN SCARCITY. The valuations probably underestimate shifts in the relevant demand curves as the sources of ecosystem services become more limited. The values of many ecological services rapidly increase as they become increasingly scarce.[30] If B.C.'s Lower Mainland aquatic ecosystem services are scarcer than assumed here, their value has been underestimated in this study. Such reductions in supply appear likely as land conversion and development proceed; climate change may also adversely affect the ecosystems, although the precise impacts are more difficult to predict.

30 Boumans et al., 2002.

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

NON-ECONOMIC VALUES. This report adopts an explicitly economic perspective on the links between economic development, natural resources and ecosystem services. This implies a focus on the value of functioning ecosystems *to people*, rather than the intrinsic value of nature in its own right. This is not to suggest that nature's intrinsic biological, aesthetic, cultural, and evolutionary merits do not hold substantial and significant value. Such values are relevant and should be factored into decision-making.

AN ECONOMIC APPROACH FURTHER IMPLIES THAT INCENTIVES MATTER. That is to say that price signals, subsidies, taxes and property rights influence human behaviour and the use of natural capital. The lack of market incentives and public policy to indicate the full value of ecosystem services is a key contributor to the continued loss of natural resources and their associated ecosystem services. A technique called multi-criteria decision analysis is available to formally incorporate economic values with other social and policy concerns.[31] Having economic information on ecosystem services usually helps this process because traditionally, only opportunity costs of forgoing development or exploitation are counted against non-quantified environmental concerns.

The lack of market incentives and public policy to indicate the full value of ecosystem services is a key contributor to the continued loss of natural resources and their associated ecosystem services.

PHOTO COURTESY
DARREN BAREFOOT/FLICKR

BENEFIT TRANSFER LIMITATIONS

A benefit transfer analysis estimates the economic value of a given ecosystem (e.g., wetlands) from prior studies of that ecosystem type. Like any economic analysis, this methodology has strengths and weaknesses.

UNIQUE ECOSYSTEMS: It can be argued that every ecosystem is unique; per-hectare values derived from another location may be irrelevant to the ecosystems being studied. While every wetland, forest or other ecosystem is unique in some way, ecosystems of a given type, by their definition, have many things in common. The use of average values in ecosystem valuation is no more or less justified than their use in other macroeconomic contexts; for instance, the development of economic statistics such as Gross Domestic or Gross National Product. This study's estimate of the aggregate value of the B.C.'s Lower Mainland ecosystem services is a valid and useful (albeit imperfect, as are all aggregated economic measures) basis for assessing and comparing these services with conventional economic goods and services.

UNDER-ESTIMATING THE TRUE VALUE OF ECOSYSTEMS: It has been argued that gathering all the information needed to estimate the specific value for every ecosystem within the study area is not feasible. Therefore, the true value of all of the wetlands, forests, pastureland, etc. in a large geographic area cannot be ascertained and will be underestimated. In technical terms, we have far too few data points to construct a realistic demand curve or estimate a demand function.

As employed here, the prior studies we analyzed encompass a wide variety of time periods, geographic areas, investigators and analytic methods. Many provide a range of estimated values rather than single-point estimates. The present study preserves this variance; no studies were removed from the database because their estimated values were deemed to be "too high" or "too low," although studies that used antiquated methods and data were removed. Limited sensitivity analyses were also performed. This approach is similar to determining an asking price for a piece of land based on the prices of comparable parcels; even though the

31 See Janssen and Munda, 2002 and de Montis et al., 2005 for reviews.

property being sold is unique, realtors and lenders feel justified in following this procedure to the extent of publicizing a single asking price rather than a price range.

In this report, we have displayed our study results in a way that allows one to appreciate the range of values and their distribution. It is clear from inspection of the tables that the final estimates are not extremely precise. However, they are much better estimates than the alternative of assuming that ecosystem services have zero value, or, alternatively, of assuming they have infinite value. Pragmatically, in estimating the value of ecosystem services, it seems better to be approximately right than precisely wrong.

Pragmatically, in estimating the value of ecosystem services, it seems better to be approximately right than precisely wrong.

PHOTO COURTESY JAN KOCIAN

3.4 Previous Studies

A 1997 global study of 17 ecosystem services across 16 biomes by Costanza et al. drew attention to the immense value of near-shore marine ecosystems when its estimates revealed that coastal ecosystems account for over two-thirds of the total value of all ecosystems surveyed. In monetary terms, this amounts to a value between $18 trillion and $61 trillion U.S. (2012 dollars).

Within North America there are four U.S. and one Canadian study that include coastal ecosystem services in the valuation of natural capital. They include *Valuing New Jersey's Natural Capital* (State of New Jersey, 2007), *The Economic Value of Ecosystem Services Provided by the Galveston Bay/Estuary System* (Ko, 2007), *The Economic Value of Coastal Ecosystems in California* (Raheem et al., 2009), *A New View of the Puget Sound Ecosystem* (Batker et al., 2009), and *The Value of Natural Capital in Settled Areas of Canada* (Olewiler, 2004). The first two studies listed estimated ecosystem services on the eastern coast of the U.S. Both reported near-shore marine services as the highest value services. In New Jersey the most valuable services are disturbance regulation (U.S. $3 billion/yr, 2007 dollars) and water filtration (U.S. $2.4 billion/yr, 2007 dollars), whereas beaches provide by far the highest value per acre (U.S. $330 million/yr, 2007 dollars). Similarly coastal wetlands ranked high in value in Galveston Bay, Texas, where the non-use value was estimated at U.S. $5.77 billion (2007 dollars), based on replacement cost analysis.

The Economic Value of Coastal Ecosystems in California surveyed the value of estuaries and beaches using the benefit transfer method. Of the ecosystem services valued, which include erosion regulation, water purification and waste treatment, pest regulation, natural hazard regulation, cultural heritage values, recreation, habitat, and primary production, the highest values were for primary production (U.S. $1,351 — 69,671/acre/yr, 2007 dollars) and erosion regulation (U.S. $31,131/acre/yr, 2007 dollars). The authors of the study urged state officials, specifically the California Ocean Protection Council, to map ecosystems and their services and conduct primary valuation studies, so priority areas can be identified for protection or enhanced management practices.

A New View of the Puget Sound Ecosystem, prepared by Earth Economics, utilized current geographic information system data for a suite of ecosystems including forests, freshwater wetlands, grasslands, agricultural lands, pastures, rivers and lakes, beach, estuary, salt marsh, eel grass beds, and marine waters. Regardless of the fact that many near-shore and marine services were unable to be estimated due to a lack of data, coastal services reported significant values, such as storm protection from salt marshes (U.S. $96,000/acre/yr, 2006 dollars), aesthetic and recreational value of beaches (U.S. $45,000/acre/yr, 2006 dollars), and disturbance protection from beaches (U.S. $36,000/acre/yr, 2006 dollars). The total value of services was estimated to range from $7.4 billion to $61.7 billion annually. A recent follow-up report recently (*Valuing the Puget Sound Basin*, 2010) added the value of the Pacific Yew tree for its medicinal value, as well as the value of snow pack for its water storage services. These services alone amounted to over $500 million.

The Value of Natural Capital in Settled Areas of Canada, commissioned by Ducks Unlimited and the Nature Conservancy of Canada, estimates the economic values of natural capital of four Canadian locations. Of the areas, the Lower Mainland of B.C. includes limited coastal services. Estuaries are valued at C $22,832/hectare/yr (2004 dollars) with the largest values coming from waste treatment services. In addition, it was noted that the value of replacing waste treatment in the lower Fraser Valley is worth a minimum of C $230 million per year (2004 dollars) in forgone treatment costs. This number increases if the costs of infrastructure capital costs are factored in. The study recommends the creation of national inventories on the physical quantities and attributes of natural capital and their changes over time.

Within North America there are four U.S. and one Canadian study that include coastal ecosystem services in the valuation of natural capital.

NEW JERSEY PHOTO COURTESY DORIAN WALLENDER/FLICKR

PART 4

Aquatic Land Cover in the Lower Mainland

4.1 Overview

The valuation of aquatic ecosystem services in the Lower Mainland can be divided into the following steps:

- **QUANTIFICATION OF LAND COVER CLASSES:** Geographic Information Systems (GIS) data is used to assess the hectares of each land cover class within the study region. Examples of land cover classes include marine, estuary, eelgrass beds and riparian forest.
- **IDENTIFICATION OF ECOSYSTEM SERVICES:** The ecosystem services provided within the watershed are identified. See Part 5 for a review of ecosystem services within the study region.
- **VALUATION OF LAND COVER CLASSES:** Using a database of peer reviewed ecosystem service valuation studies, a range of studies for each specific land cover class are selected depending on the geographic and land-cover match to the site, as well as the valuation method utilized. These are like comparables used in a house or business appraisal. Each land cover class has a table of values based on the ecosystem services provided. The valued services can be totaled from the peer reviewed academic literature showing high and low annual per-hectare values for each land cover type.
- **VALUATION OF THE AQUATIC ECOSYSTEMS OF THE LOWER MAINLAND:** The total high and low annual values of ecosystem services for each land cover class is multiplied by the hectares of that land cover class to arrive at total high and low annual value estimates. Land cover class values are summed to arrive at a total annual value for the study area. Net present values are calculated for the watershed over 50 years at a range of discount rates: zero (no discount), 3 per cent (commonly used in socio-economic studies) and 5 per cent (a more conventional rate).

PHOTO COURTESY JACKSON CARSON/FLICKR

4.2 Quantification of Land Cover Classes

Geographic Information Systems (GIS) data are used to assess and categorize the water/land cover in the study area. The GIS data is gathered through aerial and/or satellite photography and can be classified according to several classification systems or "layers." Earth Economics maintains a database of peer-reviewed valuation studies organized by land cover class, which typically requires GIS data from several sources. For this valuation, the study area was divided into nine land cover classes. The following five datasets were compiled for the region's land cover and land use data within B.C. (see Appendix C for details):

- The Biophysical Shore-Zone Mapping System;
- Land Cover, Circa 2000;
- Vegetation Resources Inventory;
- National Ecological Framework for Canada; and
- National Hydro Network.

For the portion of the study area within the United States, the following five land cover and land use datasets were compiled:

- The Washington State ShoreZone Inventory;
- The National Land Cover Database 2006;
- Interagency Vegetation Mapping Project;
- EPA Ecoregions of the United States; and
- The National Hydrography Dataset.

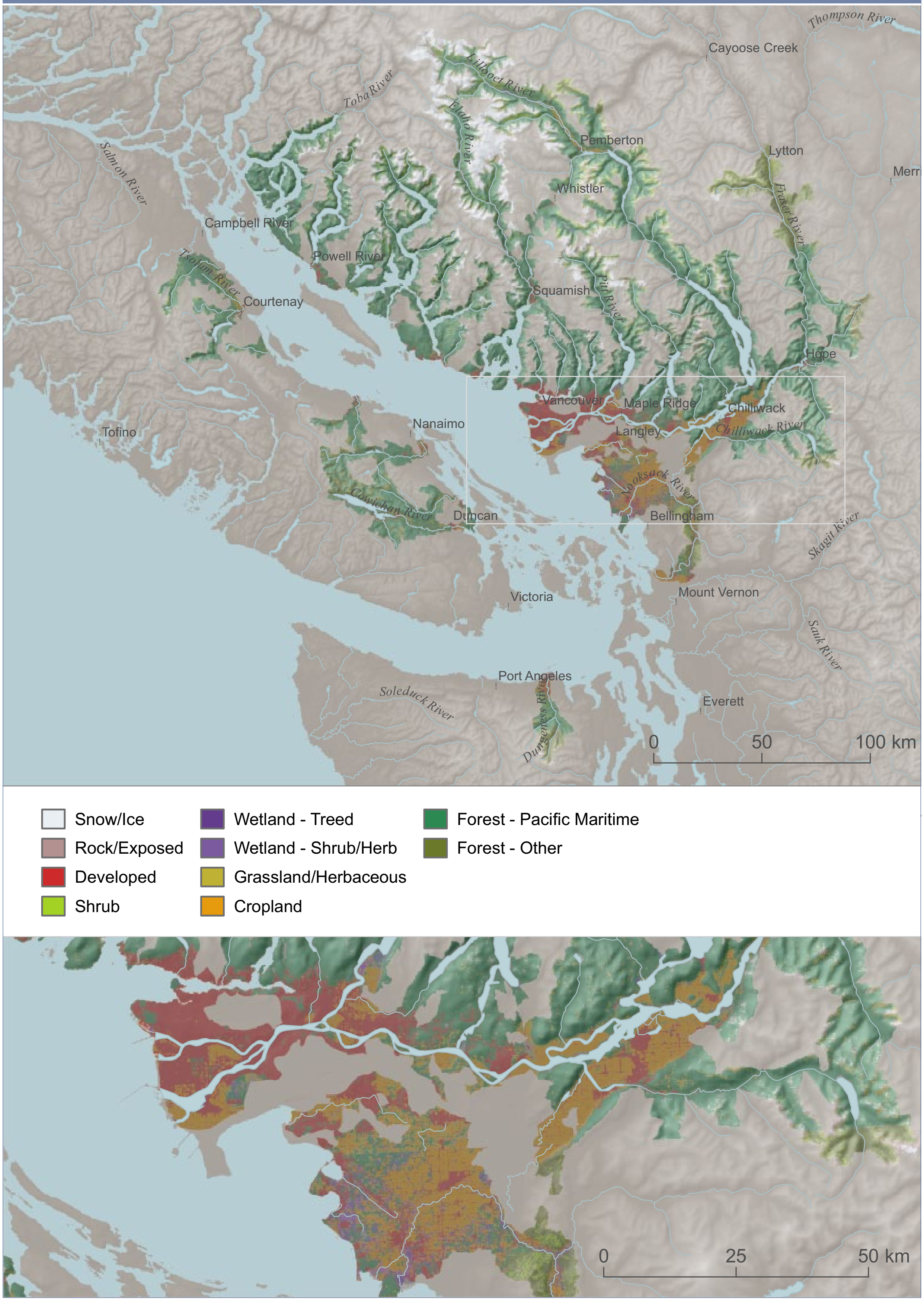
Geographic Information Systems (GIS) data are used to assess and categorize the water/land cover in the study area.

Land cover types found in the study area are referenced in Table 6, which presents the final land cover classes and hectares that comprise the study area as categorized for this report, and a description of the layer(s). Figure 6 on the following page provides a snapshot of the distribution of these land classes.

TABLE 6: TOTAL HECTARES BY LAND COVER CLASS IN THE STUDY AREA

Land Cover Class	Hectares	% of study area	Data Source(s)/Layers used
Beach	580	< 1	B.C. Biophysical Shore-Zone Mapping System Washington State ShoreZone Inventory
Estuary	34,016	1	B.C. Biophysical Shore-Zone Mapping System Washington State ShoreZone Inventory
Forest	1,192,502	40	B.C. Land Cover, Circa 2000 Vegetation Resources Inventory (for basal areas classes) National Ecological Framework for Canada (maritime versus non-maritime) WA National Land Cover Database 2006 Interagency Vegetation Mapping Project (for basal area classes) EPA Ecoregions of the United States (maritime versus non-maritime)
Lakes/Rivers	115,089	4	National Hydro Network (B.C.) National Hydrography Dataset (WA)
Marine	1,237,210	42	B.C. Watershed Atlas Maps B.C. Marine Ecosystem Classifications Ecounits Water Resource Inventory Areas (WA)
Riparian buffer	373,099	13	National Hydro Network (B.C.) National Hydrography Dataset (WA)
Salt Marsh	537	< 1	B.C. Biophysical Shore-Zone Mapping System Washington State ShoreZone Inventory
Wetland	12,271	< 1	B.C. Land Cover, Circa 2000 Vegetation Resources Inventory (for basal areas classes) National Ecological Framework for Canada (maritime versus non-maritime) WA National Land Cover Database 2006 Interagency Vegetation Mapping Project (for basal area classes) EPA Ecoregions of the United States (maritime versus non-maritime)
Eelgrass Beds	7,134	< 1	B.C. Biophysical Shore-Zone Mapping System Washington State ShoreZone Inventory
Total	2,972,438	100	

FIGURE 6: LAND COVER CLASSES WITHIN THE STUDY AREA



4.3 Identification of Ecosystem Services and Valuation of Land Cover Classes

IDENTIFICATION OF ECOSYSTEM SERVICES

The spatial distribution of goods and services produced in a region's economy can be mapped across the landscape. Mapping goods and services provided by factories, restaurants, schools and businesses provides a view of the economy of that region. For example, retail, residential and industrial areas occur in different parts of the landscape. The economic value of these goods, services, housing and industry can also be estimated from market or appraisal values.

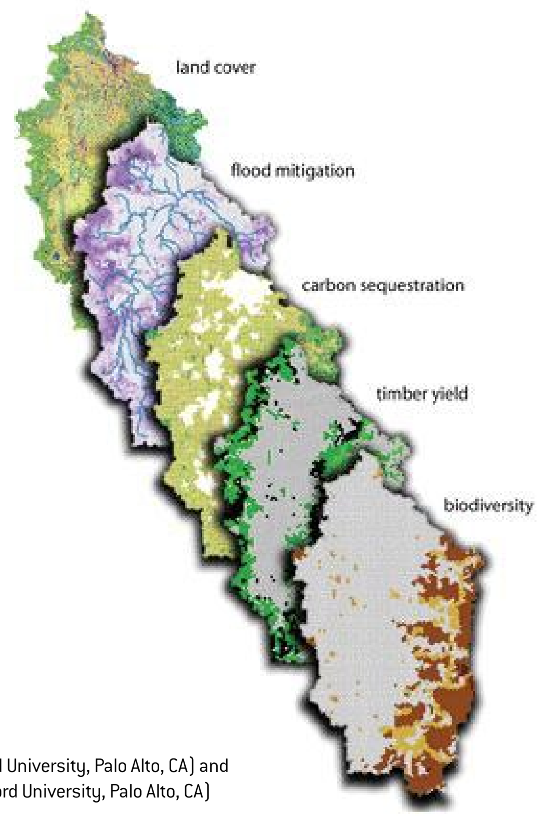
The distribution of ecosystem services throughout B.C.'s aquatic regions is similar. Each land cover class, from wetland to mature forest to eelgrass beds, provides economically valuable goods and services. For example, a wetland provides ecosystem services such as flood risk reduction, biodiversity, climate regulation and soil formation. Eelgrass provides shoreline stabilization and climate regulation, but not soil formation. Figure 7 illustrates how ecosystem services are "stacked" upon the landscape, in the Willamette Basin in Oregon. The first layer, "land cover," depicts the land cover classes providing ecosystem services. Some land cover classes produce both flood risk reduction and carbon sequestration, while others produce only flood risk reduction. Note that biodiversity is concentrated in one half of the basin, so these areas are critical to a biodiversity strategy.

Each land cover class, from wetland to mature forest to eelgrass beds, provides economically valuable goods and services.

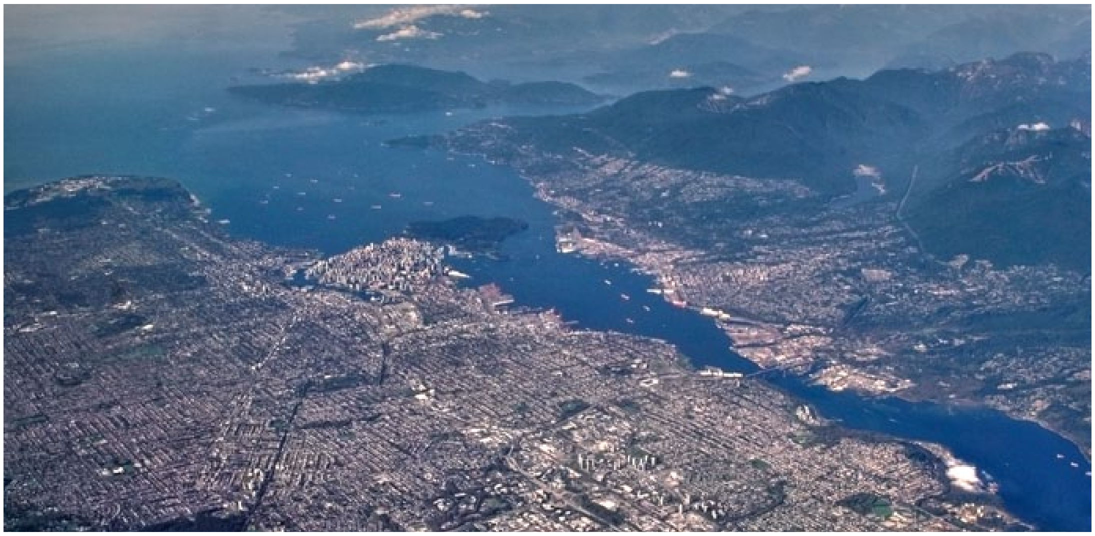
EELGRASS PHOTO COURTESY JAN KOCIAN

FIGURE 7: SUITES OF ECOSYSTEM SERVICES

Example of different suites of ecosystem services provided by various land covers



Source: Erik Nelson (Stanford University, Palo Alto, CA) and Heather Tallis (Stanford University, Palo Alto, CA)



4.4 Land Cover Class Values

Natural capital in B.C.'s Lower Mainland generates a flow of value, comparable to an annual stream of income. As long as the natural infrastructure of these aquatic ecosystems is not degraded or depleted, this flow of value will likely continue into the distant future. This flow of value is expressed in C$/hectare/year, which represents the dollar value generated by a single ecosystem service on a particular land cover class. For example, based on a specific peer-reviewed scientific report, urban wetlands in Abbotsford, B.C. were shown to provide up to $452/hectare/year in water supply benefits.[32]

The full suite of ecosystem services produced by a particular land cover class yield a total flow of value for that land cover class, yet this report is focused on non-market services. In the case of wetlands, this means summing all of its known non-market ecosystem service values (i.e., water regulation, habitat, recreation, etc.), for which valuation studies have been completed. This number can then be multiplied by the number of hectares of wetlands in the Lower Mainland for a value in $/year.

By "transferring" values from a database of peer-reviewed academic studies and journal articles the appraisal of ecosystem service values is accomplished (for more on benefit transfer see Section 3.2). This approach yields an appraisal, rather than a precise measure, because often the location of the wetland or other land cover is critical to the valuation. For example, one wetland may be crucial for salmon rearing, while another may be too far upstream.

This study provides specific references for every value provided for every land cover type. See Appendix E for an annotated bibliography of primary studies applied in this valuation. Each of these primary studies utilized one of the eight valuation methods shown in Table 4 on page 28. Due to limitations in the range of primary valuation studies conducted on aquatic ecosystem services, not all ecosystem services that were identified on each land cover class in the previous section could be assigned a known value from the database. For example, the land cover class "marine" has only been valued for three ecosystem services — habitat refugium and nursery, food provisioning, and aesthetic and recreational — though such areas also clearly provide medicinal resources, genetic resources, gas and climate regulation, water regulation, water supply, biological control, waste treatment, spiritual and cultural values, and a number of other important benefits. While we were able to complete in-house calculations, based on local data for food provisioning and gas and climate regulation, resource limitations restricted our ability to carry out any more valuations.

As long as the natural infrastructure of the Lower Mainland's aquatic ecosystems is not degraded or depleted, the flow of economic value that its natural capital generates will likely continue into the distant future.

PHOTO COURTESY
EVAN LEESON/FLICKR

32 Hauser and van Kooten, 1993.

A matrix that summarizes the suite of ecosystem services identified by each land cover type in the study area, compared with those that were actually valued in this study, is provided in Table 7. Where ecosystem services do not exist, such as pollination in underwater marine systems (except for eel grass), there is a white box. Where ecosystem services exist and provide value to people, but there are no valuation studies available, the box is colored blue. Where valuable ecosystem services exist and values are available, the box is grey and has an X.

This study provides specific references for every value provided for every land cover type.

PHOTO COURTESY MTS VANCOUVER/FLICKR

TABLE 7: AQUATIC ECOSYSTEM SERVICES VALUED AND/OR IDENTIFIED IN THE LOWER MAINLAND

		Beach	Estuary	Eel grass beds	Salt Marsh	Wetland	Marine	Lakes/Rivers	Riparian buffer	Forest
Food							X			
Water Supply			X			X		X		X
Raw Materials										
Medicinal Resources										
Genetic Resources										
Ornamental Resources										
Gas and Climate Regulation	Air Pollution									X
	Carbon Sequestration		X	X	X					X
	Carbon Storage		X	X	X	X	X			X
Disturbance Regulation		X				X			X	X
Soil Erosion Control										
Water Regulation										
Biological Control										
Waste Processing					X	X			X	
Soil Formation										
Nutrient Cycling			X	X						
Pollination										
Habitat Refugium and Nursery			X	X	X	X	X	X	X	X
Aesthetic Information		X	X		X	X	X	X	X	X
Recreation and Tourism		X	X		X	X	X	X	X	X
Science and Education										
Spiritual and Religious										

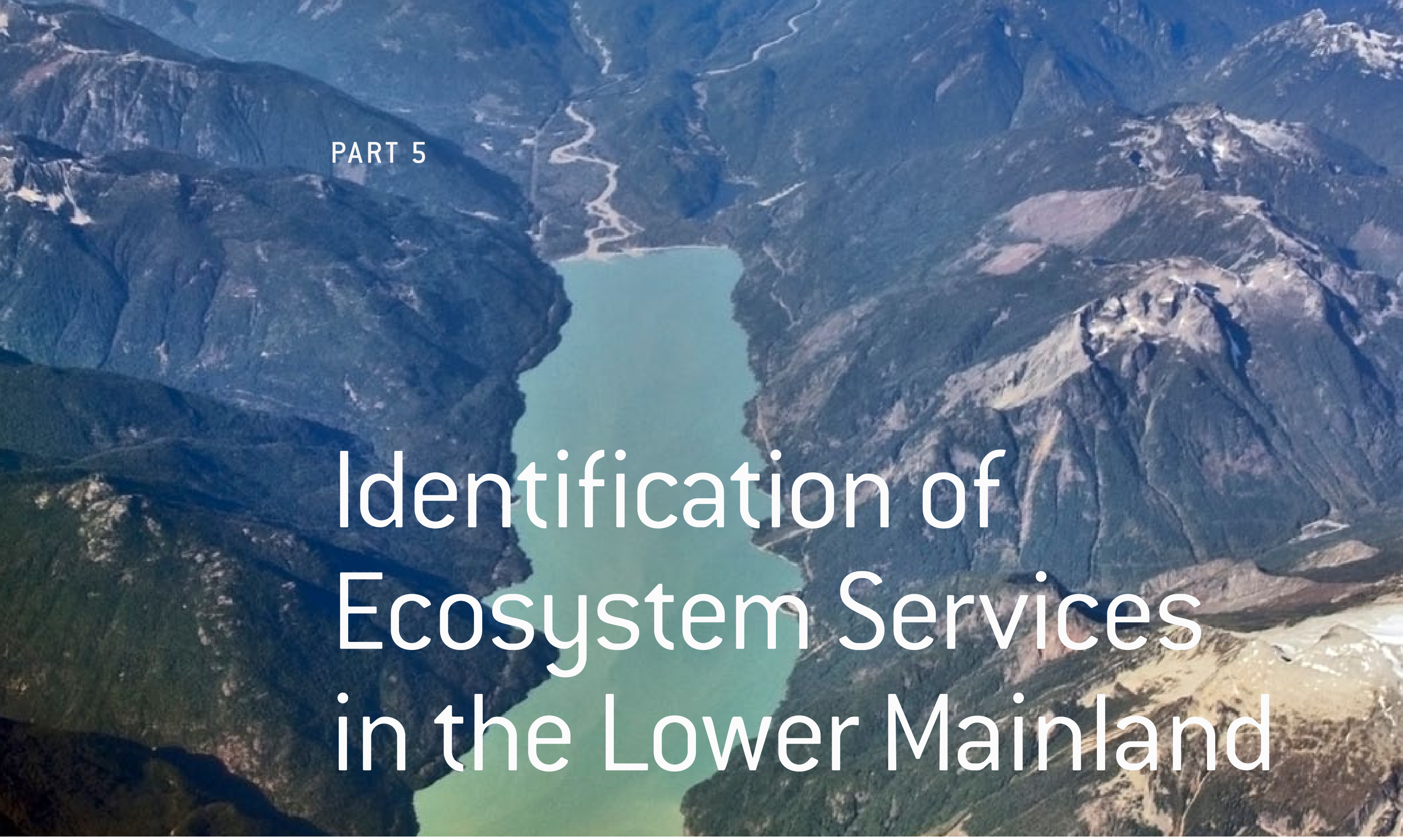
KEY

Ecosystem service produced by land cover class but not valued in this report	(blue)
Ecosystem service produced by land cover class and valued in this report	X
Ecosystem service not produced by land cover class	(white)

Many ecosystem services identified as valuable do not have an associated valuation study. As further primary studies are added to the database, the combined known value of aquatic ecosystem services in the Lower Mainland will rise.

PHOTO COURTESY MTS VANCOUVER/FLICKR

A large number of ecosystem services (for each land cover class) have yet to be valued in a primary study. This suggests that the valuation is a significant undervaluation of the true value, because many ecosystem services identified as valuable do not have an associated valuation study. As further primary studies are added to the database, the combined known value of aquatic ecosystem services in the Lower Mainland will rise.



PART 5

Identification of Ecosystem Services in the Lower Mainland

Metro Vancouver is fortunate in having large, protected watersheds capable of supplying more than two million people with naturally filtered water. In Squamish and most rural parts of the FVRD, water supply comes primarily from wells.

PHOTO COURTESY EVAN LEESON/FLICKR

5.1 Provisioning Services

FRESH WATER

This ecosystem service refers to the benefits associated with the filtering, retention and storage of water that occurs primarily in streams, lakes and aquifers. Watersheds provide fresh water for human consumption and agriculture, including surface water and ground water for large metropolitan and rural areas, wells, industry, and irrigation. The hydrological cycle is affected by structural elements of a watershed such as forests, wetlands and geology, as well as processes such as evapotranspiration and climate. Sixty per cent of the world's population gets their drinking water from forest and mountain ecosystems.[33] Increasing loss of forest cover around the world has decreased water supply, due to lower ground water recharge and to lower flow reliability.[34]

The study area's drinking water comes from streams, rivers, and aquifers. Metro Vancouver is fortunate in having large, protected watersheds (the Lower Seymour and Capilano watersheds) that are capable of supplying more than two million people in the Lower Mainland with water that is naturally filtered. In Squamish and most rural parts of the FVRD, water supply comes primarily from wells.

The value of water supply is estimated for four land classes, including estuaries, forests, lakes and rivers, and wetlands. Table 8 lists the primary studies used to develop the range of values, including the study location, methodology, and the per hectare value in 2010 Canadian dollars. The primary valuation methodology followed was contingent valuation. A number of authors estimated the value of water supply by surveying residents on their willingness-to-pay for cleaner water (e.g., Bockstael et al., Croke et al., Pate and Loomis,

33 UNEP, 2005.
34 Syvitski, 2005.

Hauser and van Kooten, and Whitehead et al.). Other methods used include travel cost, which examines the value of improvements in water quality through travel expenditures (e.g., Ribaudo and Epp; Creel and Loomis). Wilson uses replacement cost to value water supply by comparing the cost of naturally filtered water with that of an alternative water source. The highest value for the service of water supply was provided by Gupta and Foster, who use the opportunity cost method to compare the cost of wetland water with that of an alternative water source. Further details of the primary studies can be found in Appendix E, which provides an annotated bibliography of all studies used.

The total value for water supply services in the Lower Mainland ranges from $2.7 billion to $7 billion per year (see Appendix D). We found wetlands to be the highest per hectare value land class for this ecosystem service, ranging in value from $5,236.18 to $36,653.04 per hectare per year. Wetland cover in a watershed is integral to a clean water supply, as it controls the quality of water entering streams, rivers and lakes. Replacing this service is time consuming and expensive, as Gupta and Foster demonstrate. Their study calculates the cost at the wellhead of supplying water from well fields, much like what is done in regions of the Lower Mainland without access to the Seymour and Capilano watersheds. Unfortunately, wetlands are highly threatened ecosystems. An estimated 50 to 70 per cent of the original wetlands in the Lower Mainland have been destroyed, resulting in loss of species habitat, lower water quality, more flooding, and less reliability of stream flow.

TABLE 8: STUDIES USED TO VALUE WATER SUPPLY

Author(s) and date of study	Location of study	Methodology	Value/hectare/year (2010 $Can)
ESTUARY			
Bockstael, N.E., et al., 1989	Baltimore-Washington	Contingent valuation	$222–$394
Whitehead, J.C., et al., 1997	North Carolina	Contingent valuation	$18–$67
FOREST			
Ribaudo, M. and Epp, D.J., 1984	St. Albans Bay, Vermont	Travel cost	$4,130–$5,237
Wilson, S.J., 2010 (based on Ernst C., et al., 2007)	British Columbia	Replacement cost	$2,057 (no range)
LAKES AND RIVERS			
Bouwes, N.W. and Scheider, R., 1979	Pike Lake, Wisconsin	Travel cost	$1,905 (no range)
Croke, K., et al., 1986	Chicago	Contingent valuation	$1,746 (no range)
Ribaudo, M. and Epp, D.J., 1984	St. Albans Bay, Vermont	Travel cost	$2,602 (no range)
WETLANDS			
Creel, M. and Loomis, J., 1992	California	Travel cost	$1,674 (no range)
Gupta, T.R. and Foster, J.H., 1975	Massachusetts	Opportunity cost	$5,236–$36, 653
Hauser, A and van Kooten, C., 1993	Abbotsford, B.C.	Contingent valuation	$111–$452
Hayes, K.M., et al., 1992	Rhode Island	Contingent valuation	$4,171–$6,483
Pate, J. and Loomis, J., 1997	California	Contingent valuation	$11,101 (no range)
Wilson, S.J., 2010 (based on data from Ernst, C., Gullick, R. and Nixon, K. 2007)	British Columbia	Replacement cost	$2,057 (no range)

We found the total value for water supply services in the Lower Mainland to be from $2.7 billion to $7 billion per year.

PHOTO COURTESY PETE TUEPAH

PHOTO COURTESY EVAN LEESON/FLICKR

FOOD

Marine ecosystems are the last natural systems that supply people with large amounts of wild-caught food.

PHOTO COURTESY PETER GORDON/FLICKR

Food includes biomass for human consumption, provided by a web of organisms and a functioning ecosystem. Providing food is one of the most important functions of marine ecosystems. Globally, fish and seafood provide the primary source of protein to one billion people. Fishing and fish industries provide direct employment to some 38 million people.[35] Marine ecosystems are the last natural systems that supply people with large amounts of wild-caught food.

The fisheries of the Pacific Northwest Coast are renowned worldwide, particularly for its many salmon runs, but also for its halibut, herring, sea urchin, hake, crab and shellfish. Wild salmon runs have been significantly diminished since pre-contact years, whereas the salmon aquaculture industry has grown rapidly over the past three decades. There is currently much controversy about the ecological and health impacts of intensive open-net pen Atlantic salmon aquaculture. Of particular concern are the impacts on wild salmon and marine ecosystems.

While the values of commercial fisheries and aquaculture have a well-established market value, the value of recreational and First Nation subsistence fisheries have no market values. The non-market value of First Nations and recreational fisheries were estimated through primary research for the purpose of this report.[36] Landing prices from commercial fisheries were transferred to catch data for 41 recreational and subsistence fisheries, located within Pacific Management Areas 14–19, 28 and 29 (see Section 6 for further information). By transferring the per hectare value of $1.58 to the marine region, we arrived at a total value of $1.95 million per year in non-market food provisioning. This value is likely an under-estimate as the data represents only what has been reported and recorded.

TABLE 9: STUDY USED TO VALUE MARINE FOOD PROVISIONING

Author(s) and date of study	Location of study	Methodology	Value/hectare/year (2010 $Can)
In house calculation (based on DFO 2001–2010 data)	Salish Sea, B.C. and Washington, U.S.	Production approach	$1.58 (no range)

35 FAO, 2004.

36 Catch data for First Nations and recreational fisheries was obtained from the Department of Fisheries and Oceans for the period 2001-2010.

RAW MATERIALS

Raw materials include biological materials used for medicines, fuel, art and building; and geological materials used for construction or other purposes. The sea has provided basic provisioning materials to coastal communities for centuries. The skin of marine mammals has been used for clothing, gas deposits for energy production, lime (extracted from coral reefs) for building construction, and the timber of mangroves and coastal forests for shelter are some of the more familiar uses of marine organisms. Raw marine materials are utilized for non-essential goods as well, such as shells and corals in ornamental items.

No value for raw materials has been included in this report due to a lack of primary studies for this ecosystem service.

5.2 Regulating Services

GAS AND CLIMATE REGULATION

Marine ecosystems play a critical role in carbon sequestration and storage. They help to regulate the gaseous portion of nutrient cycles that effect atmospheric composition, air quality and climate regulation. Both carbon sequestration and storage enable higher climate stability by removing greenhouse gases from the atmosphere.

The value used for sequestered and stored carbon was from the Intergovernmental Panel on Climate Change (IPCC) at $56.60 Canadian 2010 dollars per tonne, per hectare, per year (an average within a large range from voluntary and enforced markets), meaning, for every tonne of carbon released into the atmosphere it costs the economy $56.60 in physical, social and natural capital annually to offset the damage done by undesirable carbon dioxide levels. The dollar value attributed to an ecosystem can be determined by the land cover type, location and is based on whether carbon is sequestered (flow) or stored (stock).

Marine ecosystems play a critical role in carbon sequestration and storage.

PHOTO COURTESY EVAN LEESON/FLICKR

Carbon sequestration removes carbon dioxide (CO_2) from the atmosphere providing the mitigation of carbon dioxide in the atmosphere (gas regulation). During the sequestration of carbon dioxide, trees, marine algae and seaweeds use photosynthesis to convert carbon dioxide into biomass, organic matter used to fuel the plant. This sequestration contributes to the "flow" of carbon.

Storage of greenhouse gases contributes to the build-up of carbon "stocks." Just as living plants sequester and store carbon dioxide, non-living biomass, organic matter, sediments and rocks can store carbon stocks without consuming it.[37] Because the mass of stored carbon is so great with respect to its host, large amounts of carbon are expelled from decaying organic matter. Thus, dying species of terrestrial and marine plants are replaced with healthy ones, which sequester and store carbon storage for the next generation.

In this report the value of carbon sequestration was calculated for four land classes: forests, salt marshes, eelgrass beds, and estuaries. Sequestration rates were identified from several recent publications on the value of aquatic ecosystems for carbon removal (see Spotlight on Services: Blue Carbon in the Lower Mainland). The value of carbon storage was calculated for six land classes: forests, wetlands, salt marshes, eelgrass beds, estuaries, and marine. A similar methodology was used for both sequestration and storage values.

The economic value of forests for air pollution removal was based upon Wilson's study, which used CITYgreen software to assess the amount of air pollutants removed by the tree canopy cover. Applying the per hectare value of $538.64 to the total forest cover of our study area amounted to $642 million in air pollution removal services.

37 The biomass of the average tree is approximately 50 per cent carbon by weight (NSFA 2002).

TABLE 10: STUDY USED TO VALUE AIR POLLUTION (FORESTS)

Author(s) and date of study	Location of study	Methodology	Value/hectare/year (2010 C$)
FOREST			
Wilson, S.J., 2010	U.S. average	Avoided cost (CITYgreen software)	$539 (no range)

TABLE 11: STUDIES USED TO VALUE CLIMATE AND GAS REGULATION — CARBON SEQUESTRATION

Author(s) and date of study	Location of study	Methodology	Value/hectare/year (2010 C$)
FOREST			
Wilson, S.J., 2010	British Columbia	Avoided cost (CITYgreen software)	$42 (no range)
SALT MARSH			
Duarte (based on IPCC values)	Global average	Avoided cost	$85 (no range)
Laffoley, D., and Grimsditch, G., 2009 (based on IPCC values)	Global average	Avoided cost	$168–$338
Crooks, S. et al., 2011 (based on IPCC values)	Global average	Avoided cost	$28–$142
EELGRASS BEDS			
Laffoley, D., and Grimsditch, G., 2009 (based on IPCC values)	Global average	Avoided cost	$226–$462
Crooks, S. et al., 2011 (based on IPCC values)	Global average	Avoided cost	$25–$108
ESTUARIES			
Duarte (based on IPCC values)	Global average	Avoided cost	$25 (no range)

TABLE 12: STUDIES USED TO VALUE GAS AND CLIMATE REGULATION — CARBON STORAGE

Author(s) and date of study	Location of study	Methodology	Value/hectare/year (2010 C$)
FOREST			
Wilson, S.J., 2010 (based on Keith et al. 2009)	North America Pacific Northwest region	Avoided cost	$1,860 (no range)
WETLAND			
Wilson, S.J., 2010	British Columbia	Avoided cost	$1,550 (no range)
SALT MARSH			
Laffoley, D., and Grimsditch, G., 2009 (based on IPCC values)	Global average	Avoided cost	$367–$906
Nellemann, C., et al. 2009 (based on IPCC values)	Global average	Avoided cost	$10–$979
EELGRASS BEDS			
Laffoley, D., and Grimsditch, G., 2009 (based on IPCC values)	Global average	Avoided cost	$47–$75
Nellemann, C., et al. 2009 (based on IPCC values)	Global average	Avoided cost	$32–$103
ESTUARIES			
Nellemann, C., et al. 2009 (based on IPCC values)	Global average	Avoided cost	$28 (no range)
MARINE			
Nellemann, C., et al. 2009 (based on IPCC values)	Global average	Avoided cost	$0.01 (no range)

PHOTO COURTESY JAN KOCIAN

SPOTLIGHT ON SERVICES: Blue Carbon in the Lower Mainland

New research is revealing that the ocean's vegetated habitats rank among the most intense carbon sinks on the planet.[38] Similar to forests, aquatic environments such as mangroves, salt marshes and seagrasses are incredibly productive at sequestering carbon, but they do so much more efficiently — up to 90 times the uptake for a comparative area. Coastal wetlands sequester carbon within standing biomass, but significantly more is stored within soils, which can remain undisturbed for thousands of years, if not millennia. Currently the CO_2 emissions and sequestration associated with coastal wetlands are not accounted for in national greenhouse gas (GHG) inventories. Incentives for restoration or disincentives for degradation in coastal marine ecosystems do not exist in international climate change policy frameworks.

The marine floor, salt marshes, eelgrass beds, estuaries, beaches, and rivers and lakes of the study area provide carbon sequestration to the residents of the Lower Mainland and globally. Anywhere from 1 billion to 19 billion tonnes of carbon are stored in these areas (see Section 6: Case Studies), yet they are increasingly being degraded, resulting in a release of stored carbon.

In the period between 1990 and 2008 B.C.'s CO_2 emissions increased by 32 per cent, representing the third highest percentage increase out of the Canadian provinces.[39] The creation of policies that promote the protection and restoration of blue carbon ecosystems would further the effectiveness of the province's GHG targets of 6 per cent below 2007 levels by 2012 and 33 per cent by 2020. Funding for such initiatives could come from B.C.'s carbon tax, which recently rose to $30 per tonne.

Carbon storage is of critical importance. To compensate for population growth, either emissions per capita must decrease or urban carbon sequestration must increase. If carbon sequestration, per capita emissions, and population growth remain where they are today, B.C. will experience a host of negative impacts, from depressed air quality to sea level rise. This not only jeopardizes B.C.'s international reputation for having a pristine natural environment, but also the health and quality of life of B.C. residents.

38 Duarte et al., 2005; UNEP, 2009; IUCN, 2009; World Bank, 2011.

39 Environment Canada, 2010.

Disturbance Regulation

Estuaries and bays, coastal wetlands, headlands, intertidal mudflats, seagrass beds, rock reefs, and kelp forests provide protection from storms, storm surges, tsunamis and other disturbances. These ecosystems are able to absorb and store large amounts of rainwater or water runoff during a storm, in addition to providing a buffer against coastal waves. Estuaries, bays, and wetlands are particularly important for absorbing floodwaters.[40]

Today, changes in land use, combined with the potential for higher frequency storm events due to climate change, make this service one of the most important for economic development in the Lower Mainland. In order to have productive lands, protected built capital, and high value, productive ecosystems, damage reduction strategies must be effective and efficient. Given that significant infrastructure can be damaged during large storm events, tourism and recreation could be harmed as well.

One of the most significant factors in an ecosystem's ability to prevent flood damage is the absorption capacity of the landscape. This is determined by land cover type (forest vs. pavement), soil quality, and other hydrological and geological dynamics within the watershed. The retention of forest cover and restoration of floodplains and wetlands provide this tangible and valuable ecosystem service. Most notably, it reduces property damage, lost work time, injury, and loss of life posed by floods. With sea level rise the slope of rivers is being reduced creating greater flood threats, particularly at high tide; this increase in threat was not considered here.

The value of disturbance regulation was estimated for four land classes: beach, forest, riparian buffer, and wetlands. The studies we drew from used the avoided cost, replacement cost and hedonic pricing methodologies to value the service of disturbance regulation (see Table 13). The hedonic approach studies measured the value of beaches for storm protection through price differentials (Parsons and Powell; Pompe and Rinehart), whereas the replacement cost studies determined the value of intact ecosystems for disturbance regulation by comparison with the value of a marketed substitute (Wilson; Leschine et al.). Lastly, the avoided cost study

The value of disturbance regulation was estimated for four land classes: beach, forest, riparian buffer, and wetlands.

PHOTO COURTESY JEFF GUNN/FLICKR

TABLE 13: STUDIES USED TO VALUE DISTURBANCE REGULATION

Author(s) and date of study	Location of study	Methodology	Value/hectare/year (2010 C$)
BEACH			
Parsons, G.R. and Powell, M., 2001	Delaware	Hedonic pricing	$68,526 (no range)
Pompe, J.J. and Rinehart, J.R., 1995	North Carolina	Hedonic pricing	$158–$418
FOREST			
Wilson, S.J., 2010	British Columbia	Replacement cost	$1,633 (no range)
RIPARIAN BUFFER			
Rein, F.A., 1999	Elkhorn Slough, Monterey Bay, California	Avoided cost	$23–$727
WETLAND			
Leschine, T.M., et al., 1997	Washington State	Replacement cost	$34,633–$225,999
U.S. Army Corps, 1971	Charles River Massachusetts	Avoided cost	$1,126

40 Costanza et al., 2008; UNEP, 2005.

PHOTO COURTESY PETE TUEPAH

SPOTLIGHT ON SERVICES: DISTURBANCE REGULATION

Natural threats to the Lower Mainland include flooding, tsunamis, and earthquakes. Debris torrents from high levels of snowmelt, Fraser River flooding from heavy rains, and even tsunamis triggered from earthquakes have all been experienced in the study area. These events can cause massive economic and social hardship. The impacts from such threats can be mitigated through the protection and restoration of natural capital.

High amounts of precipitation in mountainous regions with steep stream channel slopes can cause debris torrents, characterized by a fast moving surge containing boulders and large plant debris — in both solid and liquefied form. Municipalities at the base of steep mountain streams from North Vancouver to Howe Sound show extensive evidence of such torrents. Poor logging practices are often to blame for present-day occurrences.[41] For instance, in May of this year [2012], the Fraser Basin Council issued a warning that the floodplain of the Lower Fraser River has the "greatest vulnerability to flood risk."[42] It found that the impact of aggressive salvage logging of beetle-killed pine forest has significantly increased the risk of flooding as dead pine would have provided some shade to the snowpack and reduced the rate of melt.[43]

Fraser River flooding is common during the annual spring snowmelt freshets, particularly in floodplain areas where most of the commercial and industrial development, and port facilities for the province are located. There have been two major floods, the largest in 1894 and the second largest in 1948. The floodplain areas were sparsely populated at the time of the 1894 flood, but by the time of the 1948 flood, the area was well developed. The floodwaters severed two transcontinental rail lines in 1948, inundating the Trans-Canada Highway, as well as damaging a number of urban areas, causing estimated damages of $20 million ($187.33 million in 2011 dollars).[44] Scientists at the Fraser Basin Council predict a one-in-three chance of a flood of similar magnitude occurring within the next 50 years.[45]

Earthquakes are common in B.C. They are generally minor or remote enough to have little impact but earthquakes of magnitude 7.3 have occurred within 150 kilometers of the Lower Mainland. On March 27, 1964 an 8.5 magnitude earthquake hit the west coast of North America, heaving up the ocean floor a full 15 meters. The resulting tsunami caused significant damage to Port Alberni, on the northern end of Vancouver Island causing $2.5 million to $3 million in damages ($18 million to $22 million in 2011 dollars).[46] For a province that sits nearly atop two colliding tectonic plates, the next earthquake is only a matter of time. Expert predictions of the next major quake range from 50 to 200 years.[47]

41 Environment Canada, 2011.
42 Fraser Basin Council, 2012.
43 Pynn, 2012.
44 Ibid.
45 Fraser Basin Council, 2012.
46 Environment Canada, 2011.
47 50-year prediction comes from F. Baumann (Hume, 2012); 200-year prediction comes from B.C.'s Provincial Emergency Program.

estimated the value of wetlands for flood protection by surveying the amount of flood damage avoided when the wetland is left intact (Rein; U.S. Army Corps).

The total value of disturbance regulation services in the Lower Mainland ranges from approximately $2 billion to $5 billion per year. We found wetlands to be the highest per hectare value land class for disturbance regulation. The study that provided the highest values is based upon a region with similar geography and demographics to the Lower Mainland, which is prone to flooding in many areas. Leschine et al. used the market value of engineered hydrologic enhancements to wetlands in Washington State for flood protection as a proxy for the value of disturbance regulation.

SOIL EROSION CONTROL

Natural erosion and landslides can have positive value by providing sand and gravel to streams, creating habitat for fish and other species. Natural erosion protection is provided by plant roots and tree cover. Soil erosion control is closely linked with disturbance prevention. While the absorption capacity of the land will largely determine floodwater levels, the retention of this water can play a significant role in preventing landslides and other damaging forms of erosion as well. Sedimentation from a large number of landslides can harm salmon habitat, energy production, and water supplies and require costly dredging in port areas.

Soil erosion control is closely linked with disturbance prevention.
PHOTO COURTESY JAN KOCIAN

On the other hand, human armouring of shorelines and stream corridors can prevent the type of natural erosion upon which salmon and other species depend. Forested and vegetated areas naturally provide stability and erosion control, while impermeable built surfaces or deforested areas cannot retain soil well. Human activities may not only affect an area's ability to retain soil, but can also increase the flow of water that may mobilize soil particles.

In the late 1990s, the moratorium on river removal was lifted by the federal government and the Fraser River has been mined for gravel to support the construction of everything from sidewalks to bridges. While government states that gravel removal is necessary for flood protection, local scientists and activists suggest most extraction is unnecessary.

No value for soil erosion control has been included in this report due to a lack of acceptable primary studies for this ecosystem service.

WATER REGULATION

Ecosystems absorb water during rains and release it in dry times, and also regulate water temperature and flow for plant and animal species. Forest cover, riparian vegetation, and wetlands all contribute to modulating the flow of water from upper portions of the watershed to streams and rivers in the lower watershed as well as recharging groundwater.

Expansion of agricultural lands and urban development often result in the loss of forest cover or riparian vegetation. This shift in land cover is among the most important causes of reduced fresh water flow to coastal wetlands and bays. When forested basins are heavily harvested, the landscape becomes predominantly clear-cut areas or young stands, reducing the capacity of the remaining vegetation and litter layer on the forest floor to absorb water. Water flows off the surface quickly into streams and rivers, contributing to higher peak flows, flood events, erosion and landslides.[48] Rapid runoff reduces the needed water in aquifers. Water supply is reduced and springs that enter and cool water in streams and rivers during low-flow periods for salmon and other species. The soil from erosion entering streambeds injures fish and fills spawning beds and irrigation structures. These cumulative effects can damage built and natural capital reducing the economic value of natural, agricultural and industrial systems.

48 Moore and Wondzell, 2005.

As was discussed in the section on drinking water, ecosystems are able to provide the good of water supply and the service of filtration, providing clean water for human use. One way to understand the economic value of intact watersheds is to compare it to the cost of building and maintaining water supply and treatment facilities. To the extent that loss of ecological systems results in reduced water supply, value can also be ascertained through the cost of having to import water as an alternative source. These are examples of what economists call replacement costs (see section 3.2 on Valuation Methods).

A wide variety of stream-flow augmentation techniques have been adopted in the United States, Great Britain, and elsewhere. In order to balance the need for water supply with other services such as water regulation and habitat, these types of management techniques must be carefully evaluated regarding the impact on water flows elsewhere in the watershed. Much of the science behind stream-aquifer relationships and other hydrologic relationships within the watershed are still not fully understood, and will greatly impact our ability to protect other ecosystem services as we utilize this valuable water for other purposes. Understanding the value of water to people through natural systems provides information that justifies better water efficiency in the built economy and overall greater economic value.

No value for water regulation has been included in this report however, due to a lack of acceptable primary studies for this ecosystem service. This is a critical area for economic research in B.C.

Understanding the value of water to people through natural systems provides information that justifies better water efficiency in the built economy and overall greater economic value.

PHOTO COURTESY
MTS VANCOUVER/FLICKR

WASTE PROCESSING

Microorganisms in sediments and mudflats of estuaries, bays, and nearshore areas break down human and other animal wastes.[49] They can also detoxify petroleum products. The physical destruction of habitat, alteration of food webs, or overload of nutrients and waste products disrupts disease regulation and waste processing services increasing the economic costs of damage from waste materials. Changes to ecosystems can also create breeding sites for disease vectors where they were previously non-existent. People can be exposed to disease in coastal areas through direct contact with bacterial or viral agents while swimming or washing in fresh or saltwater, and by ingesting contaminated fish, seafood, or water. The recent rise of cholera outbreaks in the southern hemisphere is associated with degradation of coastal ecosystems.[50] In the late 1800s, the cities of Tacoma and Seattle also had cholera outbreaks until safe drinking water and better sanitation were secured.[51]

Wetlands, estuarine macroalgae, and nearshore sedimentary biota play a crucial role in removing nitrogen and phosphorous from water.[52] Burns Bog in Delta is the largest wetland in the Lower Mainland and the largest raised peat bog on the west coast of the Americas, spanning over 3,000 hectares of the Fraser River delta.[53] Unfortunately, freeway expansion plans running adjacent to the Burns Bog may jeopardize its effectiveness at waste processing. This cost has not been included in the benefit/cost analysis of the freeway.

The total value of waste processing services in the study area ranges from approximately $290 million to $1 billion per year. We were able to estimate the value of this service for salt marshes, riparian buffers and wetlands using the replacement cost approach and contingent valuation. Breaux et al. estimated cost savings from using coastal wetlands as a substitute waste treatment, whereas Wilson measures the costs of removing nitrogen and phosphorus by waste treatment plants. Pate and Loomis surveyed residents of the San Joaquin Valley about their willingness-to-pay for three proposed environmental programs. We found wetlands to be the highest per hectare value land class for waste processing, ranging in value from $242.04 to $59,792.70 per hectare, per year.

Burns Bog in Delta is the largest wetland in the Lower Mainland and the largest raised peat bog on the west coast of the Americas, spanning over 3,000 hectares of the Fraser River delta.

BURNS BOG PHOTO COURTESY MARK LINK/FLICKR

TABLE 15: STUDIES USED TO VALUE WASTE PROCESSING

Author(s) and date of study	Location of study	Methodology	Value/hectare/year (2010 C$)
SALT MARSH			
Breaux, A., et al., 1995	Louisiana	Replacement cost	$339–$54,523
RIPARIAN BUFFER			
Zhongwei, L., 2006	Little Miami River watershed, Ohio	Replacement cost	$770–$773
WETLAND			
Breaux, A., et al., 1995	Louisiana	Replacement cost	$515–$59,793
Olewiler, N., 2004	Vancouver, B.C	Replacement cost	$507–$1,424
Pate, J. and Loomis, J., 1997	California	Contingent valuation	$242–$1,090
Wilson, S.J., 2010 (based on Olewiler, N., 2004)	Vancouver, B.C.	Replacement cost	$1,523–$4,644

49 Weslawski et al., 2004.
50 UNEP, 2006.
51 Seattle Public Utilities, 2011.
52 Garber and Collins, 1992; Weslawski et al., 2004.
53 Environment Canada, 2012.

NUTRIENT CYCLING

There are 22 elements essential to the growth and maintenance of living organisms. While some of these elements are needed only by a small number of organisms, or in small amounts in specific circumstances, all living things depend on the nutrient cycles of carbon, nitrogen, phosphorous, and sulfur in relatively large quantities. These are the cycles that human actions have most affected. Silicon and iron are also important elements in ocean nutrient cycles because they affect phytoplankton community composition and productivity. Living things facilitate the movement of nutrients between and within ecosystems and which turn them from biologically unavailable forms, such as rocks or atmospheric gases, into forms that can be used by other forms of life. Without functioning nutrient cycles, life on the planet would cease to exist.

As plants and plant parts die, they contribute to the pool of organic matter that feeds the microbial, fungal and micro-invertebrate communities in soils. These communities facilitate the transformation of nutrients from one form to another. Larger animals play a crucial role in nutrient cycles by moving nutrients from one place to another in the form of excrement, and through the decomposition of their bodies after death. Forests also play a significant role in global nutrient cycles; they hold large volumes of basic nutrients and keep them within the system, buffering global flows. Deforestation has played a large part in altering global carbon and nitrogen cycles.[54]

The removal of forests, riparian areas, and wetlands has had a significant effect on nutrient cycles. These ecosystems trap and retain nutrients that would otherwise run off into streams and rivers, and eventually end up in the ocean. A combination of increased use of fertilizers and the loss of the buffering capacity of these ecosystems has led to fresh water, estuarine, and ocean systems suffering nutrient overloads which lead to large blooms of phytoplankton. Loss of commercially, recreationally, and culturally important fish species has occurred as one result. Loss of recreational time on contaminated beaches, the degradation of coastal aquifers and threats to public health are occurring more often. The number of marine dead zones in the world has doubled every decade since the advent of nitrogen fertilizers after World War II.[55] The presence of these dead zones is a clear indication that global nutrient cycles have been severely altered by human actions.

Ecosystem services depend on nutrient cycling. Given that ecosystem productivity would cease without it, production is impaired when these cycles become significantly altered.

PHOTO COURTESY ROSS MCLAREN

Many other ecosystem services depend on nutrient cycling. Given that ecosystem productivity would cease without it, production is impaired when these cycles become significantly altered. Nutrient cycling is a fundamental precursor to ecosystem and economic productivity. This fundamental role cannot be fully substituted by human-made solutions, and operates at multiple, overlapping scales, so it is difficult to arrive at an accurate economic value for these services, and is often undervalued.[56] Given that nutrient cycling is fundamental to the operation of life on the planet, it is important that biological science inform policy that will protect this critical service. Yet, also because it is so fundamental, economic techniques for valuing nutrient cycling at the appropriate scale are few. The value of nutrient cycling is not included in the value of final goods and services for which nutrient cycling is an essential input process. For this reason, valuing nutrient cycling is not double counting.

The total value of nutrient cycling in the study area was estimated to range from $130 million to $350 million per year. We were able to estimate the value of this service for estuaries and eelgrass beds using the production approach and replacement cost method. Newell et al. employ an innovative approach to arrive at a value for nutrient cycling. They estimate the possible effects of stocks of sub-tidal eastern oysters on the watershed-level nitrogen and phosphorus budgets for the Choptank River (U.S.). The authors assess the cost of alternative ways of obtaining these same nutrient reductions. To the extent that reductions of any given amount of nutrients by oysters obviate the need to incur those costs, this is their value in terms of nutrient reduction. Costanza et al. estimated the value of eelgrass beds for nutrient cycling by calculating the replacement cost

54 Vitousek et al., 1997.

55 UNEP, 2005.

56 Farber et al., 2006.

to remove nitrogen and phosphorus. We found eelgrass beds to be the highest per hectare value land class for this service, ranging in value from $16,989 to $47,573 per hectare, per year.

TABLE 15: STUDIES USED TO VALUE NUTRIENT CYCLING

Author(s) and date of study	Location of study	Methodology	Value/hectare/year (2010 C$)
ESTUARY			
Newell, R.I.E., et al., 2005	Chesapeake Bay, U.S.	Production approach	$261 (no range)
EELGRASS BEDS			
Costanza, R., et al., 1997 (based on Postel, S. and Carpenter, S. *in* Daily, G., 1997)	Global estimate	Replacement cost	$16,989–$47,573

5.3 Habitat Services

BIODIVERSITY AND HABITAT

For all ecosystems, biodiversity is both a precondition of the flow of ecosystem services (capital asset producing services) and an ecosystem service in itself.

Biological diversity is defined as the number and types of species and the ecosystems they comprise. It is measured at gene, population, species, ecosystem, and regional levels.[57] For all ecosystems, biodiversity is both a precondition of the flow of ecosystem services (capital asset producing services) and an ecosystem service in itself.[58] It is a precondition because ecosystems, with their full native complement of species, tend to be more productive and more resilient to change in environmental conditions or external shocks. Biodiversity is also an ecosystem service in itself because novel products have been derived from genetic and chemical properties of species, it provides a secure food base (multiple sources of food with different seasonal availability), and people ascribe value to it simply for its existence.

Habitat is the biophysical space and process in which wild species meet their needs — a healthy ecosystem provides physical structure, adequate food availability, appropriate chemical and temperature regimes, and protection from predators. Habitat may provide refugium and nursery functions. A refugium refers to general living space for organisms, while nursery habitat is specifically habitat where all the requirements for successful reproduction occur.[59] In addition to the physical structure provided to species, food web relationships are important components of habitats that support all species.

At a global scale, the loss of biodiversity in all ecosystems through over-harvest, habitat degradation and loss has been substantial in marine and coastal ecosystems, forests, grasslands and agricultural systems. This has large implications for maintenance of ecosystem services.

Habitat contributes significantly to other ecosystem services, including fisheries, recreation, and aesthetic value through wildlife watching, and cultural or spiritual values, which are often expressed though people's ability and willingness to pay for protection of natural areas and through public or private expenditures on acquiring and protecting habitat.

The total value of habitat refugium and nursery services was estimated to range from approximately $60 million to $770 million per year. We were able to estimate the value of this service for eight land classes, including estuaries, forests, lakes and rivers, marine, riparian buffer, salt marsh, wetlands, and eelgrass beds. A range of valuation methods was used to arrive at estimates, with the production approach being the most

57 Magurran, 1988.
58 UNEP, 2006.
59 De Groot et al., 2002.

widely used. This approach measures the ability of healthy habitats to enhance income. For instance, the value of healthy wetlands for commercial fisheries was estimated by Batie and Wilson, Kahn and Buerger, Johnston et al., and Knowler et al. While the contingent valuation approaches focused on measuring consumer value of habitat through surveys, the hedonic pricing approach focused on comparing the value of stream restoration measures to property price differentials. Lastly, the avoided cost approach used the average annualized wetland habitat restoration costs for Great Lakes projects in Canada, whereas the opportunity cost approach measured the costs to a forestry company in terms of timber income foregone to protect habitat.

We found eelgrass beds to be the highest per hectare value land class for habitat refugium and nursery, ranging in value from $4,744.15 to $32,790.37 per hectare, per year.

TABLE 16: STUDIES USED TO VALUE HABITAT REFUGIUM AND NURSERY SERVICES

Author(s) and date of study	Location of study	Methodology	Value/hectare/ year (2010 C$)
ESTUARY			
Johnston, R.J., et al., 2002	Peconic Estuary, New York	Production approach	$269 (no range)
FOREST			
Haener, M.K. and Adamowicz, W.L., 2000	Alberta	Contingent valuation and Opportunity cost	$4.64–$31.84
Knowler, D.J, et al., 2003	British Columbia	Production approach	$3.25 (no range)
LAKES AND RIVERS			
Kahn, J.R. and Buerger, R.B., 1994	Lake Montauk, New York	Production approach	$7.00–$56.32
Streiner, C. and Loomis, J., 1996	California	Hedonic pricing	$881.87 (no range)
MARINE			
Knowler, D.J. et al., 2003	British Columbia	Production approach	$1.75–$9.32
RIPARIAN BUFFER			
Knowler, D.J. et al., 2003	British Columbia	Avoided cost and Production approach	$27–$124
SALT MARSH			
Batie, S.S. and Wilson, J.R., 1978	Virginia	Production approach	$19 (no range)
Johnston, R.J., et al., 2002	Peconic Estuary, New York	Production approach	$1,506 (no range)
Lynne, G.D., et al., 1981	Florida	Production approach	$3.61 (no range)
WETLAND			
Knowler, D.J. et al., 2003	British Columbia	Production approach	$27–$124
Mazzotta, M., 1996	Peconic Estuary, New York	Contingent valuation	$27,022 (no range)
Pate, J. and Loomis, J., 1997	San Joaquin Valley, California	Contingent valuation	$316–$1,005
Streiner, C. and Loomis, J., 1996	California	Hedonic pricing	$677 (no range)
Wilson, S.J., 2008	Great Lakes, Canada	Avoided cost	$6,069 (no range)
EELGRASS BEDS			
Johnston, R.J., et al., 2002	Peconic Estuary, New York	Production approach	$4,744 (no range)
Mazzotta, M., 1996	Peconic Estuary, New York	Contingent valuation	$32,790 (no range)

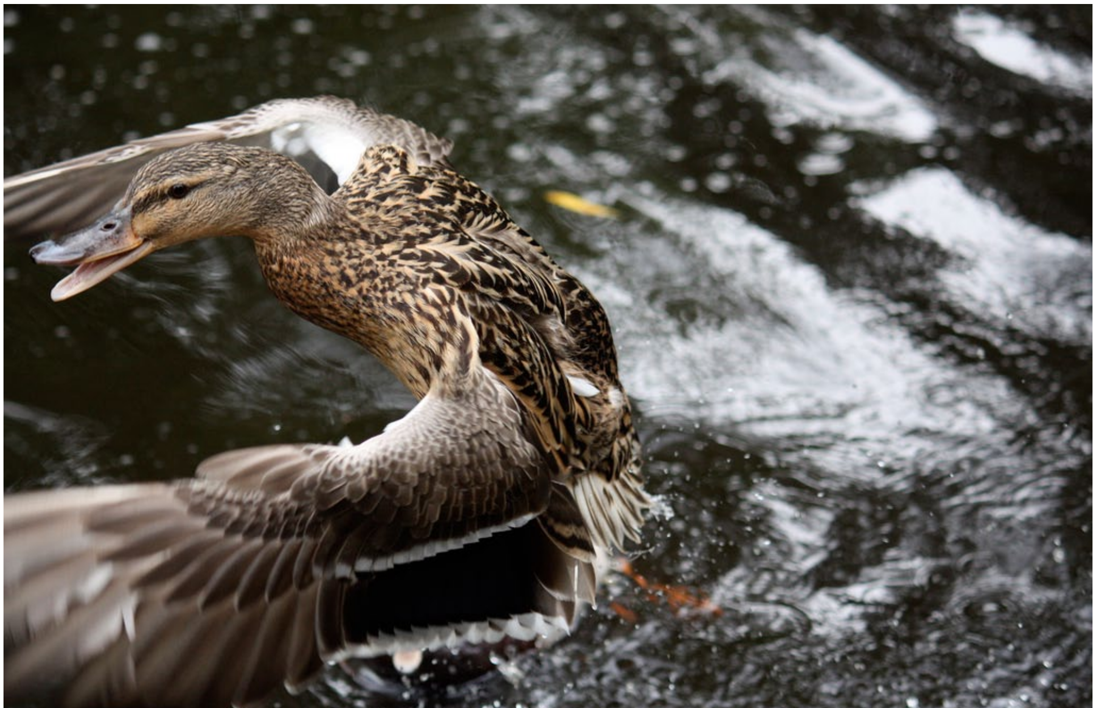


PHOTO COURTESY DINA CORTEZ

SPOTLIGHT ON SERVICES: AQUATIC HABITATS

The waters surrounding the Lower Mainland provide a range of habits for a wide variety of marine, freshwater and anadromous species, including plants, fish, mussels, crayfish, snails, reptiles, amphibians, insects, micro-organisms, birds, mammals and salmon. Natural aquatic habitats provide breeding and nursery space, which can be particularly important during the juvenile stages for feeding and protection from predators. The destruction of such habitats has profound effects upon local population dynamics.

Nearshore ecosystems are highly variable and dynamic. They interact with adjacent riparian ecosystems, sharing physical habitats and ecological processes, and can be highly sensitive to impacts resulting from human activities. A provincial conservation status assessment of major drainage areas ranked the coastal drainage area as "vulnerable/apparently secure," and the Fraser basin area as "imperiled/vulnerable."[60] The poor rankings, particularly for the Fraser basin, are undoubtedly due to the increase in human activity throughout the Lower Mainland over the past 100 years. The destruction of streamside vegetation, water diversion, and stream channelization has caused severe damage to streams that once supported salmon and other wildlife. In fact, today this region is the spawning habitat for 66 per cent of the wild coho salmon in the Fraser River.[61]

A 1997 survey of the Lower Mainland found that 86 per cent of the 779 streams classified were lost (i.e., they no longer exist as surface waterways), endangered (i.e., meets more than one impact criterion of the study) or threatened (i.e., meets one impact criterion of the study).[62] Of these, 117 streams were lost in the last 150 years. All of the lost streams were originally in areas that are now human settlements.

60 Austin et al., 2008.
61 Ibid.
62 Ibid.

5.4 Cultural Services

AESTHETIC

Aesthetic value, as an ecosystem service, refers to the appreciation of and attraction to beautiful natural land and seascapes.[63] The existence of seashores, federal and provincial parks, scenic areas, and officially designated scenic roads and pullouts attest to the social importance of this service. There is also demonstrative evidence that proximity to healthy ecosystems enhances property value. Greater economic value provided by environmental aesthetics is shown by analysis of data on housing markets, wages, and relocation decisions.[64] Similar data show degraded landscapes are associated with lower property values, economic decline and stagnation.[65]

The Lower Mainland is acclaimed for its scenic beauty. Rainforests, mountain ranges, rivers and torrents, waterfalls, fjords, and sandy beaches have helped shaped the region's culture. The influence of the land is apparent in many of works of art, such as Emily Carr's paintings, the carvings of First Nations, and the story of The Golden Spruce (John Vaillant). These and countless other artistic works have helped to form a sense of pride, beauty and identity that cannot be adequately captured by any market price.

Ecosystem features like biological diversity and clean water attract people to engage in recreational activities, and can also increase property values or attractiveness for business.

BUNTZEN LAKE PHOTO
COURTESY NADENE REHNBY

RECREATION AND TOURISM

Ecosystem features like biological diversity and clean water attract people to engage in recreational activities, and can also increase property values or attractiveness for business. Tourism and recreation are related to, but not totally encompassed by, aesthetic values. People travel to beautiful places for vacation, but they also engage in specific activities associated with the ecosystems in those places. Recreational fishing, scuba diving, surfing, biking, swimming, kayaking, whale and bird watching, hunting, enjoying local seafood and wines, and beachcombing are all activities that would not occur or be thoroughly enjoyed without intact shorelines, healthy fish and wildlife populations, and clean water.

While teasing out the direct monetary contribution of the ecosystems themselves to the recreation and tourism economy, there is no doubt that attractive landscapes, clean water, and healthy fish and wildlife populations provide a necessary underpinning to this sector of the economy. Several studies of nature-related recreation are included in the ecosystem service value analysis described below.

The value of recreational services was estimated for eight land classes, including beach, estuaries, forests, lakes and rivers, marine, riparian buffer, salt marsh, and wetlands. The studies predominantly relied on the travel cost, contingent valuation, and hedonic pricing methods, but one study used the opportunity cost approach (Gupta and Foster, 1975). Travel cost and contingent valuation are well-accepted valuation methods for recreational services, whereas the hedonic pricing method is used to estimate aesthetic value. These methods measure the associated costs of recreation, willingness to pay for increased recreational services, and price differentials in housing located near recreational sites, respectively. Although, opportunity cost is not an often-used approach for this service, we believed it worthy of inclusion. Gupta and Foster measured wetland value based on actual purchases of wetlands for recreation by towns in Massachusetts, U.S.

We calculated the total value of aesthetic and recreational services in the study area to range from approximately \$22.6 billion to \$44 billion per year. We found beaches to be the highest per hectare value land class for this service, ranging in value from \$454 to \$65,620 per hectare, per year. It should be noted that this is likely an under-estimate as no study valued the totality of services provided in the study area.

63 De Groot et al., 2002.
64 Palmquist and Smith, 2002.
65 Power, 1996.

TABLE 17: STUDIES USED TO VALUE AESTHETIC AND RECREATIONAL SERVICES

Author(s) and date of study	Location of study	Methodology	Value/hectare/year (2010 C$)
BEACH			
Edwards, S.F. and Gable, F.J., 1991	Rhode Island	Hedonic pricing	$454 (no range)
Kline, J.D. and Swallow, S.K., 1998	Gooseberry, Massachusetts	Contingent valuation	$108,817–$140,431
Silberman, J., et al., 1992	New Jersey	Contingent valuation	$65,620 (no range)
Taylor, L.O. and Smith, V.K., 2000	North Carolina	Hedonic pricing	$1,245 (no range)
ESTUARY			
Johnston, R.J. et al., 2002	Peconic Estuary, New York	Hedonic pricing and Travel Cost	$486–$1,096
Leggett, C.G. and Bockstael, N.E., 2000	Anne Arundel County, Maryland	Hedonic pricing	$133 (no range)
Whitehead, J.C., et al., 1997	Albemarie-Pamlico Estuary, North Carolina	Contingent valuation	$4–$27
FOREST			
Knowler, D., and Dust, K., 2008	Fraser Timber Supply Area, B.C.	Contingent valuation	$124 (no range)
Shafer, E.L., et al., 1993	Pennsylvania	Travel Cost and Contingent valuation	$8–$1, 603
Wilson, S.J., 2010 (based on Duwors, E. et al. 1999)	Lower Mainland, B.C.	Travel Cost	$52 (no range)
LAKES AND RIVERS			
Burt, O.R. and Brewer, D., 1971	Missouri	Travel Cost	$1,425 (no range)
Cordell, H.K. and Bergstrom, J.C., 1993	North Carolina	Contingent valuation	$585–$2,457
Kahn, J.R. and Buerger, R.B., 1994	Chesapeake Bay, New York	Travel Cost	$4–$12
Kealy, M.J. and Bishop, R.C., 1986	Lake Michigan, Wisconsin	Travel Cost	$40 (no range)
Loomis, J.B., 2002	Washington	Travel Cost	$34,339–$60,770
Piper, S., 1997	South Dakota and Wyoming	Travel Cost	$741 (no range)
Shafer, E.L., et al., 1993	Pennsylvania	Travel Cost	$3,275 (no range)
Ward, F.A., et al., 1996	Sacramento, California	Travel Cost	$61–$5,704
MARINE			
Mazzotta, M., 1996	Peconic Estuary, New York	Contingent valuation	$18,259 (no range)

TABLE 17: STUDIES USED TO VALUE AESTHETIC AND RECREATIONAL SERVICES *continued*

Author(s) and date of study	Location of study	Methodology	Value/hectare/year (2010 C$)
RIPARIAN BUFFER			
Bowker, J.M., et al., 1996	North Carolina and South Carolina	Travel Cost	$13,637–$32,775
Duffield, J.W., et al., 1992	Montana	Contingent valuation and Travel Cost	$974–$16,520
Greenley, D., et al., 1981	South Platte River Basin, Colorado	Contingent valuation	$26 (no range)
Kulshreshtha, S.N. and Gillies, J.A., 1993	Saskatoon, Saskatchewan	Hedonic pricing	$220 (no range)
Mullen, J.K. and Menz, F.C., 1985	Adirondack Mountain region of northern New York	Travel Cost	$2,410 (no range)
Rein, F.A., 1999	Monterey Bay, California	Travel Cost	$137–$601
Sanders, L.D., et al., 1990	Rocky Mountain region of Colorado	Contingent valuation	$6,831 (no range)
SALT MARSH			
Anderson, G.D. and Edwards, S.F., 1986	Southern Rhode Island	Contingent valuation	$64–$301
Bergstrom, J.C., et al., 1990	Louisiana	Contingent valuation	$46–$73
WETLAND			
Bauer, D.M., et al., 2004	Rhode Island	Contingent valuation	$393 (no range)
Costanza, R., et al., 1989	Terrebonne Parish, Louisiana	Travel Cost	$283–$1,115
Doss, C.R. and Taff, S.J., 1996	Minnesota	Hedonic pricing	$13,563–$14,984
Gupta, T.R., and Foster, J.H. 1975.	Massachusetts	Opportunity cost	$262–$3,534
Hayes, K.M., et al., 1992	Rhode Island	Contingent valuation	$3,928–$7,507
Knowler, D., and Dust, K., 2008	Fraser Timber Supply Area, B.C.	Contingent valuation	$124 (no range)
Kreutzwiser, R., 1981	Long Point and Point Pelee, Ontario	Travel Cost	$559 (no range)
Mahan, B.L., et al., 2000	Portland, Oregon	Hedonic pricing	$109 (no range)
Thibodeau, F.R. and Ostro, B.D. (1981)	Charles River Basin, Massachusetts	Travel Cost and Contingent valuation	$27,513 (no range)
Whitehead, J.C., 1990	Kentucky	Contingent valuation	$3,106–$6,245
Whitehead et al., 2009	Michigan	Contingent valuation	$599 (no range)
Wilson, S.J., 2008 (based on Duwors, E. et al. 1999)	Lower Mainland, B.C.	Travel Cost	$52 (no range)

PHOTO COURTESY HEIDI HUDSON

SPOTLIGHT ON SERVICES: RECREATION

Recreation is a definitive aspect of life for many British Columbians. B.C. has an impressive array of natural recreational geographies including 29,500 km of coastline, 38 ski resorts, over 2,200 lakes, 37 major river systems, and 999 parks.[66] People travel from all over the world to recreate here. B.C.'s coastline is the third largest in Canada, behind Newfoundland and Labrador and Northwest Territories including Nunavut.[67] Lastly, B.C.'s park system is the largest provincial park system in Canada and has recently made parking in provincial parks free in an effort to remove barriers to entry and encourage recreation.[68] It is no surprise then that B.C. was found to have the lowest proportion of overweight people and the highest proportion of physically active people in 2004.[69] These health benefits are closely associated with outdoor recreation.

The natural geography of the Lower Mainland lends itself easily to recreation. Few places in the world can facilitate wind surfing, rock climbing and snowboarding within a few kilometers. Furthermore, the proximity of these varied landscapes to the urban centers of Vancouver and Victoria make recreation appealing and incredibly convenient. The region's mild climate also allows outdoor recreation activities to go year round, minimizing the proportion of seasonal activities and allowing recreation to form a permanent part of one's lifestyle.

66 DFO, 2011; Canada Ski Resorts, 2011; BC Fact Sheet, 2011; BC Parks, 2011.
67 Natural Resources Canada, 2011.
68 Lus, 2011.
69 Atlas of Canada, 2007.

PART 6

Case Studies

6.1 Blue Carbon

While efforts are being made to slow the degradation of terrestrial ecosystems (most notably rainforests) as a means to mitigate climate change, the value of marine ecosystems has largely been ignored. However, a growing body of research is revealing that the conversion of wetlands represents a significant loss of carbon storage capacity. The value of carbon sequestration and storage is estimated at over $40 million annually in physical, social and natural capital annually for B.C.'s Lower Mainland coastal regions, and signifies the need for policies to promote the protection, restoration, and enhancement of aquatic ecosystems. Of particular significance to Lower Mainland municipalities is the lack of recognition of the sequestration potential of coastal wetlands in greenhouse gas inventories.

Healthy coastal wetlands such as salt marshes, estuaries, eelgrass beds, and tidal freshwater wetlands, store vast amounts of organic carbon within standing biomass, and soil. Recent reports by the World Bank (2011), the UNEP (2009) and the IUCN (2009) are calling attention to the fact that even though marine vegetation is a mere fraction of that on land (approximately 0.05 per cent), these areas cycle the same amount of carbon per year.[70] This activity is concentrated in nearshore wetlands, where undisturbed soils can build for centuries, if not millennia, and range in depth from several meters to more than 10 meters deep. Such soils can contain up to an estimated 65,000 tonnes of carbon (238,000 tC) per square kilometer for every meter depth of soil.[71] Figure 8 on the following page shows the relative storage capacity of a range of terrestrial and aquatic ecosystems.

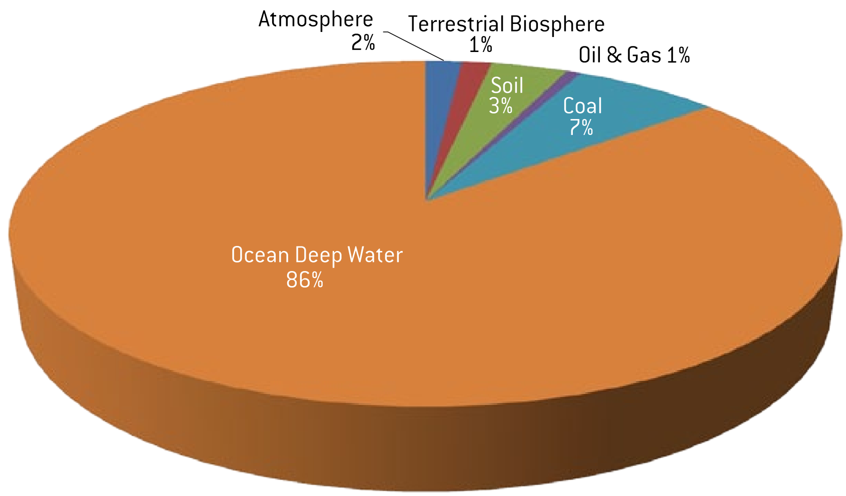
Healthy coastal wetlands such as salt marshes, estuaries, eelgrass beds, and tidal freshwater wetlands, store vast amounts of organic carbon within standing biomass, and soil.

PHOTO COURTESY PETE TUEPAH

70 Bouillon et al., 2008; Houghton, 2007.

71 Crooks et al., 2011.

FIGURE 8: CARBON STORAGE CAPACITY OF ECOSYSTEMS



Source: IPCC data in Figure 1, Nelleman, C. et. al. (2009)

B.C. wetlands are being lost at an astounding rate. The Lower Mainland Valuation reported that the wetlands of the Fraser Lowlands have experienced an average loss of 67 hectares per year over the past two decades (1989 to 2009). With only 28,072 hectares remaining as of 2009, this is a concern for the sustainability of wetland-related services. Table 18 estimates the value of carbon storage capacity for the study area at $40 million to $44 million per year. Extrapolating these results to the findings of the Lower Mainland case study, we find that the conversion of wetlands to golf courses, agriculture, and landfills has resulted in costs ranging from $2.3 million to $4.7 million in lost carbon sequestration and storage value.[72]

TABLE 18: VALUE OF CARBON STORAGE CAPACITY IN B.C.'S LOWER MAINLAND AQUATIC ECOSYSTEMS

Wetland type	Area (ha)	Price of carbon based on IPCC	Carbon sequestered[a] ($tC\ ha^{-1}\ yr^{1}$)	Value per hectare sequestered ($/ha)	Carbon stored[b] ($tC\ ha^{-1}\ yr^{1}$)	Value per hectare stored ($/ha)	Total value sequestered and stored
Salt Marsh	537	$56.60	.5–5.98	$28.30–$338.47	.18 –17.3	$10–$979	$20,669–$237,180
Eelgrass Beds	7,134	$56.60	.45–8.17	$25.47–$462.42	.56–1.82	$32–$103	$407,851–$4,033,778
Estuary	34,016	$56.60	.45	$25.47	.50	$28.30	$1,829,040
Marine	1,237,210	$56.60			.00018	$0.01	$12,372
Wetland	12,271	$56.60				$1,549.71	$19,016,491
Total	1,394,566		1.4–14.6	$79.24–$826.36	1.24–19.62		$40,302,915–$44,145,353

Notes: [a]Sources for carbon sequestration rates are: salt marsh – high value Crooks et al., 2011, low value Laffoley et al., 2009; eelgrass beds – high value Crooks et al., 2011, low value Laffoley et al., 2009; estuary – value from Duarte, 2005. [b]Sources for carbon storage rates are: salt marsh – value from Nellemann et al., 2009; eelgrass beds – value from Nellemann et al., 2009; estuary – value from Nellemann et al., 2009; marine – value from Nellemann et al., 2009; wetland – value per hectare from Wilson, 2010 (unable to obtain tC/ha/yr).

72 Estimate is based upon the total value of sequestered and stored carbon per hectare ($1,699.15–$3,486.57).

6.2 Fisheries Productivity in the Georgia Strait

As discussed, biodiversity is both a precondition of the flow of ecosystem services and an ecosystem service in itself. By affecting the magnitude, pace, and temporal continuity by which energy and materials are circulated through ecosystems, biodiversity influences the provision of regulating services, such as pollination and seed dispersal, regulation of climate, the control of pests, invasive species and disease, and the regulation of human health. Also, by affecting nutrient and water cycling, and soil formation and fertility, biodiversity indirectly supports the production of food, fiber, potable water, shelter and medicines. Although complete longitudinal records do not exist for population levels of the diverse assemblage of species occupying the Georgia Strait, the health of the region and its ecosystem services can be partially assessed by fisheries productivity (landings) over time.

PHOTO COURTESY CANADIAN PACIFIC/FLICKR

Catch data for 41 commercial, recreational, and First Nations fisheries located within Pacific Management Areas 14–19, 28 and 29 (see Figure 9) were obtained from S. Wallace (pers.comm.) for the period 1950 – 1996 and from the Department of Fisheries and Oceans (DFO) for the period 2001 – 2010. The results are broken into historical productivity (1950 – 1996) and current productivity (2001 – 2010) to analyze trends.

FIGURE 9: PACIFIC MANAGEMENT AREAS FOR THE GEORGIA STRAIT

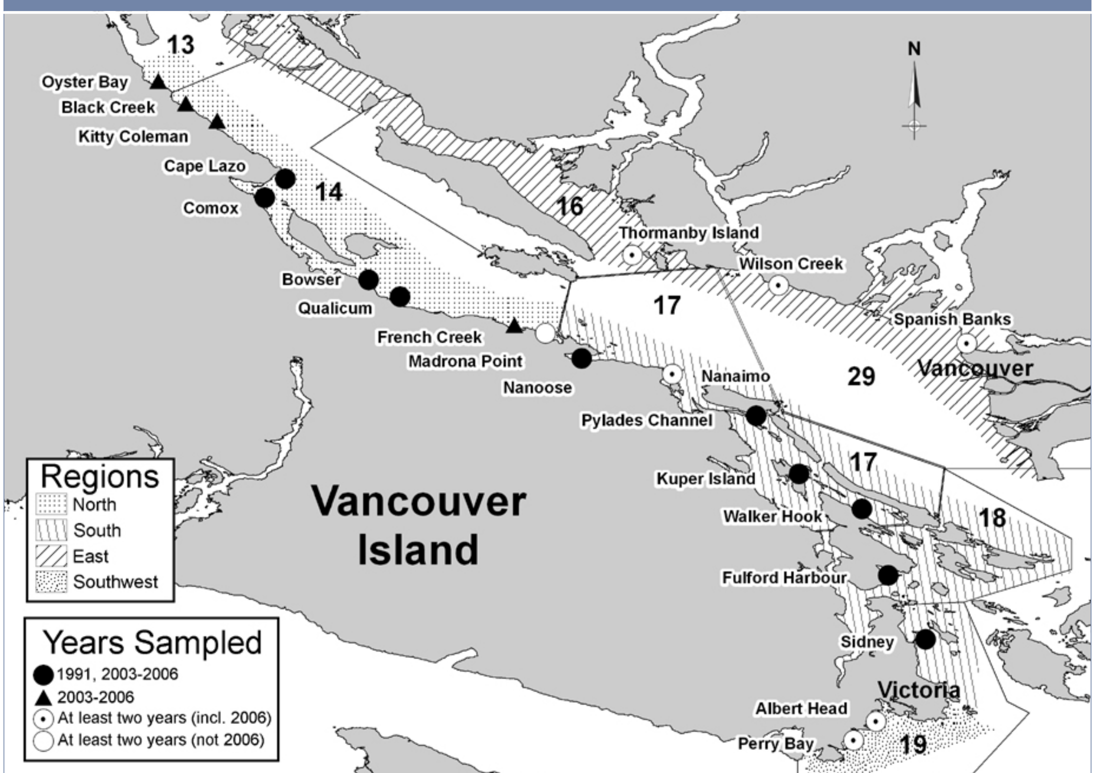


Figure 1. Statistical areas, survey regions, and index sites surveyed during the 1991 and 2003-2006 bottom trawl surveys for young-of-the-year lingcod in the Strait of Georgia (Surry et al. 2007).

Figure 10 provides the productivity of fisheries in the identified management areas of the Georgia Strait over the latter half of the 20th century. The graph is broken into four main species groups, including pelagics,[73] invertebrates,[74] salmon,[75] and groundfish.[76] A sharp overall decline in productivity occurs from the 1950s through to the mid 1970s. The decline is most pronounced for pelagic species due to a collapse and restructuring of the herring fishery. While salmon levels also decline moderately, shellfish and groundfish species remain roughly constant throughout the period. A slow increase in productivity begins in the mid-1970s, corresponding with policy changes to fisheries management. The overall increase in productivity from 1975 to 1996 fails to reach the productivity levels seen in the early 1950s. Although there are many factors impacting fishing productivity, including fisheries management, and a host of environmental impacts, it is safe to reason that a portion of marine ecosystem services have been lost since the 1950s, as species diversity and productivity underlies many services.

FIGURE 10: GEORGIA STRAIT FISHERIES PRODUCTIVITY 1950–1996 (TONNES)

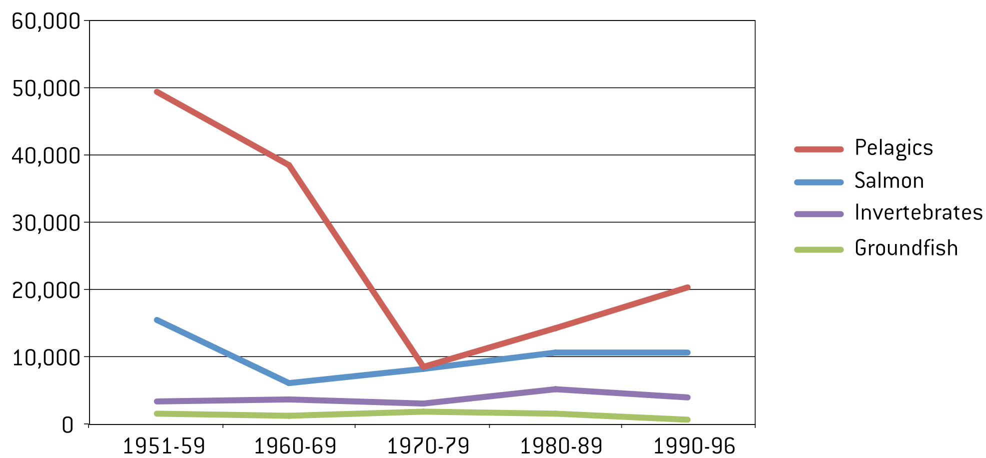


Figure 11 provides a more recent overview of fisheries productivity, based upon a comprehensive data set of commercial, recreational, and First Nation fisheries in the Strait of Georgia from 2001-2010 by statistical area. Data were obtained for salmon,[77] pelagics,[78] and groundfish.[79] Although requested from DFO, invertebrate

73 Data was obtained for the following pelagic species: tuna, Pacific cod, hake, herring, smelt, Pollock, and perch.

74 Data was obtained for the following Invertebrates species: clams, crabs, eulachon, oysters, abalone, geoducks, horseclams, octopus, prawns, shrimp, scallops, sea cucumber, sea urchin, euphasids, and squid.

75 Data was obtained for the following salmon species: Chinook, chum, coho, pink, sockeye, and steelhead, and sturgeon.

76 Data was obtained for the following groundfish species: dogfish, flounder, lingcod, halibut, Pacific Ocean perch, rockfish species, sablefish, sole, skate, and turbot.

77 Data was obtained for the following salmon species: Chinook, chum, coho, pink, sockeye, and steelhead.

78 Data was obtained for the following pelagic species: albacore, Pacific herring, Pacific sardine, pile perch, plainfin midshipman, shiner perch, smelts, surfperches, and walleye Pollock, amd wrymouth.

79 Data was obtained for the following groundfish species: arrowtooth flounder, big skate, black rockfish, bocaccio/rock salmon, brown irish lord, brown rockfish, c-o sole, cabezon, canary rockfish, china rockfish, copper rockfish, dogfish, dover sole, English sole, flatfishes (unspecified), flathead sole, flounder/other sole, greenling, greenstriped rockfish, groundfish mixed, kelp greenling, lingcod, longnose skate, other groundfish, other rockfish, Pacific cod, Pacific hake, Pacific halibut, Pacific ocean perch, Pacific sanddab, petrale sole, quillback rockfish, ratfish, red irish lord, redbanded rockfish, redstripe rockfish, rex sole, rock sole, rockfish mixed, rosethorn rockfish, rougheye rockfish, sablefish, sand sole, sanddab/lefteye flounder, sculpins/bullhead, shortraker rockfish, shortspine thornyhead rockfish, silvergray rockfish, sixgill shark, skate, southern rock sole, spiny dogfish, splitnose rockfish, spotted ratfish, starry flounder, tiger rockfish, widow rockfish, yelloweye rockfish and yellowtail rockfish.

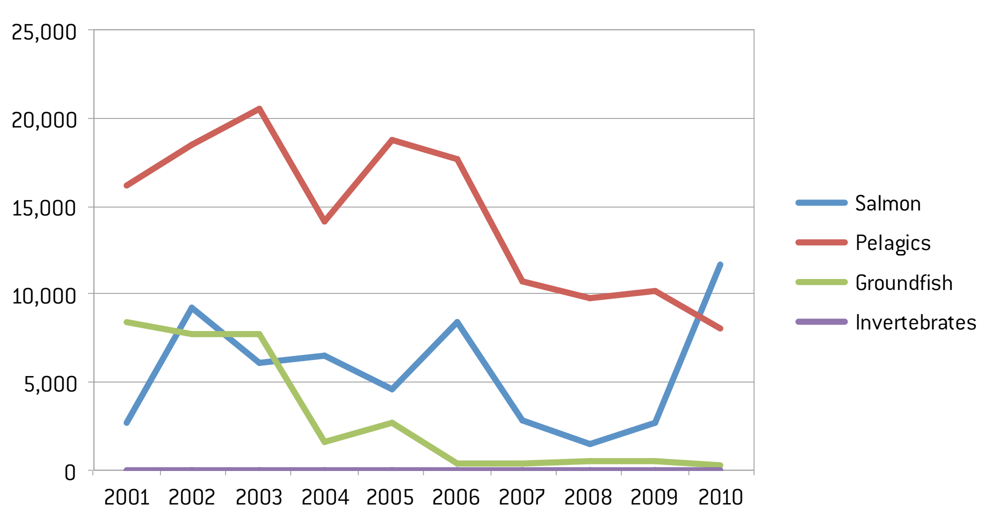
Fisheries management is yet heavily dependent upon single species stock assessments, as if those species were not directly linked to the ecosystem. Though there has been a clear recognition that an ecosystem approach is needed to improve fisheries management, it has been difficult to develop and implement.

PHOTO COURTESY KELLY MORRIS/FLICKR

fisheries were not provided to us. Similar to the data presented in Figure 11, a downward decline in productivity is apparent in the more recent data. Largely the pelagic fisheries lead this drop due to a low period of herring abundance combined with diminished market demand. While the groundfish fisheries catch levels drop in the early 2000s, they rise thereafter before leveling out on the later part of the decade. Salmon have also shown a general decline with the exception of 2010 when sockeye returned in exceptional numbers.

Fisheries management is yet heavily dependent upon single species stock assessments, as if those species were not directly linked to the ecosystem. Though there has been a clear recognition that an ecosystem approach is needed to improve fisheries management, it has been difficult to develop and implement.

FIGURE 11: GEORGIA STRAIT FISHERIES PRODUCTIVITY 2001–2010 (TONNES)



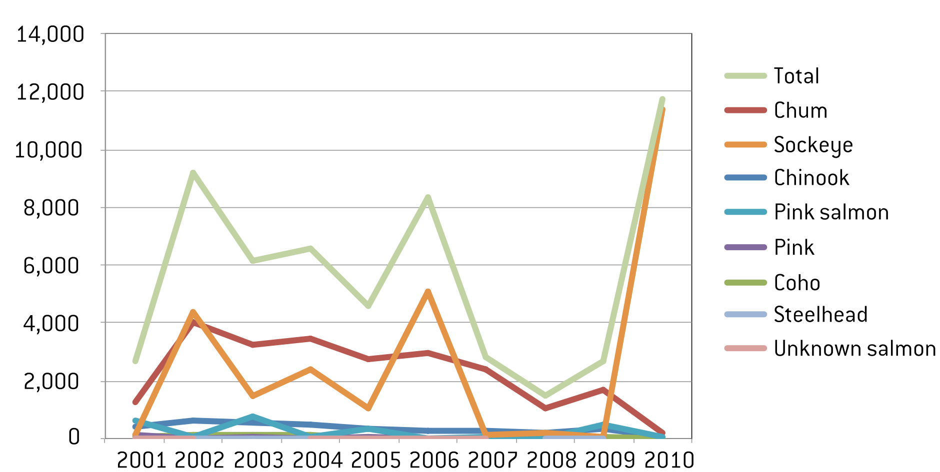
The wild Pacific salmon fishery is an important part of the economy of many coastal communities. In addition the species are considered critical components of marine and terrestrial ecosystems, feeding both inland and marine animals. Given the importance of salmon to the region, Figure 12 provides a more in-depth look at salmon fisheries productivity for the period 2001–2010, listing the six species of salmonids found in the area; sockeye, Chinook, chum, coho, pink and steelhead. The large variation in catch levels is partly expected by the species spawning cycles and natural cycles of productivity, yet some species are on a downward trajectory; most notably sockeye and chum. In their 2008 Red-List Report on sockeye salmon, the International Union for the Conservation of Nature (IUCN) classified various populations of Fraser sockeye as "vulnerable," "endangered" and "critically endangered," with a few being of "least concern." Despite the large number of Fraser sockeye populations that now appear to be in the "red zone," only one — Cultus Lake sockeye — has been identified as endangered by the federal government, although it was rejected for legal protection under the Species At Risk Act. Attempts to restore salmon populations by DFO have been inconsistent and insufficiently financed. Although Canada has developed significant improvements to salmon policy through the Wild Salmon Policy (2005), it has yet to be fully implemented.

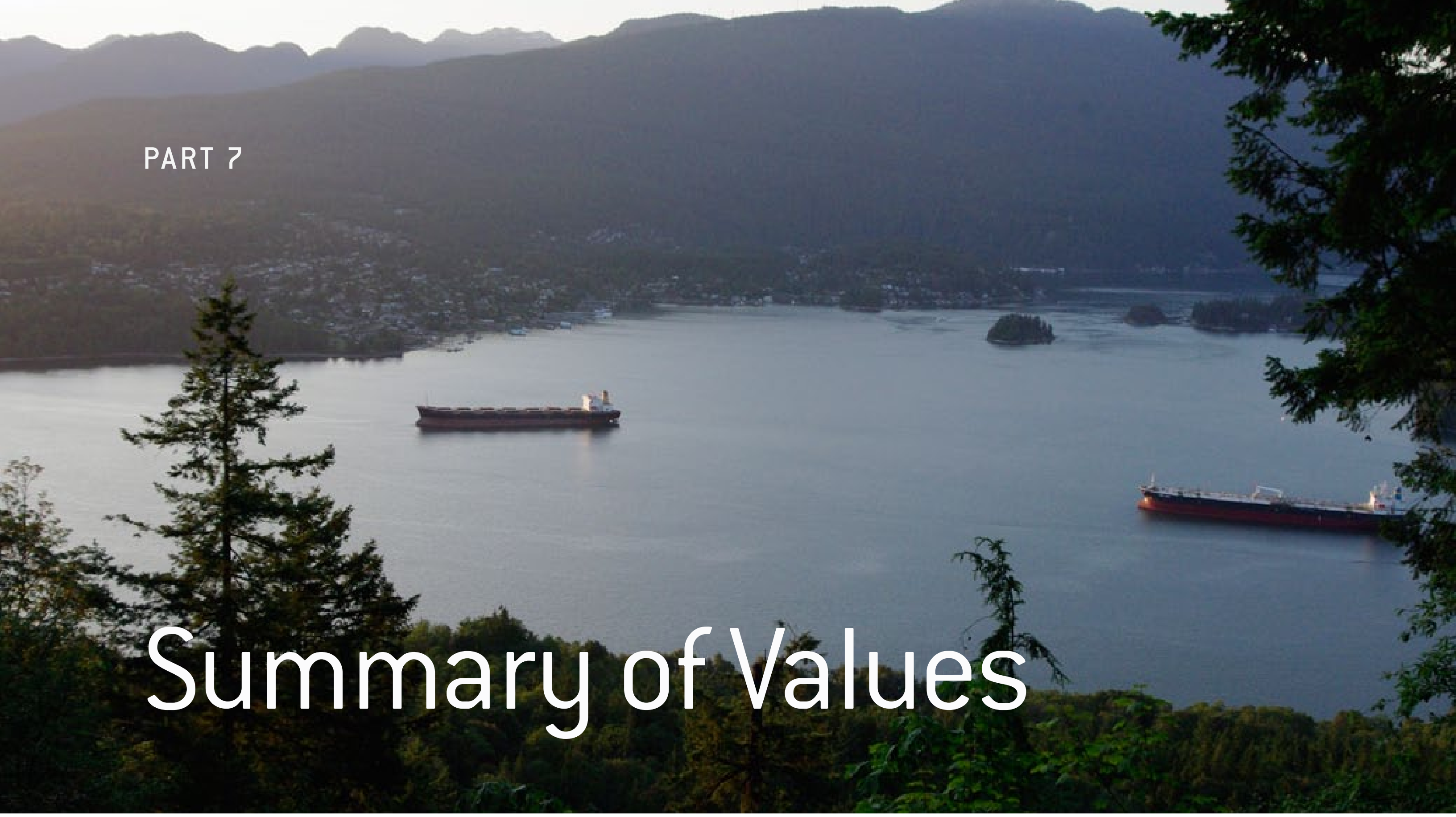
The Cohen Commission, a federal judicial inquiry into the decline of Fraser river sockeye salmon, concluded its hearings in October of 2011. After almost two years, the examination of 350 witnesses, the completion of 12 technical reports and the entry of 1,359 exhibits, Justice Cohen will be releasing a final report October 29, 2012. The hearings pointed to multiple impacts damaging salmon, including open net-cage salmon farms, overfishing of endangered stocks, and habitat loss. As members of the 'Conservation Coalition,' an official participant to the inquiry, the David Suzuki Foundation recommended restoring the independence and transparency of government-sponsored science, increased political and financial support to core functions, and implementation of the Wild Salmon Policy. Whatever the final recommendations of the Commission, we hold hope that it results in increased protection and rebuilding of salmon populations for the benefit of natural systems, their ecosystem services, the economy, and the people who depend on them.

Although not clear from the large scale trends in fisheries productivity in the study area, there have been well documented declines in several marine fish populations including dozens of smaller salmon runs, lingcod, Pacific cod, rockfish, and herring. Natural variability and ecosystem complexity combined with insufficient monitoring of fish populations makes it challenging to quantify the loss, but even under this level of uncertainty there are several well documented losses. Improving ecosystem health and function, in combination with the stabilisation in populations brought on by management improvements, is one way we could see the focus on restoring ecosystem services lead to a direct food and commercial benefit for area residents.

Although not clear from the large scale trends in fisheries productivity in the study area, there have been well documented declines in several marine fish populations including dozens of smaller salmon runs, lingcod, Pacific cod, rockfish, and herring.

FIGURE 12: GEORGIA STRAIT SALMON FISHERIES PRODUCTIVITY 2001–2010 (TONNES)





PART 7

Summary of Values

7.1 Value of Ecosystem Services by Land Cover Class

Aggregating the dollar values of ecosystem services across ecosystems and land cover types provides a partial estimate of the total flow of economic value that aquatic natural systems in B.C. provide to people. The total value estimated for eight ecosystem services over nine land classes ranges from $30 billion to $60 billion per year. This is a tremendous value by any measure. A large number of ecosystem services (for each land cover class) have yet to be valued in primary studies. This suggests that the valuation is a significant underestimate of the true value. Many ecosystem services identified as valuable do not have an associated valuation study. As further primary studies are added to the database, the combined known value of aquatic ecosystem services in the Lower Mainland will rise. Tables 18–21 summarize the final ecosystem service values for aquatic land cover classes in the Lower Mainland. Detailed tables of ecosystem service values are provided in Appendix D.

Table 19 provides the total value for the ecosystem services measured by land class. The values are provided as both total values/year and value per hectare/year. The top three land cover types in terms of ecosystem service total values are marine, estimated at $22.6 billion/year; forests, estimated at $7.3 billion to $13 billion/year; and riparian buffers, estimated at $316 million to $12.8 billion/year. This is primarily a function of the relative size of each land class however (see Table 5). It is more informative to review the top land cover types in terms of value per hectare, as this allows us to compare the land classes of high value against the remaining parcels of land and existing policy measures. Wetlands (valued at a maximum of $378,000 per hectare per year), beaches (valued at a maximum of $209,000 per hectare per year), and lakes and rivers (valued at a maximum of $64,000 per hectare per year) provide the greatest value per hectare per year.

The total value estimated for eight ecosystem services over nine land classes ranges from $30 billion to $60 billion per year. This is a tremendous value by any measure.

PHOTO COURTESY PETE TUEPAH

TABLE 19: SUMMARY OF VALUE OF ECOSYSTEM BENEFITS BY LAND COVER (2010 C$)

Land cover type	Total value/year (millions $/yr)		Value per hectare per year ($/ha/yr)	
	Low	High	Low	High
Beach	$0.35	$121	$612	$208,957
Estuary	$21	$71	$605	$2,073
Forest	$7,325	$13,053	$6,143	$10,946
Lakes/Rivers	$202	$7,395	$1,757	$64,254
Marine	$22,595	$22,604	$18,263	$18,270
Riparian Buffer	$316	$12,834	$847	$34,399
Salt Marsh	$0.23	$31	$426	$57,647
Wetland	$38	$4,645	$3,108	$378,529
Eelgrass Beds	$155	$577	$21,790	$80,929
Total	$30,653	$61,331		

Table 20 provides a synopsis of wetland and beach values per hectare per year. Wetlands have value across a range of services. We were able to estimate values for five of a possible eight services. They are particularly important for disturbance regulation, water supply, aesthetic and recreation, and gas and climate regulation, with high estimates in the range of tens of thousands per year. Beaches, on the other hand are highly valuable for a more select group of services — two of a possible eight. They are highly valued for aesthetic and recreation, and disturbance regulation. Unlike wetlands, however, they have not experience a similar degree of destruction. This is likely due to the fact that as flat lands, wetlands are easy to fill and develop, whereas coastal areas experience a high level of disturbance and as such, are not as easy to develop.

TABLE 20: HIGH AND LOW $/HECTARE ESTIMATES FOR WETLAND AND BEACH (2010 C$)

Ecosystem service general	WETLAND Value per hectare per year ($/ha/yr)		BEACH Value per hectare per year ($/ha/yr)	
	Low	High	Low	High
Aesthetic and Recreational	$52	$27,513	$454	$140,431
Disturbance Regulation	$1,126	$225,999	$158	$68,526
Habitat Refugium and Nursery	$27	$27,022		
Waste Treatment	$242	$59,793		
Water Supply	$111	$36,653		
Gas and Climate Regulation	$1,550	$1,550		
Total	$3,108	$378,529	$612	$208,957

7.2 Value of Ecosystem Services by Benefit

The benefits of ecosystem services can also be calculated by ecosystem service. This is provided in Table 21. The top three highest values are aesthetic and recreational, estimated at $22.6 billion to $44.2 billion per year; water supply, estimated at $2.7 billion to $7 billion per year; and disturbance regulation, estimated at $2 billion to $5 billion per year. Looking once again at the top values per hectare, we found the top three services to be: disturbance regulation (valued at a maximum of $297 million/hectare/year), aesthetic and recreational (valued at a maximum of $283 million/hectare/year), and waste treatment (valued at a maximum of $115 million/hectare/year). These values can change dramatically if scarcity changes. For example, water supply has been abundant; were water to become suddenly very scarce, the price would rise rapidly as would the overall value. A detailed table of ecosystem services by benefit is also provided in Appendix D.

TABLE 21: SUMMARY OF VALUE OF ECOSYSTEM SERVICES BY BENEFIT (2010 C$)

Ecosystem Service		Total value/year (millions $/yr)		Value per hectare ($/ha)	
		Low	High	Low	High
Aesthetic and Recreational		$22,612	$44,181	$18,854	$282,747
Disturbance Regulation		$1,970	$5,032	$2,941	$296,886
Habitat Refugium and Nursery		$60	$773	$5,083	$62,633
Nutrient Cycling		$130	$348	$17,249	$47,833
Waste Treatment		$291	$1,052	$1,351	$115,089
Water Supply		$2,656	$7,008	$3,932	$44,887
Food Provisioning		$1.95	$1.95	$1.58	$1.58
Gas and Climate Regulation	Air Pollution Regulation	$642	$642	$539	$539
	Carbon Sequestration	$52	$55	$122	$869
	Carbon Storage	$2,238	$2,239	$3,480	$4,520
Total		$30,653	$61,331		

The highest valued ecosystem service on a per hectare basis is disturbance regulation. This is partly a function of the rise in studies on the value of intact ecosystems for mitigating weather events.

PHOTO KAREN MASSIER/ISTOCK

The highest valued ecosystem service on a per hectare basis is disturbance regulation. This is partly a function of the rise in studies on the value of intact ecosystems for mitigating weather events. As our local news broadcasts report on the multitude of major weather events and the costs in lives, infrastructure, and businesses, and as we learn of the compounding risks associated with global warming, the case for maintaining and restoring key ecosystems is becoming stronger. There has been a significant increase in the economic analysis of disturbance regulation as greater floods and economic costs related to weather related disturbances have occurred in the last decade. Forests and wetlands play a key role in mitigating such disasters in the Lower Mainland. Much research is yet needed. Marine ecosystems have traditionally not been seen as providing great value for flood protection. Yet sea level rise reduces the slope of rivers and the speed and volume of floodwaters received by marine waters. Marine systems are crucial to flood risk reduction, yet their value for receiving floodwaters has yet to be calculated.

Aesthetic and recreational services are the second highest ecosystem service on a per hectare basis. This is of little surprise in the Lower Mainland, an area renowned for it's natural beauty. In addition to the recreational benefits associated with healthy ecosystems, are the health benefits. The positive benefits of nature, long known and discussed, is gaining greater scientific support. A recent research paper by Francis (Ming) Kuo, a faculty member at the University of Illinois, states: "In the face of the tremendously diverse and rigorous tests to which the nature-human health hypothesis has been subjected, the strength, consistency, and convergence of the findings are remarkable."[80]

TABLE 22: HIGH AND LOW DOLLAR ESTIMATES FOR DISTURBANCE REGULATION AND AESTHETIC AND RECREATIONAL SERVICES (2010 C$)

Land Cover	Disturbance Regulation Value per hectare per year ($/ha/yr)		Aesthetic and Recreational Value per hectare per year ($/ha/yr)	
	Low	High	Low	High
Beach	$158	$68,526	$454	$140,431
Estuary			$4.04	$1,096
Forest	$1,633	$1,633	$8.36	$1,603
Lakes/Rivers			$3.93	$60,770
Marine			$18,259	$18,259
Riparian Buffer	$23	$727	$26	$32,775
Salt Marsh			$45	$301
Wetland	$1,126	$225,999	$52	$27,513

These tables provide insight in to the annual flow of benefits provided by the aquatic ecosystems in B.C. This annual flow of value is provided by the natural assets of terrestrial and marine ecosystems. This is the flow of value, just as the rent paid for apartments in a building should not be mistaken for the value of the asset which provides that flow — the asset value of the apartment building, for example. Treating natural systems in an analogous way to built capital, the asset value can be calculated from the discounted flow of annual benefits that the asset provides. Because not all of the ecosystem benefits are valued, only a partial estimate of the asset value of B.C. aquatic natural capital can be estimated.

6.3 Net Present Values for Ecosystem Benefit Values

How do we compare and include the value provided by built capital (bridges, power plants, schools) or natural capital (water supply, flood protection, recreation benefits) in the future with present benefits to make good investment decisions over time? This is an area of increasing debate and importance in economics. It highlights why economic analysis must also improve to better include the economic goal of sustainability and reflect the true costs and benefits. Natural capital typically appreciates over time. The value of the watershed for providing and filtering water for the City of Vancouver is far greater on a per gallon basis or in total value than 100 years ago. A built capital alternative, a filtration plant, would have depreciated and required replacement several times during the same period. The critical difference in how value is provided across time by natural and built capital is not reflected through discounting.

Discount rates are used to assess the economic benefits of investments across time. The logic behind using a discount rate reflects: 1) that people generally value benefits in the present over benefits in the future

80 Kuo, 2010:4.

(this is referred to as the 'pure time preference of money'); 2) that a dollar in one year's time is assumed to have a value of less than a dollar today, because it is assumed that a dollar today could be invested for a return in one year that is greater than the original investment amount (this is referred to as the 'opportunity cost of investment') and 3) manufactured capital depreciates over time resulting in decreased future value. An ecosystem produces a flow of valuable services across time. In this sense it can be thought of as a capital asset. This analogy can be extended by calculating the net present value of the future flows of ecosystem services, just as the asset value of a traditional capital asset (or large project) can be approximately calculated as the net present value of its future benefits. This calculation is analogous, because ecosystems with all their realized public returns are not bought and sold in markets.

Using a discount rate assumes that the benefits humans reap in the present are more valuable than the benefits provided to future generations. Renewable resources should be treated with lower discount rates than built capital assets because they provide a rate of return over a far longer period of time. Most of the benefits that a natural asset such as the aquatic ecosystems of the Lower Mainland provide reside in the distant future, whereas most of the benefits of built capital (like a gallon of gasoline) reside in the very near-term, with few or no benefits provided into the distant future. Both types of assets are important to maintain a high quality of life, but each also operates on a different time scale. It would be unwise to treat human time preference for a forest like it was a building, or a building like it was a disposable coffee cup. While there is much academic debate on the use and specific rate chosen for natural capital discount rates, there is no clear resolution at this time on how to treat natural capital.

The analysis in this report recognizes this debate and utilizes three discount rates over a 50-year period, 5 per cent, 3 per cent and a 0 per cent to give an understanding to the reader of the impact of discounting on economic valuation. Even with the flaws of discounting, natural capital has tremendous value. Recognizing part of the total value of natural capital is superior to giving it zero value by excluding the value of natural capital in asset analysis. Over a 50-year period, the net present value is $1,533 billion to $3,067 billion at a 0 per cent discount rate, $789 billion to $1,578 billion at a 3 per cent discount rate, and $560 billion to $1,120 billion at a 5 per cent discount rate. Table 23 shows the net present values by discount rates and values per capita and per household.

How do we compare and include the value provided by built capital or natural capital in the future with present benefits to make good investment decisions over time? This is an area of increasingly debate and importance in economics.

PHOTO COURTESY CORINNA CARLSON/FLICKR

TABLE 23: NET PRESENT VALUES FOR ECOSYSTEM BENEFITS (2010 C$)

Discount rate	Net Present Value (50-year period) billion $		Value per capita[a]		Value per household[b]	
	Low	High	Low	High	Low	High
0%	$1,533	$3,067	$613,060	$1,226,625	$1,532,650	$3,066,562
3%	$789	$1,578	$315,478	$631,215	$788,694	$1,578,038
5%	$560	$1,120	$223,840	$447,863	$559,599	$1,119,658

Notes: [a]Based on population of 2.5 million.
[b]Based on household size of 2.6, based on total population from 2006 Census.

PART 8

Conclusions and Recommendations

The implications of not including the value of natural systems in our economic decisions are reflected in the declining health of our ecosystem services.

The aquatic ecosystems of British Columbia's Lower Mainland support an incredible wealth of services. The regions' wetlands, streams, rivers, estuaries, and marine forests provide us with food, clean water, a stable climate, protection from natural disasters, and a place to rest, play, and explore. These services underlie our health, our economy, and our culture. In addition, they provide vast amounts of economic value at a relatively low cost. As these natural systems are degraded, costly investments are required or costs exacted through increased flood events, health damage or lost economic productivity. The implications of not including the value of natural systems in our economic decisions are reflected in the declining health of our ecosystem services. Experience is teaching us that the lack of market signals to alert us of changes in the supply of services or the deterioration of underlying ecosystems means we often appreciate their value when they are lost and it is too late.

This report provides an appraisal valuation of the non-market aquatic ecosystem services in B.C.'s Lower Mainland. By protecting against flooding, providing waste treatment, assuring water supply, supporting fisheries, providing space for recreation, and other benefits, these aquatic ecosystems provide between $30 billion and $61 billion in non-market benefits every year. The results are compelling. Yet, these values appear in no balance sheets or national accounts, and consequently are not factored into decision-making that aims to improve our well-being. However, *if* they were treated as an economic asset, providing a stream of benefits over 50 years, the present value would be between $560 billion and $1,120 billion, using a 5 per cent discount rate. The net present value per household would range between $559,599 and $1,119,658. This demonstrates that natural systems are essential and tremendously valuable assets for Lower Mainland residents.

The population of the Lower Mainland is predicted to grow to more than 3 million by 2020. This will increasingly stress natural capital systems. Higher levels of development to accommodate a growing population will inevitably decrease the supply of natural capital while simultaneously demanding the remaining intact ecosystems provide services for more residents. The development path will determine whether these natural systems are restored or severely degraded, driving either greater prosperity or economic decline. Natural capital valuation is a tool that can assist with the management of these valuable assets. Though a snapshot in time, these appraisal values are defendable and applicable to decision-making at every jurisdictional level. They

provide a basis for investment decisions and the development of new funding mechanisms that restore valuable ecosystems. Ecosystem service valuations can aid effective and efficient natural resource management. It can also be used to help guide advancements towards a sustainable green economy by shifting investment toward a more realistic appreciation of natural capital in comparison to the other types of capital we are already more familiar with and used to managing.

Quantification of tradeoffs among ecosystem services and their interactions with human well-being are now among the most pressing areas of concern in the Lower Mainland. Decision-makers, such as government — local, regional, First Nations, and national — business and others can use the concepts and values presented in this study to incorporate ecosystem services into agency goals, metrics, indicators, assessments and general operations. For example, ecosystem service values should be considered when developing budgets and program planning; land use planning; grant applications to secure federal and outside funding; examining policies and accounting practices; reporting; and development review and permitting processes in urban areas.

This report provides a valuation of non-market aquatic ecosystem services in the Lower Mainland. It is only a first step in the process of developing policies, measures and indicators that support discussions about the tradeoffs in and better allocation of investments of public and private money that ultimately shape the regional economy, quality of life and natural systems for the generations to come.

This report is only a first step in the process of developing policies, measures and indicators to support discussions that ultimately shape the regional economy, quality of life and natural systems for the generations to come.

PHOTO COURTESY PETE TUEPAH

Summary of Conclusions

1. The partial annual value of the goods and services of the aquatic ecosystems of the Lower Mainland ranges between $30 billion and $61 billion.
2. The present value for this flow of benefits, analogous to an asset value, is partially valued between $560 billion and $1.1 trillion.
3. Ongoing studies are critically needed to update valuations and further improve investment.

PHOTO COURTESY PETE TUEPAH

4. It is possible, in fact imperative, to identify specific providers of ecosystem services, the beneficiaries of those services and impediments to their continued supply.
5. Mapping and modeling of ecosystem services is advancing rapidly.
6. Further funding and research can play a key role in informing public and private investment.
7. Achieving sustainability requires shifting investment from investments that damage ecosystem services to investments that improve and sustain them.
8. Improving economic analysis to secure more productive and sustainable investment requires:
   - Accounting for natural capital;
   - Improving jobs analysis for restoration;
   - Adopting new industrial indicators;
   - Changing cost/benefit analysis;
   - Upgrading environmental impact assessments;
   - Including ecosystem service valuation in all watershed scale studies and economic analysis; and
   - Training government, private firm and non-profit staff in ecosystem services and the use of ecosystem service valuation tools.

Tribes and Nations in the Study Region

- Burrard (Tsleil-Waututh)
- Stz'uminus — formerly Chemainus
- Comox people
  - Homalco
  - Klahoose
  - Tla A'min (Sliammon)
- Cowichan Tribes (Quw'utsun, Khowutzun, Cowichan)
  - Clemclemaluts (L'uml'umuluts)
  - Comiaken (Qwum'yiqun')
  - Khenipsen (Hinupsum)
  - Kilpahlas (Tl'ulpalus)
  - Koksilah (Hwulqwselu)
  - Quamichan (Kw'amutsun)
  - Somena (S'amuna')
- Cowlitz (Kawlic — Lower Cowlitz only, Upper are Sahaptian)
- Halalt
- Klallam (Clallam)
  - Lower Elwha
  - Jamestown
  - Port Gamble
  - Beecher Bay
- Lamalchi (Lamalcha)
- Lummi (Lhaq'temish)
- Musqueam
- Nanaimo (Snuneymuxw)
- Nanoose (Snaw'Naw'As)
- Nooksack (Noxws'a7aq)
- Penelakut
- Pentlatch (extinct)
- Qualicum
- Saanich (SANEC)
  - Becher Bay
  - Esquimalt
  - Malahat
  - Pauquachin (BOḰEĆEN)
  - Semiahmoo
  - Sooke (T'sou-ke)
  - Tsartlip (W̱JOȽEȽP)
  - Tsawout (ȾÁ,UTW̱)
  - Tseycum (W̱SÍKEM)
- Sawhewamish (S'əhiw'abš)
- Semiahmoo (SEMYOME)
- Shishalh (Sechelt)
- Skagits
  - Lower Skagit (Whidbey Island Skagits)
  - Upper Skagit
- Snohomish (Sduhubš)
- Songhees (Lekwungen)
- Squamish (Sḵwxwú7mesh)
- Squaxin
- Stillaguamish
- Stó:lõ
  - Aitchelitz
  - Chawathil
  - Cheam
  - Kwantlen
  - Katzie
  - Leq' a: mel
  - Matsqui
  - Popkum
  - Seabird Island
  - Shxw'ow'hamel
  - Skway (Shxwhá:y)
  - Skowkale
  - Skwah
  - Soowahlie
  - Sts'Ailes (Chehalis, B.C.)
  - Sumas
  - Tzeachten
  - Yakweakwioose
- Sui'aẋbixw
- Swinomish
- Tsawwassen
- Tulalip (dxwlilap)

Sources: B.C. Ministry of Aboriginal Relations and Reconciliation, 2012; Porter, 1989

Limitations of Study and Results

The results of the first attempt to assign monetary value to the ecosystem services rendered by B.C.'s Lower Mainland aquatic ecosystems have important and significant implications on the restoration and management of natural capital. Valuation exercises have limitations that must be noted, although these limitations should not detract from the core finding that ecosystems produce a significant economic value to society. A benefit transfer analysis estimates the economic value of a given ecosystem (e.g., wetlands) from prior studies of that ecosystem type. Like any economic analysis, this methodology has strengths and weaknesses. Some arguments against benefit transfer include:

1. Every ecosystem is unique; per-hectare values derived from another location may be irrelevant to the ecosystems being studied.
2. Even within a single ecosystem, the value per hectare depends on the size of the ecosystem; in most cases, as the size decreases, the per hectare value is expected to increase and vice versa. (In technical terms, the marginal cost per hectare is generally expected to increase as the quantity supplied decreases; a single average value is not the same as a range of marginal values).
3. Gathering all the information needed to estimate the specific value for every ecosystem within the study area is not feasible. Therefore, the true value of all of the wetlands, forests, pastureland, etc. in a large geographic area cannot be ascertained and will be underestimated. In technical terms, we have far too few data points to construct a realistic demand curve or estimate a demand function.
4. To value all, or a large proportion, of the ecosystems in a large geographic area is questionable in terms of the standard definition of exchange value. We cannot conceive of a transaction in which all or most of a large area's ecosystems would be bought and sold. This emphasizes the point that the value estimates for large areas (as opposed to the unit values per hectare) are more comparable to national income account aggregates and not exchange values.[81] These aggregates (i.e., GDP) routinely impute values to public goods for which no conceivable market transaction is possible. The value of ecosystem services of large geographic areas is comparable to these kinds of aggregates (see below).

Proponents of the above arguments recommend an alternative valuation methodology that amounts to limiting valuation to a single ecosystem in a single location. This method only uses data developed expressly for the unique ecosystem being studied, with no attempt to extrapolate from other ecosystems in other locations. An area with the size and landscape complexity of B.C.'s Lower Mainland aquatic ecosystems will make this approach to valuation extremely difficult and costly. Responses to the above critiques can be summarized as follows (See Costanza et al., 1998; and Howarth and Farber, 2002 for more detailed discussion):

81 Howarth and Farber, 2002.

1. While every wetland, forest or other ecosystem is unique in some way, ecosystems of a given type, by their definition, have many things in common. The use of average values in ecosystem valuation is no more or less justified than their use in other macroeconomic contexts; for instance, the development of economic statistics such as Gross Domestic or Gross National Product. This study's estimate of the aggregate value of the B.C.'s Lower Mainland ecosystems ecosystem services is a valid and useful (albeit imperfect, as are all aggregated economic measures) basis for assessing and comparing these services with conventional economic goods and services.
2. The results of the spatial modeling analysis that are described in other studies do not support an across the board claim that the per hectare value of forest or agricultural land depends on the size of the parcel. While the claim does appear to hold for nutrient cycling and other services, the opposite position holds up fairly well for what ecologists call "net primary productivity" or NPP, which is a major indicator of ecosystem health. It has the same position, by implication, of services tied to NPP — where each hectare makes about the same contribution to the whole, regardless of whether it is part of a large plot of land or a small one. This area of inquiry needs further research, but for the most part, the assumption that average value is a reasonable proxy for marginal value is appropriate for a first approximation. Also, a range of different parcel sizes exists within the study site, and marginal value will average out.
3. As employed here, the prior studies we analyzed encompass a wide variety of time periods, geographic areas, investigators and analytic methods. Many of them provide a range of estimated values rather than single-point estimates. The present study preserves this variance; no studies were removed from the database because their estimated values were deemed to be "too high" or "too low," although studies that used antiquated methods and data were removed. Limited sensitivity analyses were also performed. This approach is similar to determining an asking price for a piece of land based on the prices of comparable parcels; even though the property being sold is unique, realtors and lenders feel justified in following this procedure to the extent of publicizing a single asking price rather than a price range.
4. The objection to the absence of even an imaginary exchange transaction was made in response to the study by Costanza et al. (1997) of the value of all of the world's ecosystems. Leaving that debate aside, one can conceive of an exchange transaction in which, for example, all of, or a large portion of a watershed was sold for development, so that the basic technical requirement of an economic value reflecting the exchange value could be satisfied. Even this is not necessary if one recognizes the different purpose of valuation at this scale — a purpose that is more analogous to national income accounting than to estimating exchange values, which are highly volatile and poor indicators for making long-tern investment decisions.[82]

In this report, we have displayed our study results in a way that allows one to appreciate the range of values and their distribution. It is clear from inspection of the tables that the final estimates are not extremely precise. However, they are much better estimates than the alternative of assuming that ecosystem services have zero value, or, alternatively, of assuming they have infinite value. Pragmatically, in estimating the value of ecosystem services, it seems better to be approximately right than precisely wrong.

The estimated value of the world's ecosystems presented in Costanza et al. (1997), for example, has been criticized as both (1) a serious underestimate of infinity and (2) impossibly exceeding the entire Gross World Product. These objections seem to be difficult to reconcile, but that may not be so. Just as a human life is priceless so are ecosystems, yet people are paid for the work they do.

82 Howarth and Farber, 2002.

Upon some reflection, it should not be surprising that the value ecosystems provide to people exceeds the gross world product. Costanza's estimate of the work that ecosystems do is an underestimate of the "infinity" value of priceless systems, but that is not what he sought to estimate. Consider the value of one ecosystem service, such as photosynthesis, and the ecosystem good it produces: atmospheric oxygen. Neither is valued in Costanza's study. Given the choice between breathable air and possessions, informal surveys have shown the choice of oxygen over material goods is unanimous. This indicates that the value of photosynthesis and atmospheric oxygen to people exceeds the value of the gross world product — and oxygen production is only a single ecosystem service and good.

GENERAL LIMITATIONS

- STATIC ANALYSIS. This analysis is a static, partial equilibrium framework that ignores interdependencies and dynamics, though new dynamic models are being developed. The effect of this omission on valuations is difficult to assess.
- INCREASES IN SCARCITY. The valuations probably underestimate shifts in the relevant demand curves as the sources of ecosystem services become more limited. The values of many ecological services rapidly increase as they become increasingly scarce.[83] If the B.C.'s Lower Mainland aquatic ecosystems' ecosystem services are scarcer than assumed here, their value has been underestimated in this study. Such reductions in supply appear likely as land conversion and development proceed; climate change may also adversely affect the ecosystems, although the precise impacts are more difficult to predict.
- EXISTENCE VALUE. The approach does not fully include the infrastructure or existence value of ecosystems. It is well known that people value the existence of certain ecosystems, even if they never plan to use or benefit from them in any direct way. Estimates of existence value are rare; including this service will obviously increase the total values.
- OTHER NON-ECONOMIC VALUES. Economic and existence values are not the sole decision-making criteria. A technique called multi-criteria decision analysis is available to formally incorporate economic values with other social and policy concerns.[84] Having economic information on ecosystem services usually helps this process because traditionally, only opportunity costs of forgoing development or exploitation are counted against non-quantified environmental concerns.

GIS LIMITATIONS

- GIS DATA. Since this valuation approach involves using benefit transfer methods to assign values to land cover types based, in some cases, on their contextual surroundings, one of the most important issues with GIS quality assurance is reliability of the land cover maps used in the benefits transfer, both in terms of accuracy and categorical precision.
    - *Accuracy*: The source GIS layers are increasingly accurate, and highly accurate in comparison to historical standards, but may contain some minor inaccuracies due to land use changes after the data was sourced, inaccurate satellite readings and other factors.
    - *Categorical Precision*: The absence of certain GIS layers that matched the land cover classes used in the Earth Economics database created the need for multiple datasets to be combined. For example, a "Riparian Buffer layer" was not obtainable for B.C.'s Lower Mainland ecosystems,

83 Boumans et al., 2002.

84 See Janssen and Munda, 2002 and de Montis et al., 2005 for reviews.

so the "Riparian Buffer cover" class was applied to all forest and layers (i.e., forest cover) within 50 feet of the Rivers and Lakes layer (NLCD Code 11 minus Estuary). This process is likely to produce some inaccuracies in final hectare values for each land cover class and thus affect the final dollar valuation of B.C.'s Lower Mainland aquatic ecosystems.

- ECOSYSTEM HEALTH. There is the potential that ecosystems identified in the GIS analysis are fully functioning to the point where they are delivering higher values than those assumed in the original primary studies, which would result in an underestimate of current value. On the other hand, if ecosystems are less healthy than those in primary studies, this valuation will overestimate current value. There is ongoing research into ecosystem health that will inform future studies.
- SPATIAL EFFECTS. This ecosystem service valuation assumes spatial homogeneity of services within ecosystems, i.e., that every hectare of forest produces the same ecosystem services. This is clearly not the case. Whether this would increase or decrease valuations depends on the spatial patterns and services involved. Solving this difficulty requires spatial dynamic analysis. More elaborate system dynamic studies of ecosystem services have shown that including interdependencies and dynamics leads to significantly higher values (Boumans et al., 2002), as changes in ecosystem service levels ripple throughout the economy. Earth Economics received a National Science Foundation grant to help examine this issue. In the future, spatial effects will be better included in valuation studies.

BENEFIT TRANSFER/DATABASE LIMITATIONS

- INCOMPLETE COVERAGE. That not all ecosystems have been valued or studied well is perhaps the most serious limitation of this study, because it results in a significant underestimate of the value of ecosystem services. More complete valuation coverage would certainly increase the values shown in this report; since no known valuation studies exist, these clearly valuable ecosystem services yet have reported estimated values of zero. Table 7 illustrates which ecosystem services were identified in the study site for each land cover type, and which of those were valued.
- SELECTION BIAS. Bias can be introduced in choosing the valuation studies, as in any appraisal methodology. The use of a range partially mitigates this problem.
- CONSUMER SURPLUS. Because the benefit transfer method is based on average rather than marginal cost, it cannot provide estimates of consumer surplus. However, this means that valuations based on averages are more likely to underestimate total value.

PRIMARY STUDY LIMITATIONS

- WILLINGNESS-TO-PAY LIMITATIONS. Most estimates are based on current ability and willingness to pay or proxies, which are limited by people's incomes, perceptions and knowledge base. Often the "ability to pay" is omitted from WTP discussions. Wealth distribution has a clear impact on valuation. Often coastal communities highly dependent upon ecosystem services have lower purchasing power than urban communities. This places a bias in valuation data. In addition, improving people's knowledge base about the contributions of ecosystem services to their welfare would almost certainly increase the values based on ability and willingness to pay, as people would realize that ecosystems provided more services than they had previously known.

- **PRICE DISTORTIONS.** Distortions in the current prices used to estimate ecosystem service values are carried through the analysis. These prices do not reflect environmental externalities and are therefore again likely to be underestimates of true values.
- **NON-LINEAR/THRESHOLD EFFECTS.** The valuations assume smooth responses to changes in ecosystem quantity with no thresholds or discontinuities. Assuming (as seems likely) that such gaps or jumps in the demand curve would move demand to higher levels than a smooth curve, the presence of thresholds or discontinuities would likely produce higher values for affected services.[85] Further, if a critical threshold is passed, valuation may leave the normal sphere of marginal change and larger-scale social and ethical considerations predominate, such as an endangered species listing.
- **SUSTAINABLE USE LEVELS.** Value estimates are not necessarily based on sustainable use levels. Limiting use to sustainable levels would imply higher values for ecosystem services as the effective supply of such services is reduced.

If the above problems and limitations were addressed, the result would most likely be a narrower range of values and significantly higher values overall. At this point, however, it is impossible to determine more precisely how much the low and high values would change.

85 Limburg et al., 2002.

APPENDIX C

Land Cover Sources

BIOPHYSICAL SHORE-ZONE MAPPING SYSTEM

http://apps.gov.bc.ca/pub/geometadata/metadataDetail.do?recordUID=34311&recordSet=ISO19115

ftp://ftp.gis.luco.gov.bc.ca/pub/coastal/rpts/BCBiophysicalShore-ZoneMapping.pdf

"The British Columbia biophysical shore-zone mapping system was developed in 1979 to support the systematic inventory of the British Columbia coastal zone. It is a descriptive, cost-effective mapping methodology consisting of two interdependent mapping components (physical and biological) to document the physical and biological character of the shore zone. The foundation of the biophysical system is the physical shore-zone mapping component and its hierarchical framework. The physical mapping system segments the shoreline into homogenous along- and across-shore units and components within zones. The physical character of the shoreline is described within this framework. The biotic mapping uses the framework of the physical mapping system to record shoreline biological 'bio-bands' and species data. The shoreline mapping relies on oblique, low tide aerial video imagery flown at spring low tides as the primary source of information."

WASHINGTON: WASHINGTON STATE SHOREZONE INVENTORY

www.dnr.wa.gov/ResearchScience/Topics/AquaticHabitats/Pages/aqr_nrsh_inventory_projects.aspx

"The ShoreZone Inventory describes physical and biological characteristics of intertidal and shallow subtidal areas along Washington State 's saltwater shorelines. This synoptic inventory includes more than 50 habitat characteristics, including physical features such as shoreline type, vegetation types such as kelp and eelgrass, and anthropogenic features such as bulkheads. It has been used in a wide range of planning and research projects."

LAND COVER, CIRCA 2000

http://geobase.ca/geobase/en/data/landcover/csc2000v/description.html

http://geobase.ca/doc/specs/pdf/GeoBase_LCC2000V_product_specifications_en.pdf

"Land Cover information is the result of vectorization of raster thematic data originating from classified Landsat 5 and Landsat 7 ortho-images, for agricultural and forest areas of Canada, and for Northern Territories. The forest cover was produced by the Earth Observation for Sustainable Development (EOSD) project, an initiative of the Canadian Forest Service (CFS) with the collaboration of the Canadian Space Agency (CSA) and in partnership with the provincial and territorial governments. The agricultural coverage is produced by the National Land and Water Information Service (NLWIS) of Agriculture and Agri-Food Canada (AAFC). Northern Territories land cover was realized by the Canadian Centre of Remote Sensing (CCRS).

Land Cover vector data are closest as possible to the source (original raster data). Slight differences can occur because the raster data goes through a data portrayal before being vectorized in order to enhance visual representation such as minimum size, smoothness of polygons and geometry.

This product aims to offer a Canadian integrated Land Cover base produced from various available classified satellite data. The Land Cover base dating extended from 1996 to 2005 nevertheless 80% of the Land Cover base come from 1999 to 2001 defined by circa 2000."

VEGETATION RESOURCES INVENTORY (FOR BASAL AREAS CLASSES)

www.for.gov.bc.ca/hts/vri/index.html

"In 1991 the Forest Resources Commission recommended a review of the provincial resource inventory process in its report The Future of our Forests. The result of that was a re-design of the inventory which resulted in the Vegetation Resources Inventory (VRI). The VRI is a photo-based, two-phased vegetation inventory design consisting of:

- Phase I: Photo Interpretation
- Phase II: Ground Sampling

Within the ground sampling phase, Net Volume Adjustment Factor (NVAF) sampling is a mandatory component that is integral in the calculation of inventory adjustment factors.

Vegetation Resources Inventories are typically funded by government. There is no re-inventory cycle per se and the decision of conducting a VRI is based on a number of factors including age of the inventory, known problems of the inventory, recent catastrophic events (such as mountain pine beetle) and other emerging issues that require a new inventory.

Updating of the inventory due to changes in the forest such as harvesting, fire and other catastrophic events are done through electronic data submissions from licensees and as well through a combination of mapping from satellite imagery, aerial photography and Global Positioning System mapping. The Inventory is updated continuously."

NATIONAL ECOLOGICAL FRAMEWORK FOR CANADA (MARITIME VERSUS NON-MARITIME)

http://sis.agr.gc.ca/cansis/nsdb/ecostrat/intro.html

http://ecozones.ca/english/index.html

"Fifteen ecozones make up terrestrial Canada, and five make up the marine waters bordering Canada. Canada's 15 terrestrial ecozones can be subdivided into 53 ecoprovinces, which can be further broken into 194 ecoregions. Ecozones are useful for general national reporting and for placing Canada's ecosystem diversity in a North American or global context. Ecoprovinces are useful units at an intermediate scale for national and regional planning and reporting purposes. Ecoregions are a useful ecosystem scale for national, provincial, and regional planning and reporting purposes. Regardless of the level in the hierarchy, each unit is distinguished from others by its unique mosaic of plants, wildlife, climate, landforms, and human activities."

NATIONAL LAND COVER DATABASE 2006

www.mrlc.gov

"The National Land Cover Database (NLCD) serves as the definitive Landsat-based, 30-meter resolution, land cover database for the Nation. NLCD provides spatial reference and descriptive data for characteristics of the land surface such as thematic class (for example, urban, agriculture, and forest), percent impervious surface, and percent tree canopy cover. NLCD supports a wide variety of Federal, State, local, and nongovernmental applications that seek to assess ecosystem status and health, understand the spatial patterns of biodiversity, predict effects of climate change, and develop land management policy. NLCD products are created by the Multi-Resolution Land Characteristics (MRLC) Consortium, a partnership of Federal agencies led by the U.S. Geological Survey."

INTERAGENCY VEGETATION MAPPING PROJECT (FOR BASAL AREA CLASSES)

ftp://ftp.blm.gov/pub/OR/gisweb/

www.blm.gov/or/gis/files/docs/Interagency%20Vegetation%20Mapping%20Project.pdf

www.blm.gov/or/gis/data-details.php?data=ds000103

"The Interagency Vegetation Mapping Project (IVMP) provides maps of existing vegetation, canopy cover, size, and cover type for the entire range of the Northern Spotted Owl using satellite imagery from the Landsat Thematic Mapper (TM). This area is commonly called the FEMAT area, in reference to the area's analysis by the Forest Ecosystem Management Assessment Team. A regression modeling approach was used to predict vegetation characteristics from this Landsat data. This process involved the use of numerous sources of ancillary data, the most crucial being USFS, BLM, and Forest Inventory and Analysis (FIA) plot field data and plot photo interpreted information. This data served as training data in the regression modeling. The final products include a vegetation cover prediction map, conifer cover prediction map, broadleaf cover prediction map, and size prediction map."

EPA ECOREGIONS OF THE UNITED STATES (MARITIME VERSUS NON-MARITIME)

www.epa.gov/wed/pages/ecoregions.htm

"The ecoregions shown here have been derived from Omernik (1987) and from refinements of Omernik's framework that have been made for other projects. These ongoing or recently completed projects, conducted in collaboration with the U.S. EPA regional offices, other federal agencies, state resource management agencies, and groups from neighboring North American countries, involve refining and subdividing ecoregions. Designed to serve as a spatial framework for the research assessment, and monitoring of ecosystems and ecosystem components, ecoregions denote areas within which ecosystems (and the type, quality, and quantity of environmental resources) are generally similar. By recognizing the spatial differences in the capacities and potentials of ecosystems, ecoregions stratify the environment by its probable response to disturbance (Bryce et al. 1999). These general purpose regions are critical for structuring and implementing ecosystem management strategies across federal agencies, state agencies, and nongovernmental organizations that are responsible for different types of resources within the same geographical areas (Omernik et al. 2000, McMahon et al. 2001)."

NATIONAL HYDRO NETWORK

www.geobase.ca/geobase/en/data/nhn/description.html

www.geobase.ca/doc/catalogue/GeoBase_NHN_Catalogue_1.0.1_EN.html

"The National Hydro Network (NHN), for which the standard was officially adopted by the Canadian Council on Geomatics (CCOG) in August 2004, focuses on providing a quality geometric description and a set of basic attributes describing Canada's inland surface waters. It provides geospatial vector data describing hydrographic features such as lakes, reservoirs, rivers, streams, canals, islands, obstacles (e.g., waterfalls, rapids, rocks in water) and constructions (e.g., dams, wharves, dikes), as well as a linear drainage network and the toponymic information (geographical names) associated to hydrography.

The NHN forms the hydrographic layer of the GeoBase. The best available federal and provincial/territorial data are used for its production, which is done jointly by the federal government and interested provincial and territorial partners."

NATIONAL HYDROGRAPHY DATASET

http://nhd.usgs.gov

"The National Hydrography Dataset (NHD) is the surface water component of The National Map. The NHD is a digital vector dataset used by geographic information systems (GIS). It contains features such as lakes, ponds, streams, rivers, canals, dams and streamgages. These data are designed to be used in general mapping and in the analysis of surface-water systems."

Detailed Ecosystem Service Tables

Every value in this study is backed up by a specific valuation study. The low and high values, with references, are provided in Table 24.

TABLE 24: LAND COVER VALUES FOR B.C.'S LOWER MAINLAND AQUATIC ECOSYSTEMS (2010 C$)

Land cover	Total value (millions $/yr)		Value per hectare per year ($/ha/yr)	
	Low	High	Low	High
BEACH				
Aesthetic and Recreational	$0.26	$81.45	$454.07	$140,430.63
Disturbance Regulation	$0.09	$39.75	$158.27	$68,526.21
Total	$0.35	$121.20	$612.34	$208,956.84
ESTUARY				
Aesthetic and Recreational	$0.14	$37.27	$4.04	$1,095.65
Habitat Refugium and Nursery	$9.15	$9.15	$268.88	$268.88
Nutrient Cycling	$8.86	$8.86	$260.53	$260.53
Water Supply	$0.60	$13.42	$17.53	$394.38
Carbon Sequestration	$0.87	$0.87	$25.47	$25.47
Carbon Storage	$0.96	$0.96	$28.30	$28.30
Total	$20.58	$70.53	$604.75	$2,073.21
FOREST				
Aesthetic and Recreational	$9.97	$1,911.03	$8.36	$1,602.54
Disturbance Regulation	$1,947.84	$1,947.84	$1,633.41	$1,633.41
Habitat Refugium and Nursery	$3.88	$37.97	$3.25	$31.84
Water Supply	$2,452.98	$6,245.36	$2,057	$5,237.19
Air Pollution Removal	$642.33	$642.33	$538.64	$538.64
Carbon Sequestration	$50.61	$50.61	$42.44	$42.44
Carbon Storage	$2,217.70	$2,217.70	$1,859.70	$1,859.70
Total	$7,325.31	$13,052.84	$6,142.80	$10,945.76
LAKES AND RIVERS				
Aesthetic and Recreational	$0.45	$6,993.99	$3.93	$60,770.31
Habitat Refugium and Nursery	$0.81	$101.49	$7	$881.87
Water Supply	$200.92	$299.46	$1,745.79	$2,601.98

TABLE 24: LAND COVER VALUES FOR B.C.'S LOWER MAINLAND AQUATIC ECOSYSTEMS (2010 C$)				
Land cover	Total value (millions $/yr)		Value per hectare per year ($/ha/yr)	
	Low	High	Low	High
Total	$202.18	$7,394.94	$1,756.72	$64,254.16
MARINE				
Aesthetic and Recreational	$22,591.75	$22,591.75	$18,259.43	$18,259.43
Habitat Refugium and Nursery	$2.17	$11.53	$1.75	$9.32
Food Provisioning	$1.95	$1.95	$1.58	$1.58
Carbon Storage	$0.01	$0.01	$0.01	$0.01
Total	$22,594.88	$22,604.24	$18,262.77	$18,270.34
RIPARIAN BUFFER				
Aesthetic and Recreational	$9.77	$12,228.27	$26.18	$32,774.88
Disturbance Regulation	$8.70	$271.32	$23.31	$727.20
Habitat Refugium and Nursery	$10.06	$46.09	$26.95	$123.53
Waste Treatment	$287.37	$288.57	$770.23	$773.44
Total	$315.90	$12,834.25	$846.67	$34,399.05
SALT MARSH				
Aesthetic and Recreational	$0.02	$0.16	$45.40	$300.96
Habitat Refugium and Nursery	$0.002	$0.81	$3.61	$1,505.66
Waste Treatment	$0.18	$29.28	$338.67	$54,522.80
Carbon Sequestration	$0.02	$0.18	$28.30	$338.47
Carbon Storage	$0.005	$0.53	$10.19	$979.18
Total	$0.23	$30.96	$426.17	$57,647.07
WETLAND				
Aesthetic and Recreational	$0.64	$337.61	$52.20	$27,512.75
Disturbance Regulation	$13.81	$2,773.24	$1,125.61	$225,999.39
Habitat Refugium and Nursery	$0.33	$331.58	$26.95	$27,021.67
Waste Treatment	$2.97	$733.72	$242.04	$59,792.70
Water Supply	$1.37	$449.77	$111.45	$36,653.04
Carbon Storage	$19.02	$19.02	$1,549.71	$1,549.71
Total	$38.14	$4,644.94	$3,107.96	$378,529.26
EELGRASS BEDS				
Habitat Refugium and Nursery	$33.84	$233.93	$4,744.15	$32,790.37
Nutrient Cycling	$121.20	$339.39	$16,988.79	$47,572.92
Carbon Sequestration	$0.18	$3.30	$25.47	$462.42
Carbon Storage	$0.23	$0.73	$31.70	$103.01
Total	$155.45	$577.35	$21,790.11	$80,928.72

TABLE 25: SUMMARY OF VALUE OF ECOSYSTEM SERVICES BY BENEFIT (2010 C$)

Benefits	Land cover type	Total value per year (millions $/yr)		Value per hectare per year ($/ha/yr)	
		Low	High	Low	High
Aesthetic and Recreational	Beach	$0.26	$81.45	$454.07	$140,430.63
	Estuary	$0.14	$37.27	$4.04	$1,095.65
	Forest	$9.97	$1,911.03	$8.36	$1,602.54
	Lakes/Rivers	$0.45	$6,993.99	$3.93	$60,770.31
	Marine	$22,590.75	$22,590.75	$18,259.43	$18,259.43
	Riparian buffer	$9.77	$12,228.27	$26.18	$32,774.88
	Salt Marsh	$0.02	$0.16	$45.40	$300.96
	Wetland	$0.64	$337.61	$52.20	$27,512.75
	Total	$22,612.00	$44,180.53		
Disturbance Regulation	Beach	$0.09	$39.75	$158.27	$68,526.21
	Forest	$1,947.84	$1,947.84	$1,633.41	$1,633.41
	Riparian buffer	$8.70	$271.32	$23.31	$727.20
	Wetland	$13.81	$2,773.24	$1,125.61	$225,999.39
	Total	$1,970.44	$5,032.15		
Food Provisioning	Marine	$1.95	$1.95	$1.58	$1.58
	Total	$1.95	$1.95		
Habitat Refugium and Nursery	Estuary	$9.15	$9.15	$268.88	$268.88
	Forest	$3.88	$37.97	$3.25	$31.84
	Lakes and Rivers	$0.81	$101.49	$7.00	$881.87
	Marine	$2.17	$11.53	$1.75	$9.32
	Riparian buffer	$10.06	$46.09	$26.95	$123.53
	Salt Marsh	$0.002	$0.81	$3.61	$1,505.66
	Wetland	$0.33	$331.58	$26.95	$27,021.67
	Eelgrass Beds	$33.84	$233.93	$4,744.15	$32,790.37
	Total	$60.24	$772.55		
Nutrient Cycling	Estuary	$8.86	$8.86	$260.53	$260.53
	Eelgrass Beds	$121.20	$339.39	$16,988.79	$47,572.92
	Total	$130.06	$348.25		
Waste Treatment	Riparian Buffer	$287.37	$288.57	$770.23	$773.44
	Salt Marsh	$0.18	$29.28	$338.67	$54,522.80
	Wetland	$2.97	$733.72	$242.04	$59,792.70
	Total	$290.52	$1,051.57		

TABLE 25: SUMMARY OF VALUE OF ECOSYSTEM SERVICES BY BENEFIT (2010 C$)

Benefits		Land cover type	Total value per year (millions $/yr)		Value per hectare per year ($/ha/yr)	
			Low	High	Low	High
Water Supply		Estuary	$0.60	$13.42	$17.53	$394.38
		Forest	$2,452.98	$6,245.36	$2,057	$5,237.19
		Lakes and Rivers	$200.92	$299.46	$1,745.79	$2,601.98
		Wetland	$1.37	$449.77	$111.45	$36,653.04
		Total	$2,655.87	$7,008.01		
Gas and Climate Regulation	Air Pollution Removal	Forest	$642.33	$642.33	$538.64	$538.64
		Total	$642.33	$642.33		
	Carbon Sequestration	Estuary	$0.87	$0.87	$25.47	$25.47
		Forest	$50.61	$50.61	$42.44	$42.44
		Salt Marsh	$0.02	$0.18	$28.30	$338.47
		Eelgrass Beds	$0.18	$3.30	$25.47	$462.42
		Total	$51.68	$54.96		
	Carbon Storage	Estuary	$0.96	$0.96	$28.30	$28.30
		Forest	$2,217.70	$2,217.70	$1,859.70	$1,859.70
		Marine	$0.01	$0.01	$0.01	$0.01
		Salt Marsh	$0.005	$0.53	$10.19	$979.18
		Wetland	$19.02	$19.02	$1,549.71	$1,549.71
		Eelgrass Beds	$0.23	$0.73	$31.70	$103.01
		Total	$2,237.93	$2,238.95		
	Gas and Climate Regulation Total		$2,931.94	$2,936.24		

Primary Studies Annotated Bibliography

Anderson, G.D. and Edwards, S.F. (1986). Protecting Rhode Island's coastal salt ponds: An economic assessment of downzoning. *Coastal Zone Management Journal,* 14(1-2), 67-91.

This paper presents an economic analysis of a downzoning program proposed in Southern Rhode Island (U.S.) to protect coastal salt ponds. Hedonic price and contingent valuation methods are used to value coastal amenities. The contingent valuation study described four water-quality levels and respondents were then asked to state their WTP for various changes in water quality. The hedonic pricing study considered 15 attributes of housing prices for 738 transactions over three years.

Batie, S. S. and Wilson, J.R. (1978). Economic Values Attributable to Virginia's Coastal Wetlands as Inputs in Oyster Production. *Southern Journal of Agricultural Economics*, 10(1), 111-118.

This study estimates the marginal value product accruing to society from wetlands' contributions to Virginia oyster production. First a physical production function relating Virginia oyster harvest and Virginia coastal wetlands as inputs is estimated. This oyster yield function then is used to derive the marginal value product where the variable input is wetlands acreage.

Bergstrom, J. C., Stoll, J.R., Titre, J.P. and Wright, V.L. (1990). Economic value of wetlands-based recreation. *Ecological Economics,* 2(2), 129-147.

This study estimates the value of on-site recreational use of coastal wetlands in Louisiana (U.S.). Personal, on-site interviews were conducted with people who use the study area for hunting, fishing, shrimping, and crabbing. Respondents were asked to value a wetland protection program under three scenarios using a dichotomous choice format (i.e., whether or not they would pay a fixed amount of money).

Bockstael, N.E., McConnell, K.E., Strand, I.E., (1989). Measuring the benefits of improvements in water quality: the Chesapeake Bay. *Marine Resource Economics*, 6(1), 1-18.

This study estimates the value of a moderate improvement in water quality in Chesapeake Bay, U.S. A contingent valuation survey was administered to a random subset of residents in the Baltimore-Washington region of the U.S. Respondents were asked whether they would be willing to pay an amount ($A) in additional taxes per year, providing the water quality was improved to a level acceptable for swimming. The amount of money ($A) varied randomly from $5 to $50 per year. When the authors aggregated the results for the identified population, they found the total annual benefits of improved water quality to amount to just under $10 million ($910,000 1984 dollars).

Bouwes, N. W., and Scheider, R. (1979). Procedures in estimating benefits of water quality change. *American Journal of Agricultural Economics*, 61(3), 635-639.

This paper presents a method for estimating, ex ante, the benefits of water quality change by presenting a model including recreators' ratings of water quality. A decline in water quality in Pike Lake, Wisconsin can be prevented by the construction of a storm sewer diversion project. This undertaking can be accomplished for a fixed cost. The question being asked is whether the benefits to be derived from preserving the present high level of water quality will justify the project cost. The demand curve for recreation is measured by the number of trips under various scenarios.

Bowker, J. M., English, D.B.K. and Donovan, J.A. (1996). Toward a Value for Guided Rafting on Southern Rivers. *Journal of Agricultural and Applied Economics,* 28(2), 423-432.

This study examines per trip consumer surplus associated with guided whitewater rafting on two southern rivers in the U.S. In order to provide information about the value of guided rafting on rivers for management decisions dealing with

such rivers and their corridors, an independent travel cost model was developed. A six-page questionnaire was sent to a random selection of names drawn from outfitter records.

Breaux, A., Farber, S., and Day, J. (1995). Using Natural Coastal Wetlands Systems for Waste Water Treatment — an Economic Benefit Analysis. *Journal of Environmental Management,* 44(3), 285-291.

This paper reports on estimates of cost savings from using coastal wetlands for substitute treatment in Louisiana (U.S.). It reports on a set of three existing or proposed wetland waste water treatment projects in Louisiana. The focus of this paper is the economic benefit of these projects. Estimates of discounted cost savings ranged from $785 to $34,700 per acre of wetlands used for treatment.

Burt, O. R. and Brewer, D. (1971). Estimation of Net Social Benefits from Outdoor Recreation. *Econometrica*, 39(5), 813-827.

This study estimates the value of a new outdoor recreational site in Missouri (U.S.). Consideration for the influence that existing recreation developments had on the demand for the new site was built into the study. Respondents were asked about the number of days spent at each site, expenditures on each trip, mileage driven for each trip, and family income.

Cordell, H. K. and Bergstrom, J.C. (1993). Comparison of recreation values among alternative reservoir water level management scenarios. *Water Resources Research*, 29(2), 247-258.

This policy-informing study measured the change in recreational value of four reservoirs in North Carolina (U.S.) under three alternative water level management scenarios. Recreational user surveys were used to determine the extent users value higher water levels held longer into the summer and fall. This was compared to the value of using these reservoirs as they were managed at the time of the study.

Costanza, R., Farber, S.C. and Maxwell, J. (1989). Valuation and management of wetland ecosystems. *Ecological Economics*, 1(4), 335-361.

This study used the travel cost method to estimate the value of wetland recreation in Terrebonne Parish, Louisiana (U.S.). A survey of recreational user costs was conducted over a 1- year period to elicit willingness-to-pay to preserve wetlands for recreational purposes.

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P., and van den Belt, M. (1997). The value of the world's ecosytem services and natural capital. *Nature*, 387(15), 253-260.

This groundbreaking study estimated the economic value of 17 ecosystem services for 16 biomes, based on published studies and a few original calculations. For the entire biosphere, the value (most of which is outside the market) was estimated to be in the range of US$16– 54 trillion ($10^{12}$) per year, with an average of US$33 trillion per year. At the time of the study, global gross national product total was around US$18 trillion per year.

Creel, M., and Loomis, J. (1992). Recreation Value of Water to Wetlands in the San Joaquin Valley: Linked Multinomial Logit and Count Data Trip Frequency Models. *Water Resources Research,* 28(10), 2597-2606.

This study values the recreational benefits from providing increased quantities of water to wildlife and fisheries habitats using linked multinomial logit site selection models and count data trip frequency models. The study encompasses waterfowl hunting, fishing and wildlife viewing at 14 recreational resources in the San Joaquin Valley, including the National Wildlife Refuges, the State Wildlife Management Areas, and six river destinations. The economic benefits of increasing water supplies to wildlife refuges were also examined by using the estimated models to predict changing patterns of site selection and overall participation due to increases in water allocations. Estimates of the dollar value per acre foot of water are calculated for increases in water to refuges. The resulting model is a flexible and useful tool for estimating the economic benefits of alternative water allocation policies for wildlife habitat and rivers.

Croke, K., Fabian, R., and Brenniman, G. (1986). Estimating the value of improved water-quality in an urban river system. *Journal of Environmental Systems*, 16, 13-24.

This article estimates the value that cleaner rivers would have to Chicago citizens, and thus measures an important component of value to which the Chicago Deep Tunnel project was expected to contribute. In a contingent value survey, average annual household values ranging from $30 to $50 were observed for various degrees of improvement. An important result is that from two-thirds to nine-tenths of these reflect the intrinsic value of the rivers nonuse values related to the existence of clean rivers or the option to use them in the future. A comparison with similar published studies confirms the credibility of the results.

Crooks, S., Herr, D., Tamelander, J., Laffoley, D., and Vandever, J. (2011). *Mitigating Climate Change through Restoration and Management of Coastal Wetlands and Near-shore Marine Ecosystems: Challenges and Opportunities*. Environment Department Paper 121, World Bank, Washington, DC.

This study was commissioned and overseen by a team at the World Bank. In light of rapidly evolving policy on the eligibility of REDD+ activities under the UNFCC, this activity was designed to inform policymakers and climate change practitioners on the capture and conservation of blue carbon in natural, coastal carbon sinks. This report consolidates information from the literature and provides analysis on the climate change mitigation potential of seagrasses and coastal wetlands, including coastal peats, tidal freshwater wetlands, salt marshes and mangroves.

Daily G.C. (1997). *Nature's Services: Societal Dependence on Natural Ecosystems*. Island Press. 392 pp.

This book is a collection of different essays divided by chapters by distinct authors. It provides a significant introduction to what ecosystem services are and also explains many of the methodologies used in order to value these services in different land cover types. Some of the authors participating are: Jane Lubchenco, Sandra Postel, Norman Myers, Roberts Costanza and many more. Apart from explaining key concepts to understanding ecological economics, some chapters give detailed synthesis of preliminary assessment of services economic value.

Doss, C. R. and Taff, S.J. (1996). The Influence of Wetland Type and Wetland Proximity on Residential Property Values. *Journal of Agricultural and Resource Economics*, 21(1), 120-129.

This study estimated the value of wetlands in Minnesota (U.S.) through the hedonic pricing method. The authors used detailed residential housing pricing data and wetland location to determine relative preferences for proximity to four broad classes of wetlands.

Duarte, C., Middelburg, J., and Caraco, N. (2005). Major role of marine vegetation on the oceanic carbon cycle. *Biogeosciences*, 2, 1-8.

The carbon burial in vegetated sediments was evaluated using a bottom-up approach derived from upscaling a compilation of published individual estimates of carbon burial in vegetated habitats (seagrass meadows, salt marshes and mangrove forests) to the global level and a top-down approach derived from considerations of global sediment balance and a compilation of the organic carbon content of vegetated sediments.

Duffield, J. W., Neher, C.J., and Brown, T.C. (1992). Recreation benefits of instream flow: Application to Montana's Big Hole and Bitterroot Rivers. *Water Resources Research*, 28(9), 2169-2181.

A framework for estimating the recreational value of instream flows was developed for two Montana rivers (U.S.). The valuation survey employed in this study was specifically designed to examine the influence of stream flow levels on willingness to pay for recreational trips.

Duwors, E. et al. (1999). *The Importance of Nature to Canadians: The Economic Significance of Nature-Related Activities.* Environmental Economics Branch. Environment Canada. Ottawa, Canada.

The value of recreation is based on a 1996 national survey (Canada) that estimates the economic impact of nature-based recreation and the willingness to pay for nature-based activities.

Edwards, S. F., and Gable, F.J. (1991). Estimating the value of beach recreation from property values: An exploration with comparisons to nourishment costs. *Ocean and Shoreline Management,* 15(1), 37-55.

This paper explores how the economic value of recreation at local public beaches can be estimated from nearby property values. The negative effect of distance from the nearest public beach on coastal property values was used to reveal recreational value. Estimates of recreational value were also compared to the costs of beach nourishment that were calculated from a simulation of beach erosion caused, in part, by increases in relative sea-level. Although a complete benefit-cost analysis was not feasible, the results suggest that potential losses of recreational value by local users alone could establish the efficiency of beach nourishment projects.

Ernst, C. (2004). *Protecting the Source: Land conservation and the future of America's Drinking Water*. Published by The Trust for Public Land and American Water Works Association.

The water filtration services provided by forests have been calculated as the replacement cost of the current condition of the study area's watersheds. The cost of treatment is based on a U.S. study that found the cost of treatment for surface water supplies statistically varies depending on the per cent forest cover in the watershed area. This study concluded that there is a 20 per cent increase in water treatment costs for each 10 per cent loss in forest cover.

Greenley, D. A., Walsh, R.G., and Young, R.A. (1981). Option Value: Empirical Evidence from a Case Study of Recreation and Water Quality. *Quarterly Journal of Economics*, 96(4), 657-673.

This study aims to measure the preservation value of water quality in the presence of potential irreversible water quality degradation due to mining activity in the South Platte River Basin, Colorado (U.S.). Survey respondents answered "yes" or "no" to dollar increments in willingness-to-pay, dependent on hypothetical change in water quality.

Gupta, T.R., and Foster, J.H. (1975). Economic Criteria for Freshwater Wetland Policy in Massachusetts. *American Journal of Agricultural Economics*, 57(1), 40-45.

The authors of this article demonstrate that comparison of benefit value with opportunity cost of wetland preservation can be used as the basis for decisions concerning permits for wetland alteration. The approach used for measuring municipal water supply benefit from preserved wetlands compares the cost of wetland water with that of an alternative water source. The study found that an average acre of wetland could supply water at a savings of $2,800 per year compared to other water sources.

Haener, M. K., and Adamowicz, W.L. (2000). Regional forest resource accounting: a northern Alberta case study. *Canadian Journal of Forest Research*, 30(2), 264-273.

This study outlines the development of a resource accounting system for a region of public forestland in northern Alberta. The purpose of this exercise is to provide a clearer picture of the market and nonmarket benefits provided by the forest. The services valued include commercial activities such as forestry, trapping, and fishing plus noncommercial or nonmarket activities. Nonmarket services include recreational activities (fishing, hunting, and camping), subsistence resource use, and environmental control services (carbon sequestration and biodiversity maintenance). Habitat value is measured using two different approaches: contingent valuation and net factor income.

Hauser, A., and. van Kooten, G.C. (1993). *Benefits of Improving Water Quality in the Abbotsford Aquifer: An application of contingent valuation methods*. Environment Canada.

Given risks to health and lack of knowledge concerning the benefits of improved water quality, a contingent valuation survey was conducted in the Abbotsford region. The survey sought to elicit responds' willingness to pay for improvements in water quality. As well, defense expenditures (actual outlays on bottled water and water filters) and a ranking method were used to determine the value of improved water quality in Abbotsford. The survey was mailed to 347 households in the Central Fraser Valley region in May of 1993.

Hayes, K. M., Tyrrell, T.J., and Anderson, G. (1992). Estimating the Benefits of Water Quality Improvements in the Upper Narragansett Bay. *Marine Resource Economics*, 7(1), 75-85.

This study estimated the benefits to Rhode Island residents using the contingent valuation approach and responses from 435 residents to a 1985 survey about swimming and shellfishing. Aggregate annual benefits were estimated to be in the range of $30 million to $60 million for "swimmable" and $30 million to $70 million for "shell- fishable" water quality, depending on the type of measure (mean or median) and survey format.

Intergovernmental Panel on Climate Change (IPCC). (2007). Summary for Policymakers. In: *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 7-22.

This assessment of current scientific understanding of the impacts of climate change on natural, managed and human systems deals primarily with the capacity of these systems to adapt and their vulnerability in doing so. As a follow up document of past IPCC assessments this recent version incorporates new knowledge gained since then. This report includes data on anthropogenic impacts on acidification, regional climate change, temperature rise in oceans, etc. explaining not only the ecological concerns but also the health issues related to these conflicts. A conglomeration of factual data is presented such as the social cost of carbon calculated by the damages caused by climate change across the globe.

Jenkins, W. A., Murray, B.C., Kramer, R.A., and Faulkner, S.P. (2010). Valuing ecosystem services from wetlands restoration in the Mississippi Alluvial Valley. *Ecological Economics,* 69(5), 1051-1061.

This study assesses the value of restoring forested wetlands via the U.S. government's Wetlands Reserve Program (WRP) in the Mississippi Alluvial Valley by quantifying and monetizing ecosystem services. The three focal services are greenhouse gas (GHG) mitigation, nitrogen mitigation, and waterfowl recreation. Site- and region-level measurements of these ecosystem services are combined with process models to quantify their production on agricultural land, which serves as the baseline, and on restored wetlands. We adjust and transform these measures into per-hectare, valuation-ready units and monetize them with prices from emerging ecosystem markets and the environmental economics literature. By valuing three of the many ecosystem services produced, we generate lower bound estimates for the total ecosystem value of the wetlands restoration.

Johnson, R. J., Grigalunas, T.A., Opaluch, J.J., Mazzotta, M., and Diamantedes, J. (2002). Valuing Estuarine Resource Services Using Economic and Ecological Models: The Peconic Estuary System Study. *Coastal Management*, 30(1), 47-65.

This study estimates the value of wetlands for recreation and habitat using a variety of methods:

- A Property Value study examines the contribution of environmental amenities to the market price of property. Using the Town of Southold as a case study, this study was designed to measure the implicit values of policy-relevant scenic amenities to nearby residents.
- A Travel Cost study estimates the economic value that users have for four key PES outdoor recreation activities. This study also examines the impact of (1) water quality on the number of trips by, and the value of swimming to, participants and (2) catch rates on recreational fishing.
- A Wetlands Productivity Value study provides estimates of the economic value of eelgrass, inter-tidal salt marsh, and sand/mud bottoms, based on the value of the fish, shellfish and bird species that these ecosystems help produce. The focus is on the nursery and habitat services of wetland ecosystems in the production of commercial fisheries.
- A Resource Value study uses contingent choice methodology t o estimate the relative preferences that residents and second homeowners have for preserving and restoring key PES natural and environmental resources, including open space, farmland, unpolluted shellfish grounds, eelgrass beds, and intertidal salt marsh. This study also provides an estimate of the public's willingness to pay, or economic value for these resources.

Kahn, J. R. and Buerger, R.B. (1994). Valuation and the Consequences of Multiple Sources of Environmental Deterioration: The Case of the New York Striped Bass Fishery. *Journal of Environmental Management*, 40(3), 257-273.

The value of Chesapeake spawned striped bass to New York commercial fisherman was calculated by estimating demand and supply functions for striped bass caught in New York waters, where the supply function is a function of both the abundance of Hudson River spawned fish and the abundance of Chesapeake-spawned fish. Travel cost demand is estimated for charter-boat fishing in general.

Kealy, M.J., and Bishop, R.C. (1986). Theoretical and Empirical Specifications Issues in Travel Cost Demand Studies. *American Journal of Agricultural Economics Association*, 68(3), 660-667.

A travel cost demand model is derived from a utility function, which postulates that individuals choose the optimal total number of site recreation days given by the product of the number and length of their recreation trips. By relaxing the assumption that on-site time is constant across recreationists, the applicability of the travel cost method is extended. A mail survey of Lake Michigan sports anglers was used to estimate recreational value. The estimated opportunity cost of a day fishing was modeled to include both a monetary cost component and a time cost component.

Keith, H., Mackey, B.G., and Lindenmayer, D. (2009). Re-evaluation of Forest Biomass Carbon Stocks and Lessons from the World's Most Carbon Dense Forests. *PNAS*, 106(28), 11635-11640.

This study describes a framework for identifying forests important for carbon storage based on the factors that account for high biomass carbon densities, including (i) relatively cool temperatures and moderately high precipitation producing rates of fast growth but slow decomposition, and (ii) older forests that are often multiaged and multilayered and have experienced minimal human disturbance. The results are relevant to negotiations under the United Nations Framework Convention on Climate Change regarding forest conservation, management, and restoration.

Kline, J. D. and Swallow, S.K. (1998). The demand for local access to coastal recreation in southern New England. Coastal Management, 26(3), 177-190.

This study examines the demand for coastal access to a local, free-access site in Gooseberry, Massachusetts through on-site interviews. One set of interviews involved determining the number of individuals interested in key beach activities, whereas a second set of interviews focused on individuals willingness-to-pay to access the beach.

Knowler, D. J., MacGregor, B.W., Bradford, M.J., and Peterman, R.M. (2003). Valuing freshwater salmon habitat on the west coast of Canada. *Journal of Environmental Management*, 69(3), 261-273.

This paper presents a framework for valuing the benefits for fisheries from protecting areas from degradation, using the example of the Strait of Georgia coho salmon fishery in southern British Columbia, Canada. The authors use a bioeconomic model of the coho fishery to derive estimates of value that are consistent with economic theory. Then 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. Sensitivity analyses suggest that these values are relatively robust to different assumptions, and if anything, are likely to be minimum estimates.

Knowler, D., and Dust, K. (2008). *The Economics of Protecting Old Growth Forest: An analysis of Spotted Owl Habitat in the Fraser Timber Supply Area of British Columbia.* School of Resource and Environmental Management. Simon Fraser University.

The value of protecting old growth forests in the Fraser Timber Supply Area of B.C. are drawn from the Outdoor Recreation Survey from 1989/1990. The survey measures the amount consumers' value outdoor recreation beyond how much they spend on outdoor recreation. According to this report, 52 per cent of the recreation user days occur in the Vancouver Forest Region worth an estimated $79.19 per hectare per year.

Kreutzwiser, R. (1981). The Economic Significance of the Long Point Marsh, Lake Erie, as a Recreational Resource. *Journal of Great Lakes Research*, 7(2), 105-110.

This study sought to assess the economic significance of recreational use of the Long Point and Point Pelee National Park (Cdn) marshes. The authors used the travel cost method by interview and mail back questionnaires. In addition to providing data on the nature and extent of wetland recreational use and user characteristics and motivations, the surveys provided data on user-party travel and other expenditures necessary for estimating the economic value of the wetland recreational benefits.

Kulshreshtha, S. N. and Gillies, J.A. (1993). Economic Evaluation of Aesthetic Amenities: A Case Study of River View. *Journal of the American Water Resources Association*, 29(2), 257-266.

This study estimated the value of aesthetic amenities provided by the South Saskatchewan River to the residents of Saskatoon (Cdn). Differences in property value associated with a river view were estimated using a Hedonic Price Model. Actual market data was obtained to determine residents willingness-to-pay for higher property taxes or higher rents.

Laffoley, D., and Grimsditch, G. (2009). *The Management of Natural Coastal Carbon Sinks*. International Union for Conservation of Nature and Natural Resources (IUCN).

This report focuses on the management of natural coastal carbon sinks. To construct this report leading scientists were asked for their views on the carbon management potential of a number of coastal ecosystems: tidal saltmarshes, mangroves, seagrass meadows, kelp forests and coral reefs. The resultant chapters written by these scientists form the core of this report and are scientists' views on how well such habitats perform a carbon management role.

Leggett, C. G., and Bockstael, N.E. (2000). Evidence of the Effects of Water Quality on Residential Land Prices. *Journal of Environmental Economics and Management*, 39(2), 121-144.

This article assesses the effect of water quality on property values along the Chesapeake Bay (U.S.). The authors use a measure of water quality — fecal coliform bacteria — for which spatially explicit data is publically accessible. The data used in the analysis consist of sales of waterfront property in Anne Arundel County, Maryland, that occurred between July 1993 and August 1997. The dependent variable was the actual sales price adjusted to constant dollars using the CPI. After accounting for omitted variable bias and after correcting for spatial autocorrelation, the authors conclude that waterfront homeowners have a positive willingness to pay for improved water quality.

Leschine, T. M., Wellman, K.F., and Green, T.H. (1997). *The Economic Value of Wetlands: Wetlands' Role in Flood Protection in Western Washington*. Washington State Department of Ecology. 68pp.

This study estimates the dollar-per-acre values of wetland systems for flood protection in two Western Washington communities currently experiencing frequent flooding, Lynnwood and Renton. This is done via a variant of the alternative/substitute cost method. Cost estimates for engineered hydrologic enhancements to wetlands currently providing flood protection are used to establish proxies for the value of the flood protection these same wetlands currently provide. A simple "ratio analysis" scheme is employed, making the method easily transferable to other communities which, like Lynnwood and Renton, are seeking ways to enhance the flood protection their remaining wetlands provide. The proxy values estimated are in the range of tens of thousands per acre in current dollars suggesting that communities are likely to pay an increasingly high price for flood protection if they allow their remaining natural systems capable of attenuating flood flows to become further compromised in their ability to do so

Loomis, J. (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(6), 1066, doi:10.1029/2000WR000136.

A travel cost demand model that uses intended trips if dams are removed and the river restored is presented as a tool for evaluating the potential recreation benefits in this counterfactual but increasingly policy relevant analysis 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. This gain in river recreation exceeds the loss of reservoir recreation but is about $60 million less than the total costs of the dam removal alternative. The analysis suggests this extension of the standard travel cost method may be suitable for evaluating the gain in river recreation associated with restoration of river systems from dam removal or associated with dam relicensing conditions.

Lynne, G. D., Conroy, P., and Prochaska, F.J. (1981). Economic valuation of marsh areas for marine production processes. *Journal of Environmental Economics and Management*, 8(2), 175-186.

This paper develops an approach for relating blue crab economic productivity on Florida's Gulf Coast to marsh availability in the area. The marginal value productivity of marsh is shown to vary with alternative levels of marsh and effort in the fishery. A bioeconomic model, which gains its verity in the population dynamics literature, is developed and tendered as a methodology that has promise. Ordinary least squares (OLS) estimates of parameters are presented and their economic significance illustrated relative to marsh characteristics and the blue crab fishery on the Gulf Coast of Florida. Most importantly, the model allows isolating the effects and contributions of the human actors (via fisherman "effort") as compared to the contribution of the marsh.

Mahan, B. L., Polasky, S., and Adams, R.M. (2000). Valuing Urban Wetlands: A Property Price Approach. *Land Economics*, 76(1), 100-113.

This study estimates the value of wetland amenities in the Portland, Oregon (U.S.) metropolitan area using the hedonic property price model. Residential housing and wetland data are used to relate the sales price of a property to structural characteristics, neighborhood attributes, and amenities of wetlands and other environmental characteristics.

Mathews, L. G., Homans, F.R., and Easter, K.W. (2002). Estimating the Benefits of Phosphorus Pollution Reductions: An application in the Minnesota River. *Journal of the American Water Resources* Association, 38(5), 1217-1223.

This paper provides research on the benefits of reducing phosphorus pollution so that policy decisions are able to make the comparison of costs and benefits that is essential for economic efficiency. This research attempts to provide an estimate of the benefits of a 40 percent reduction in phosphorus pollution in the Minnesota River (U.S.). A 1997 mail survey gathered information on Minnesota residents' use of a recreational site on the Minnesota River, the Minnesota Valley National Wildlife Refuge, and their willingness to pay for phosphorus reductions in the Minnesota River. The random effects probit model used in this research to investigate household willingness to pay for phosphorus pollution reductions in the Minnesota River incorporates recent innovations in nonmarket valuation methodology by using both revealed and stated preference data.

Mazzotta, M. J. (1996). *Measuring public values and priorities for natural resources: An application to the Peconic Estuary system*. ETD Collection for University of Rhode Island (dissertation).

A survey was administered to 968 residents of the area surrounding the Peconic Estuary in New York State (U.S.) to estimate the value of the regions' natural resources. The survey presented sets of hypothetical alternatives, described their effects on natural resources and the associated cost to the household. The alternatives included 'no new action', and two different programs to protect or enhance natural resources.

Mullen, J. K. and Menz, F.C. (1985). The Effect of Acidification Damages on the Economic Value of the Adirondack Fishery to New York Anglers. *American Journal of Agricultural Economics Association*, 67(1), 112-119.

The purpose of this study was to estimate the effect of acidification damages on the economic value of the recreational fishery in the Adirondack Mountain region of northern New York. A travel cost model was used with cross-sectional data to estimate angling demand and economic value of the fishery. Acidification damages were assumed to cause the loss of certain ponded water angling sites, leading to changes in site use and reducing the fishery's value to anglers.

Nellemann, C., Corcoran, E., Duarte, C.M., Valdés, L., De Young, C., Fonseca, L., Grimsditch, G. (Eds). (2009). *Blue Carbon. A Rapid Response Assessment*. United Nations Environment Programme (UNEP), GRID-Arendal, www.grida.no

This report explores the potential for mitigating the impacts of climate change by improved management and protection of marine ecosystems and especially the vegetated coastal habitat, or blue carbon sinks. Carbon burial rates are presented per hectare and globally, as reported ranges of mean rates of global carbon burial derived using different methods. The data is for vegetated coastal areas and their percentage contribution to carbon burial in the coastal and global ocean.

Newell, R. I. E., Fisher, T.R., Holyoke, R.R., and Cornwell, J.C. (2005). Influence of Eastern Oysters on Nitrogen and Phosphorus Regeneration in Chesapeake Bay, U.S. NATO Science Series: IV: *Earth and Environmental Sciences*, 47, 93-120.

This paper estimates the possible effects of stocks of subtidal eastern oysters on the watershed-level nitrogen and phosphorus budgets for the Choptank River, a tributary of Chesapeake Bay (U.S.). The authors develop an elementary "spread-sheet" model to assess the influence of eastern oysters on removal of N and P inputs to the Choptank River estuary, a mesohaline Maryland tributary to Chesapeake Bay. They estimated the monthly amount of P buried and N removed due to burial and coupled nitrification-denitrification resulting from the biodeposition activity of adult eastern oysters

Olewiler, N. (2004). *The Value of Natural Capital in Settled Areas of Canada.* Ducks Unlimited and Nature Conservancy of Canada.

This study estimates the value of waste treatment by wetlands, based upon the replacement cost method. The costs of removing phosphorus vary from $21.85 to $61.20 per kilogram at Vancouver's primary and secondary waste treatment plants, while costs for nitrogen vary from $3.04 to $8.50 per kilogram. The annual value of waste treatment of phosphorus and nitrogen produced by one hectare of the Fraser Valley's wetlands is estimated to be at least $452 and may be as high as $1,270.The annual nitrogen and phosphorus waste treatment benefits received from the existing 40,000 hectares of wetlands in the Lower Fraser Valley's wetlands could thus amount to between $18 million and $50 million per year.

Parsons, G. R. and Powell, M. (2001). Measuring the Cost of Beach Retreat. *Coastal Management*, 29, 91-103.

This study estimates the cost over the next 50 years of allowing Delaware's ocean beaches to retreat inland. Since most of the costs are expected to be land and capital loss, especially in housing, the focus is on measuring that value. A hedonic price regression is used to estimate the value of land and structures in the region using a data set on recent housing sales. Then, using historical rates of erosion along the coast and an inventory of all housing and commercial structures in the threatened coastal area, the authors predict the value of the land and capital loss assuming that beaches migrate inland at these historic rates. Then the losses of any amenity values due to proximity to the coast are purged, because these are merely transferred to properties further inland. These estimates are then compared to the current costs of nourishing beaches. The authors conclude that nourishment makes economic sense, at least over this time period.

Pate, J. and Loomis, J. (1997). The effect of distance on willingness to pay values: a case study of wetlands and salmon in California. *Ecological Economics*, 20(3), 199-207.

The overall goal of this study was to determine if distance affects willingness to pay for public goods with large non-use values. The data used came from a contingent valuation study regarding the San Joaquin Valley, CA. Respondents were asked about their willingness to pay (WTP) for three proposed programs designed to reduce various environmental problems in the Valley. A logit model was used to examine the effects of geographic distance on respondents' willingness to pay for each of the three programs. Results indicate that distance affected WTP for two of the three programs (wetlands habitat and wildlife, and the wildlife contamination control programs).

Piper, S. (1997). Regional Impacts and Benefits of Water-Based Activities: An Application in the Black Hills Region of South Dakota and Wyoming. *Impact Assessment*, 15, 335-359.

This study estimates the value of water-related recreation as part of a framework for evaluating water management scenarios in regions of South Dakota and Wyoming (U.S.). A national survey of fishing, hunting, and wildlife-associated recreation was used to estimate recreation expenditures.

Pompe, J. J. and Rinehart, J.R. (1995). Beach Quality and the Enhancement of Recreational Property-Values. *Journal of Leisure Research*, 27(2), 143-154.

This study uses the hedonic pricing technique to examine the contribution of beach quality, as measured by beach width, to property values in two South Carolina coastal towns. Using two separate models, the authors estimate the values of wider beaches to vacant lots and single homes, both with and without water footage. The willingness to pay for wider beaches is an indication of the size of the storm protection and recreational values produced by wider beaches.

Rein, F. A. (1999). An Economic Analysis of Vegetative Buffer Strip Implementation. Case Study: Elkhorn Slough, Monterey Bay, California. *Coastal Management*, 27(4), 377-390.

Vegetative buffer strips (VBS) are being proposed as a tool to protect water quality from nonpoint pollution nationwide, yet no studies have investigated the economics of implementing VBS. This study evaluates environmental costs and benefits of implementing VBS, both to the grower and to society as a whole, as a means of capturing nonmarket ecosystem values and informing decision making. Most values were determined by evaluating actual market prices gathered from the region or by the replacement-cost method, in which values are determined by comparison with the value of a marketed substitute.

Ribaudo, M. O., and Epp, D.J. (1984). The Importance of Sample Discrimination in Using the Travel Cost Method to Estimate the Benefits of Improved Water Quality. *Land Economics*, 60(4), 397-403.

An application of the travel cost method with emphasis on surveying current users and former users was made at St. Albans Bay in Vermont. Increased phosphorus loading in the bay has resulted in declines in recreational use. The authors estimated the value of improvements in water quality using a sample consisting of those who currently use the subject site despite the pollution problem and those who refuse to use the site under current conditions but may return if it were to become cleaner. They concluded that substantial benefits would be generated for both current users and nonusers if the bay's water quality were improved to a level matching local substitute sites.

Sanders, L. D., Walsh, R.G., and Loomis, J.B. (1990). Toward Empirical Estimation of the Total Value of Protecting Rivers. *Water Resources Research*, 26(7), 1345-1357.

This study estimates the value of rivers for recreation use, with the intent of assisting decision-makers with the larger problem of estimating how much they should pay for the protection of resources. The authors used the contingent valuation approach to determine the demand for rivers by both users and non-users. A sample of the residents of the Rocky Mountain region of Colorado (U.S.) were asked direct questions about the value of changes in the quantity or quality of the river.

Shafer, E. L., Carline, R., Guldin, R.W., and Cordell, H.K. (1993). Economic amenity values of wildlife: Six case studies in Pennsylvania. *Environmental Management*, 17(5), 669-682.

The travel cost method (TCM) and contingent valuation method (CVM) were used to evaluate the economic value of six different ecotourism activities involving observation of wildlife in Pennsylvania. The six activities were: catch-and-release trout fishing; catch-and-release trout fishing with fly-fishing equipment; viewing waterfowl; observing migration flights of raptors; and seeing live wildlife in an environmental education setting. TCM results provided significant statistical relationships between level of use and travel costs for the two types of trout fishing activities. CVM provided estimates of consumer surplus for the other four sites. The economic amenity values of the six activities compare favourably with similarly derived values in other studies for hunting, fishing, hiking, and backpacking in dispersed recreation environments and wilderness areas in western states.

Silberman, J., Gerlowski, D.A., and Williams, N.A. (1992). Estimating Existence Value for Users and Nonusers of New Jersey Beaches. *Land Economics*, 68(2), 225-236.

This study reports empirical evidence on existence value for beach nourishment. The focus is an analysis of respondents who intend to use the beach to be nourished and those who do not. Two contingent valuation method (CVM) surveys were designed to measure the existence value of beach nourishment from Sea Bright to Ocean Township, New Jersey. Large sections of this 12-mile stretch of beach experienced substantial erosion so that beach recreation is very limited. People using the beaches at sites in the vicinity of the beach nourishment were the respondents in the on-site survey. A telephone survey queried persons not using the New Jersey beaches.

Streiner, C. and Loomis, J. (1996). Estimating the Benefits of Urban Stream Restoration Using the Hedonic Price Method. *Rivers*, 5(4), 267-278.

This study used the hedonic price method to estimate the value of stream restoration measures such as reduced flood damage and improved fishing habitat. The authors examined California's Department of Water Resources Urban Stream Restoration Program. They extracted data on property transactions, property characteristics, and demographics from seven projects in three counties.

Tanguay, M., Adamowicz, W.L., Boxall, P., Phillips, W., and White, W. (1993). *A socio-economic evaluation of woodland caribou in northwestern Saskatchewan*. Department of Rural Economy, University of Alberta, Edmonton. Project Rep. No. 93-04

Timber harvesting in the Northwestern region of Saskatchewan Canada, has had a significant effect on the woodland caribou populations. This area has high public interest in maintaining endemic species populations; given the communities openness to participate a socio-economic study was proposed to examine this impact. This study includes the cost to maintain the caribou numbers. Using the economic methodology, contingent valuation, a number of surveys were developed to collect social and economic elements that influence the value given to wildlife in the area. Opportunity cost was then used to derive the foregone harvest volumes.

Taylor, L. O. and Smith, V.K. (2000). Environmental Amenities as a Source of Market Power. *Land Economics*, 76(4), 550-568.

Using estimates from hedonic-price equations and residual-demand models, this study recovers firm-specific estimates of price markups as measures of market power, and uses these markups to estimate the implied marginal value for access to coastal beaches. The application involves rental price and occupancy data for several thousand beach properties along a portion of the North Carolina coastline during the 1987 to 1992 rental seasons.

Thibodeau, F.R. and Ostro, B.D. (1981). An Economic Analysis of Wetland Protection. *Journal of Environmental Management*, 12, 19-30.

This paper quantifies some of the economic benefits of wetlands in the Charles River Basin in Massachusetts (U.S.). The benefits resulting from flood control, pollution reduction, water supply, and recreation were monetized. The value of flood control was estimated by the cost of property damage that would occur if the wetlands were filled. Pollution reduction was estimated by estimating the replacement cost of wastewater plants. Water supply value was calculated as the difference between the cost of wetland wells and the cost of providing water from the next best source. Lastly, recreational value was estimated using a mixture of travel cost and contingent valuation.

U.S. Department of the Army, Corps of Engineers, New England Division. *Charles River Massachusetts, Main Report and Attachments*. Waltham, Massachusetts, 1971.

In this study the economic valuation method used to assign a dollar amount per wetland for this flood control function is based upon the amount of flood damage avoided when the wetland is left intact. Benefits are estimated as the difference between annual losses under present land use conditions and those associated with the projected 1990 loss of 30 per cent of valley storage. The loss of valley storage is based on hydrographic analysis to determine the effect of shrinking natural valley storage on flood flows.

Ward, F. A., Roach, B.A., and Henderson, J.E. (1996). The Economic Value of Water in Recreation: Evidence from the California Drought. *Water Resources Research*, 32(4), 1075-1081.

The question of how recreational values change with reservoir levels change is explored in this study. Reservoir visitor data from Sacramento, California (U.S.) during the 1985-1991 drought was analyzed to isolate water's effect on visits from price and other effects.

Whitehead, J. C. (1990). Measuring Willingness-to-Pay for Wetlands Preservation with the Contingent Valuation Method. *Wetlands*, 10, 187-201.

Preservation of bottomland hardwood forest wetlands is threatened by pressure from surface coal mining activities in the western Kentucky coalfield. The contingent valuation survey method was used to measure the economic benefits (willingness-to-pay) of preserving the Clear Creek wetland, the largest wetland area in the coalfield, from surface coal mining. Results indicated that Kentucky households are willing to pay in the form of voluntary contributions to a hypothetical "Wetland Preservation Fund," for preservation. Mine reclamation was used as a substitute for preservation of the recreational use of wetlands by survey respondents, conservation club membership, and age are determinants of willingness-to-pay.

Whitehead, J. C., Hoban, T.L., and Clifford, W.B. (1997). Economic analysis of an estuarine quality improvement program: The Albemarle-Pamlico system. *Coastal Management*, 25(1), 43-57.

This article presents an economic efficiency analysis of a proposed management plan for the Albemarie-Pamlico Estuary in North Carolina (U.S.). A survey was used to estimate benefits of estuary quality improvements. Respondents were asked if their household would pay higher taxes to control pollution, monitor water quality, protect habitat, and educate people. The authors concluded that the management plan would be an efficient government program if the negative externalities associated with the economic growth of the region are controlled.

Whitehead, J. C., Groothuis, P.A., Southwick, R., and Foster-Turley, P. (2009). Measuring the Economic Benefits of Saginaw Bay Coastal Marsh with Revealed and Stated Preference Methods. *Journal of Great Lakes Research*, 35(3), 430-437.

This study used both the travel cost method and contingent valuation method to value the Saginaw Bay coastal marsh in Michigan (U.S.). While the travel cost approach measured actual recreation expenses, the contingent valuation method asked a random sample of Michigan hunting and fishing license holders hypothetical survey questions. The authors found the two methods yielded complementary results.

Wilson, S. J. (2008). *Ontario's wealth, Canada's future: Appreciating the value of the Greenbelt's eco-services*. Prepared for the David Suzuki Foundation. 70 pp.

HABITAT (WETLAND AND FOREST): The annual value for wetland habitat services is based on the average annualized wetland habitat restoration costs for a group of relevant Great Lakes Sustainability Fund projects. The annualized value of restoring habitat represents the value of wetland habitat in terms of the avoided cost of damages to habitat.

Wilson, S. J. (2010). *Natural Capital in BC's Lower Mainland: Valuing the Benefits from Nature*. Prepared for the David Suzuki Foundation. 67 pp.

WATER SUPPLY (FOREST AND WETLAND): This study used the results from the Ernst et al. (2007) study to interpret the value of water filtration services by forests and wetlands in the study area's watersheds. The economic value for the benefit of water filtration was based on the potential increase in water treatment costs if the current forest/wetland cover declined from its current average cover. Thus, the value is based on the additional cost for water treatment if the current natural cover declined.

AIR REGULATION (FOREST): CITYgreen software was used to assess the amount of air pollutants removed by the tree canopy cover across the study area. CITYgreen calculates the value of air cleansing by trees using average removal rates of carbon monoxide, nitrogen dioxide, particulate matter and sulphur dioxide by trees. CITYgreen calculates the dollar value, externality costs (i.e., indirect costs borne by society such as rising health care expenditures and reduced tourism revenue) as reported by the United States Public Services Commission. An average of each state in the U.S. is used and converted to Canadian dollars.

CLIMATE STORAGE (FOREST): This study took the average of two values to estimate carbon storage. The amount of carbon stored is estimated based on the value of avoided costs of carbon emitted to the atmosphere, as given by the IPCC. The two recent studies have reviewed the site data study results in the North America Pacific Northwest region. The first study found that mature cool temperate forests in the region contain an average of 642 tonnes of carbon per hectare. The second study reports a mean total ecosystem carbon content of 487 tonnes per hectare in the Pacific Maritime ecozone. Both studies were based on site studies and provide recent data for the region.

CLIMATE SEQUESTRATION (FOREST): The annual uptake of carbon was calculated using CITYgreen software. CITYgreen's carbon module quantifies the removal of carbon dioxide by trees based on the estimated age distribution by assigning three age distribution types. Each type is associated with a multiplier, which is combined with the overall area of the site's canopy to estimate how much carbon is removed.

DISTURBANCE REGULATION (FOREST): The economic value of water regulation by forests is calculated as a replacement value using CITYgreen software. Analysis of the study area's total forest cover was assessed in terms of the replacement construction costs for water runoff control if the current forest cover was removed and converted for urban land use.

Waste treatment (wetlands): The low end of the amounts of nitrogen and phosphorus that wetlands can remove are used to estimate a wetland's capacity to treat waste. The costs of removing N & P by waste treatment plants were transferred from the Olewiler (2004) study. The respective average replacement costs can be used as a proxy for the value of wetland waste treatment services.

AESTHETIC AND RECREATION (FOREST): The value of recreation is based on a 1996 national survey that estimates the economic impact of nature-based recreation and the willingness to pay for nature-based activities. The expenditures reported for B.C. residents were used in this report. Specifically, Wilson assumed that all recreational activities were associated with the province's forested lands that cover almost 50 per cent of the land base. Given this assumption, the value of nature-based recreation can be estimated at $48 per hectare of forest per year.

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This report, the tenth in a series that studies natural capital and ecosystem services in Canada's major urban centres, assesses the value of benefits provided by the coastal shore environment to the 2.5 million residents of British Columbia's Lower Mainland. It identifies water/land cover types and quantifies the non-market value of the services provided by the aquatic ecosystems of the Strait of Georgia and the main watersheds that drain into it.

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