3. What is an Ecosystem Worth?

The Value of Nature and the Nature of Value

In the language of economics, the world's ecosystems are capital assets. If properly managed, they yield a flow of vital services, including the production of goods (such as seafood and timber), life support processes (such as pollination and water purification), and life-fulfilling conditions (such as beauty and serenity, Daily et al. 2000).

The Salish Sea is home to a remarkable assemblage of species living in habitats from the headwaters of salmon rivers to the depths of the inland sea. Many of these mammals, fish and birds migrate to places that link the Salish Sea with the entire Pacific region. Their interactions form what we see, hear, and feel when paddling, birding, working in, or simply being grateful for, our marine surroundings.

On a more tangible level, this tapestry between species and their environment provides humans with innumerable benefits, like clean water to drink, flood protection, seafood to eat, whales to watch, and even the air we breathe. Unfortunately, a growing human population has placed stress, sometimes to the breaking point, on the many species and the underlying processes that are integral to the Salish Sea.

As much as humans are an inseparable part of the natural world, human well-being ultimately depends on the connection between non-human creatures and their habitat (Chivian and Bernstein 2008). Much of this connectivity between plants, animals, and human well-being is encapsulated in the concept of ecosystem services, or nature's benefits. However, what do these terms mean, and what does the use of the term imply?

Ecosystem Services

Ecosystem services are the benefits humans derive from the workings of the natural world, such as clean air, pollination, climate regulation, and recreational and tourism opportunities. We take almost all of them for granted, but they are crucial for our survival, and to the social and economic development of societies.

Throughout human history, and certainly before terms like 'ecosystem services' existed, people have understood that their

What is an ecosystem? There is no single definition.

At its simplest level, an ecosystem is a community of plants and animals—from the largest whales to the smallest microorganisms—and the non-living environment with which they interact (e.g. carbon, oxygen, sand, or sun).

An ecosystem is characterized by its collection of species, the physical environment in which these species live, and the sum total of their interactions—with each other and with their shared environment (Chivian and Bernstein 2008).

An ecosystem is the set of organisms (including humans) living in an area, their physical environment, and the interaction among them (Daily 1997).

well-being is linked to the functioning of the world around them (Brauman et al. 2007). For some people, this relationship is core to their identity and being, but for others their personal connection is not as strong.

Historically, the commodification of the earth's products—from metals to plants and animals—has been the primary lens through which the planet's amenities have been regarded. The flaw in this standard economic approach is that it overlooks and fails to consider the processes that create the products. In an effort to use established monetary language and accounting procedures, a dollar value has been placed on the uncredited processes that created those products. This 'ecosystem services' approach captures 'services' that the natural world provides, including the wide range of conditions, processes and species, that help sustain and fulfill human life. The concept strives to place value on nature, as seen by humans (Daily 1997). Although monetary valuation is most common, recent efforts are trying to understand ecosystem services through economic valuation techniques that are non-monetary (Shroter et al. 2014).

There is no single accepted definition of ecosystem services or agreed upon methods for classifying the components. All of the definitions in Table 3.1 fall under the widely accepted approach that ecosystems or natural processes serve humanity. Within these broad definitions, ecosystem services are commonly divided into categories, either by functional grouping or otherwise. These typically fall under the following types of descriptions:

- Provisioning (material goods, like food or metals, produced by ecosystems)
- Regulating (climate regulation, flood control, water purification)
- Supporting (nutrient cycling, primary production, and soil formation)
- Cultural (recreation, spiritual, religious, heritage, etc.).

Although food and materials are obvious (provisioning), the vast array of services that provide benefits like clean air and water are crucial to human well-being. Supporting ecosystem services make these benefits possible. Cultural services enrich lives by creating a sense of place and world for discovery (Figure 3.1). Taken together, the complexity and connectivity between the natural world and humans is astounding—and profoundly essential.

What Contributes to an 'Ecosystem Service'?

The definitions of ecosystem services convey the connections between nature and humans. When adding human inputs, such as labour or capital into the equation, the service ceases to be just ecological (Boyd and Banzhaf 2007). In 2003, the Millennium Ecosystem Assessment provided a framework for people and institutions to value natural systems on a global scale.

"We need them to survive, but they don't need us at all" E.O. Wilson, eminent scientist and father of the modern concept of biodiversity. Although made in reference to ants, the same could be said when referring to any of the vast number of natural inhabitants of the Salish Sea, whether marine mammal, fish, plants, plankton, insects, fungi, or bacteria.

Number	Definition	Reference
1	Ecosystem services are the benefits people obtain from ecosystems	MEA 2005
2	Ecosystem services are the conditions and processes through which natural ecosystems—and the species that live in them—sustain and fulfill human life.	Daily 1997
3	Final ecosystem services are components of nature, directly enjoyed, consumed, or used to yield human well being (Boyd and Banzhaf 2007).	Boyd and Banzhaf 2007

Table 3.1 A range of definitions used to describe ecosystem services.

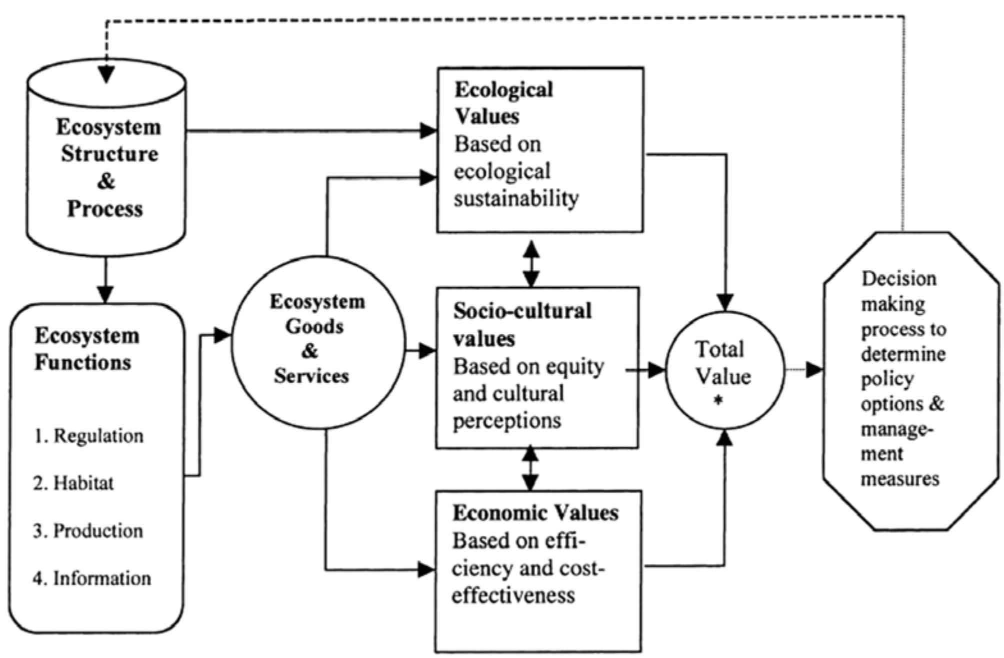


Figure 3.1: A simple framework to assess and value ecosystem functions, goods, and benefits for use in decision-making (de Groot et al. 2002).

Ecosystem Functions	Ecosystem process and components	Ecosystem service
Regulatory functions		
Gas regulation	Role of ecosystems in biogeochemical processes	Ultraviolet-B protection Maintenance of air quality Influence of climate
Climate regulation	Influence of land cover and biologically mediated processes	Maintenance of temperature, precipitation
Disturbance prevention	Influence of system structure on dampening environmental disturbance	Storm protection Flood mitigation
Water regulation	Role of land cover in regulating run-off, river discharge and infiltration	Drainage and natural irrigation Flood mitigation Groundwater recharge
Soil retention	Role of vegetation root matrix and soil biota in soil structure	Maintenance of arable land Prevention of damage from erosion and siltation
Soil formation	Weathering of rock and organic matter accumulation	Maintenance of productivity on arable land
Nutrient regulation	Role of biota in storage and recycling of nutrients	Maintenance of productive ecosystems
Waste treatment	Removal or breakdown of nutrients and compounds	Pollution control and detoxification
Habitat functions		
Niche and refuge	Suitable living space for wild plants and animals	Maintenance of biodiversity Maintenance of beneficial species
Nursery and breeding	Suitable reproductive habitat and nursery grounds	Maintenance of biodiversity Maintenance of beneficial species

Table 3.2 Examples of regulatory and habitat functions, processes, components, and the benefits they create. Source: Barbier 2007, adapted from Heal et al. 2005 and De Groot et al. 2002.

Class of Ecosystem Service	Intermediate Processes	Final Ecosystem Service	Benefit
Provisioning	Water quality, primary and secondary production, availability and quality of rearing habitats	Pacific Salmon	Salmon fishery
Cultural	Chinook salmon abundance	Killer Whales	Whale watching
Recreational	Water quality, air quality, flora and fauna	Water and aesthetics	Sea Kayaking
Cultural	Insects, fish for prey, water quality, forest canopy, nesting sites, etc.	Birds	Bird Watching

Table 3.3 Examples of final ecosystem services and the intermediate processes that lead to common benefits in the Salish Sea.

Resilience

Resilience is the tendency of an ecosystem to retain its functional and organizational structure after a disturbance. The loss of species and genetic diversity decreases the resilience of ecosystems and their ability to maintain particular services, especially as global climate and environmental conditions change (MEA 2005).

In an effort to develop standardized accounting, ecological processes are broken into two broad groups; intermediate and final services. This resulted in a set of guidelines that distinguish services, benefits and intermediate process (Table 3.3). Intermediate processes are defined as the bio-geo-chemical physical steps that result in an ecosystem service, and then the benefits to humans from that service (Mace et al. 2011).

In the case of fish for example, intermediate processes could include primary production of plankton, secondary production of zooplankton, water slowed and filtered by wetlands and sponge reefs, erosion of riverbanks, and foreshores that create spawning grounds. The final ecosystem service (i.e. fish) then provides benefits to humans—a fishery (Table 3.2). Final ecosystem services are components of nature that can be directly enjoyed, consumed, or used to yield human well-being. Benefits are the human values derived from the service, be they economic, social, or cultural.

The Value of Nature

Regardless of the particular definition, cost-benefit analysis is an important premise of ecosystem services. Although valuing nature's worth within an economic framework has its limitations (Gatto and Leo 2000; Ludwig 2000, also see text box), a context is provided within which humans can quantify results of nature's complex processes and functions.

For example, in 1997 global ecosystem services or benefits were estimated to be worth US$16-54 trillion per year—about double the global Gross Domestic Product in 1997—with marine and freshwater values exceeding terrestrial (Costanza et al. 1997). This was considered a gross underestimate because it was based on estimations of aggregated 'total economic value', an approach that is inconsistent with the marginal approach that underpins economic cost-benefit analysis (White et al. 2010). A recent update to this estimation increased the value to approximately $135 trillion annually (Costanza et al. 2014), a figure still considered a minimum estimate, but one that

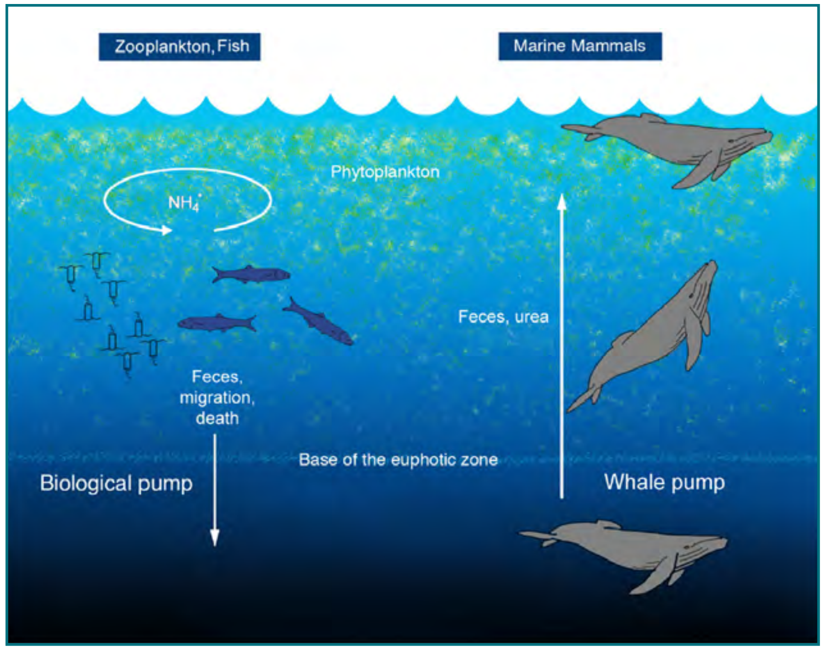


Figure 3.2: The role of species in ocean nutrient cycling. In the ocean's biological pump, nutrients are moved from the ocean surface to the bottom, and back up, by different animals. At the bottom of the food chain, zooplankton feed in surface waters but their faecal material sinks to the bottom. Fish typically release nutrients at the same depth at which they feed. In contrast, marine mammals feed at deep depths, but excrete at the surface, thus returning nutrients back to surface waters. Source: Roman and McCarthy 2010.

Whales—The Ocean's Gardeners

Commercial whaling, which continued up until several decades ago, devastated the world's large whales. While tragic in itself, no one anticipated that the loss of whales would have such a ripple effect throughout the world's oceans. It turns out that whales concentrate and redistribute iron. By doing so, they act like giant marine pumps for fertilizing the oceans, kick starting food webs, building fish populations, and even taking huge amounts of CO_2 out of the atmosphere.

How does it work?

Whales eat massive quantities of iron-rich food like krill and squid. They consume food at deep depths, but they digest and carry the waste to waters at the surface. When they excrete waste, the iron concentration in whale faeces is calculated to be up to 10 million times that of Antarctic seawater (Nicol et al. 2010).

Unlocking this mystery explains how the Southern oceans were able to support so many whales—numbers that whaling records implied, but scientists thought impossible. When excreting faeces at the surface, the whales fuelled the plankton blooms that resulted in more krill. More krill results in more food for whales, fish and the entire food web (Roman and McCarthy 2010).

The ecosystem services and benefits that the whales provide have only recently become well-known and appreciated. They range from enhancement of primary productivity to rebuilding fisheries, to climate regulation, tourism, and conservation (Roman and McCarthy 2010, Roman et al. 2014). Further, the increased amount of blooming plankton removes tens of thousands of tonnes of carbon from the atmosphere. Scientists now believe the ability of the Southern Ocean to act as a carbon sink was diminished by mass removal of whales during industrial whaling (Lavery et al. 2010).

captured a deeper understanding of ecosystem value. Despite the relative uncertainty in these values, it is unequivocal that nature's benefits carry enormous economic and societal value measurable in dollars.

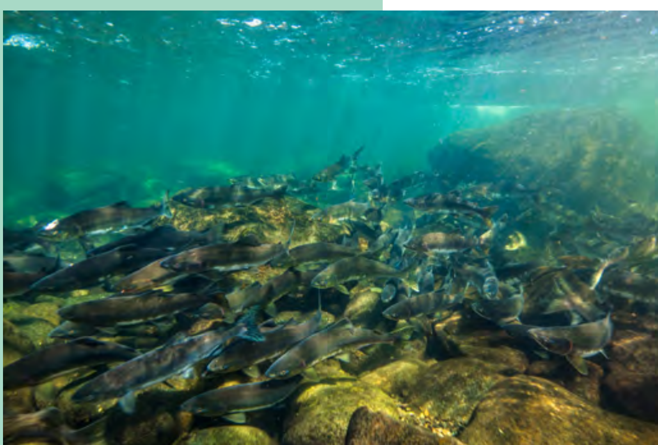
A more important question might be how much of this value translates to actual market prices, for example, seafood. A review of case studies suggests very little, and underscores the fact that exploitation of ecosystems will come at the expense of the poor and our grandchildren (de Groot et al. 2012). The irony is that economic health in the long term depends on the integrity and resilience of the natural ecosystems within which the economy is embedded (Gomez-Baggethun and de Groot 2010). Standard economic theory neglects this—and the cost is our unfolding ecological crisis.

The tapestry of life

Evidence is compelling that the degradation of the Earth's biodiversity is beginning to threaten the fulfillment of basic needs and potentially the aspirations of humanity as a whole (Diaz et al. 2006).

The Benefits of Biodiversity

Biological diversity is the variety of life on earth. The pressures of a rapidly growing human population, however, mean that biodiversity is now declining 1,000 times faster than at rates in



Already, climate change is being implicated in loss of global and regional biodiversity. For example, in the Salish Sea temperature shifts on intertidal rocks have meant increased predation on mussels by sea stars, a 50% reduction in their vertical distribution, and a complete loss of reproduction at some sites (Harley 2011).

Changing ocean conditions, habitat loss, and fishing, along with other pressures, are likely factors in the decline of Chinook and coho salmon populations in the Salish Sea (PSF 2014). Ongoing urbanization, increased destruction of natural shorelines, and increasing marine pollution, all of which are unfolding around Georgia Strait, will further exacerbate declines in salmon.

the fossil record (MEA 2005). This decline is occurring on land and in the oceans (Worm et al. 2006). Studies linking biodiversity with ecosystem benefits show clear trends that biodiversity underpins ecological goods and benefits (Diaz et al. 2006, Mace et al. 2012). Rates of resource collapse also increase with declining biodiversity (Worm et al. 2006). Conversely, retaining biodiversity has positive effects on the vast majority of ecosystem services and benefits (Balvanera et al. 2006, Harrison et al. 2014).

What is Biodiversity?

Biological diversity is the term used to describe the variety of life on Earth. This variety includes the genes found in all living things, as well as variation in species and the ecosystems these species comprise.

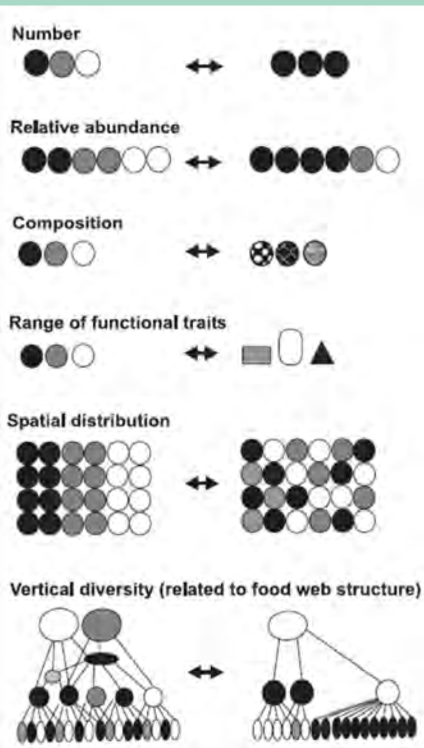


Figure 3.3: The different components of biodiversity (Diaz et al. 2006). Ecosystem components can be affected by human actions (arrows). These in turn have repercussions for ecosystem properties and services. Symbols represent individuals or biomass units. Symbols of different shades represent different genotypes, phenotypes, or species.

Ecosystem Values in the Salish Sea

The physical oceanography of the Salish Sea, including the basins, archipelago of islands, and the estuary circulation of the Fraser River, combine to create highly productive marine waters. The result is an impressive diversity of animal life, and a coast that has attracted more than 7 million residents to its shores. As an exercise in quantifying ecosystem benefits, the value of land (Wilson 2010) and aquatic services in BC's lower mainland (including Georgia Strait) (Molnar et al. 2012), and in Puget Sound (Batker et al. 2010), were assessed through an economic lens.

In BC's lower mainland (Figure 3.4), aquatic near-shore services such as flood protection, water supply, and critical habitat for fish and other animals are estimated to provide between $30 and $60 billion in benefits each year (Molnar et al. 2012). Land-based services such as climate regulation, water filtration, clean air, waste treatment, and water supply are estimated to provide $5.4 billion in benefits each year (Wilson 2010).

In Puget Sound, valuing 14 goods, services and benefits including climate regulation, pollination, water supply and treatment, nutrient cycling, and recreation, amongst others, shows between $10 and $80 billion are provided each year in benefits. Counting these as economic assets results in billions of dollars worth of 'natural capital'. When considering that only some of the known services were valued, uncertainty in the appraisal, issues with methods, and the omission of nature's intrinsic, aesthetic, cultural or irreplaceable merits, these values are undoubtedly underestimates. As context, the GDP of BC and Washington combined was about $630 billion in 2012.

The Coast at Risk: Estuaries and Coastal Habitats

Coastal habitats are some of the most intensively used and threatened natural systems on the planet (Lotze et al. 2006, Worm et al. 2006, Halpern et al. 2008). Estuarine and coastal areas face unprecedented pressures. Driven by increasing numbers of people who want to live near water, the loss of natural shorelines, increasing toxic contamination, and overharvesting of resources are all

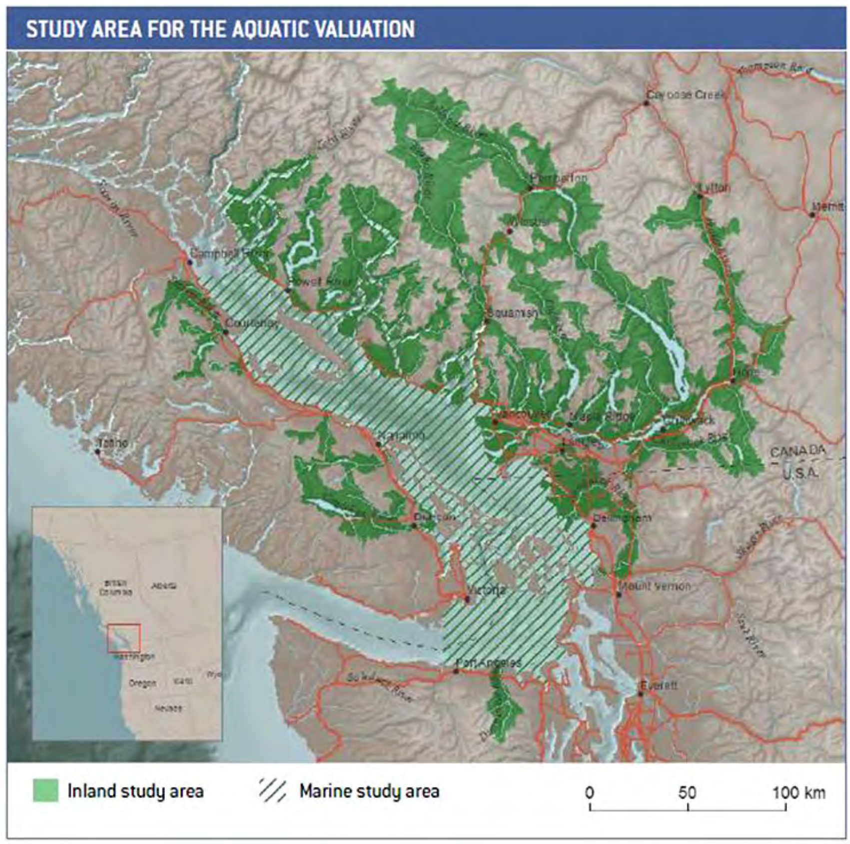


Figure 3.4 Map of the aquatic services study area within BC's lower mainland and Puget Sound. Source Molnar et al. 2012.

The Salish Sea—An Inland Sea

As an inland sea, the Salish Sea by definition lies on the continental shelf. Continental shelves are places of key ecological importance: although they cover less than 8% of the global ocean by area (Menard and Smith 1966), they contribute 69% of the global fish catch [89% if upwelling zones are included (Pauly and Christensen 1995)]. Continental shelves support high biodiversity including large populations of marine mammals (Keiper et al. 2005) and seabirds (Acha et al. 2004). In the Salish Sea, this translates to more than 200 species of fish, including five species of wild salmon, more than 3,000 invertebrate species, over 170 different seabirds and shorebirds (Gaydos and Pearson 2011) and 500 species of marine plants (Molnar et. al. 2012).

examples of activities fuelling coastal habitat destruction and the loss of species locally and globally (Gaydos et al. 2008).

This declining ecological health is affecting the benefits these areas can provide, such as viable fisheries, nursery habitats of future fish populations, filtering and detoxification processes, coastal protection, and erosion control (Worm et al. 2006, Barbier et al. 2011).

The Fraser River estuary and major rivers draining into Puget Sound are similarly affected. Massive port expansions placed on deltas of critical fish and wildlife habitat, increasing shipments of dangerous goods, marina expansions, urbanization and growing impervious surfaces, acoustic disturbance, alteration to natural water flow patterns, increased sedimentation, and frequent small oil spills are some of the threats facing the Fraser delta.

The true cost of loss. "Often the importance of ecosystem services is widely appreciated only upon their loss" (Daily et al. 2000).

Priceless and Irreplaceable

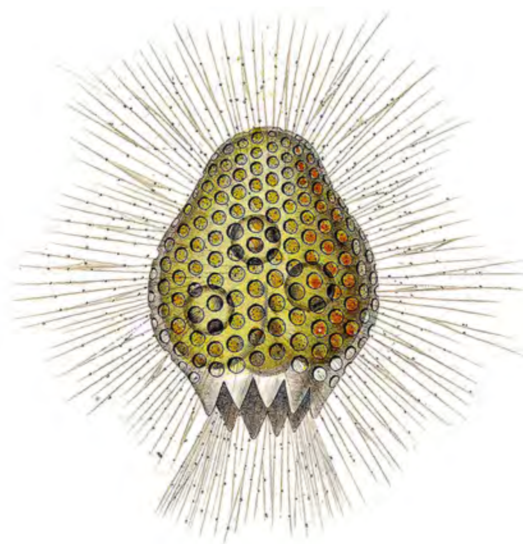
Ecological goods and services are the benefits arising from the ecological functions and processes of healthy ecosystems. Such benefits accrue to all living organisms, including animals and plants. Increasingly, there is recognition that ecological goods and services provide people with essential health, social, cultural, and economic needs. Many proponents of this perspective endeavour to categorize, measure, and value these benefits, thereby providing people with personal and often financial reasons to protect the planet's ecosystems and support conservation. In addition, assigning monetary value to natural capital such as biodiversity and ecosystem services is often viewed as a key process in influencing economic practices, policy, and decision-making.

Pragmatic and compelling, this human centric approach to conservation shares with traditional economics the assumptions that people are unfailingly rational, and market and life style choices are rooted largely in rational self-interest. In theory, reasonable self-interest maximizes benefits, minimizes costs, and is virtuously self-correcting because the consequences of one's conduct are the ultimate basis for any judgment about the rightness or wrongness of that conduct.

Although ecosystem service based conservation has proven popular, representing 'nature' primarily as a support system for humans is controversial. Critics contend that it fails to address the underlying problems with mainstream economics, growth, market capitalism, and monetary valuation of the environment. Some maintain that the underlying principles are inherently false and ultimately can be harmful to the environment because arguments for the financial value of conservation can unintentionally convince people that conservation should not be pursued when there is no financial value. Accordingly, there is a clear need to create a more meaningful relationship with nature and the non-human world than evident in the instrumentalism of shallow ecology[1].

Although classifying and commodifying 'nature' as a support system for humans does not rectify our current disconnection with the natural world, it might improve our awareness of the cycles, processes, and the interconnectedness of nature's systems. If this leads to full accounting of the costs associated with environmental damage and the benefits associated with ecological protection, ecosystems may benefit in the end. The merits, unfortunately, will only be evident in retrospect.

Raincoast believes that our connection with the natural world is not properly comprehended as a monetary and self-interested relationship. Notably, however, ecosystem service based conservation does not need to replace or conflict with this conviction. Appropriately understood and applied, it can complement the widely held moral perspective that the natural world is priceless, irreplaceable, and inherently valuable.



Small in stature, but large in scale.
Microbes provide ecosystem services that are immensely important to society. They carry out most of the biogeochemical processes, regulate climate, water quality, and atmospheric composition, and perform about half of the planet's total primary production (Duckow 2008).

The Unsung Heroes

For many people, identifying value in animals like whales and bears is understandable. Conveying the value of a coastal marsh or sub-tidal eelgrass bed however, is more difficult, even though these habitats perform functions that animals and humans alike require (Table 3.4).

Sea grasses are a case in point. As with many coastal habitats, eelgrass and other sea grasses are threatened by rapidly expanding

1 The defining feature of shallow ecology is the view that nature has instrumental value. In other words, nature is valuable as a means to an end.

Functions	Ecosystem Processes & Components	Goods and Services (examples)
Regulation Functions	*Maintenance of essential ecological processes and life support systems*	
1 Gas regulation	Role of ecosystems in bio-geochemical cycles (e.g. CO_2/02 balance, ozone layer, etc.)	1.1 UVb-protection by 0_3 (preventing disease) 1.2 Maintenance of (good) air quality 1.3 Influence on climate (see also function 2)
2 Climate regulation	Influence of land cover and biol. mediated processes (e.g. DMS-production) on climate	Maintenance of a favorable climate (temp., precipitation, etc) for example, human habitation, health, cultivation
3 Disturbance prevention	Influence of ecosystem structure on dampening env. disturbances	3.1 Storm protection (e.g. by coral reefs) 3.2 Rood prevention (e.g. by wetlands and forests)
4 Water regulation	Role of land cover in regulating runoff & river discharge	4.1 Drainage and natural irrigation 4.2 Medium for transport
5 Water supply	Filtering, retention and storage of fresh water (e.g. in aquifers)	Provision of water for consumptive use (e.g.drinking, irrigation and industrial use)
6 Soil retention	Role of vegetation root matrix and soil biota in soil retention	6.1 Maintenance of arable land 6.2 Prevention of damage from erosion/siltation
7 Soil formation	Weathering of rock, accumulation of organic matter	7.1 Maintenance of productivity on arable land 7.2 Maintenance of natural productive soils
8 Nutrient regulation	Role of biota in storage and re-cycling of nutrients (eg. N,P&S)	Maintenance of healthy soils and productive ecosystems
9 Waste treatment	Role of vegetation & biota in removal or breakdown of xenic nutrients and compounds	9.1 Pollution control/detoxification 9.2 Filtering of dust particles 9.3 Abatement of noise pollution
10 Pollination	Role of biota in movement of floral gametes	10.1 Pollination of wild plant species 10.2 Pollination of crops
11 Biological control	Population control through trophic-dynamic relations	11.1 Control of pests and diseases 11.2 Reduction of herbivory (crop damage)
Habitat Functions	*Providing habitat (suitable living space) for wild plant and animal species*	Maintenance of biological & genetic diversity (and thus the basis for most other functions)
12 Refugium function	Suitable living space for wild plants and animals	Maintenance of commercially harvested species
13 Nursery function	Suitable reproduction habitat	13.1 Hunting, gathering of fish, game, fruits, etc. 13.2 Small-scale subsistence farming & aquaculture
Production Functions	*Provision of natural resources*	
14 Food	Conversion of solar energy into edible plants and animals	14.1 Building & Manufacturing (e.g. lumber, skins) 14.2 Fuel and energy (e.g. fuel wood, organic matter) 14.3 Fodder and fertilizer (e.g. krill, leaves. litter)
15 Raw materials	Conversion of solar energy into biomass for human construction and other uses	15.1 Improve crop resistance to pathogens & pests 15.2 Other applications (e.g. health care)
16 Genetic resources	Genetic material and evolution in wild plants and animals	16.1 Drugs and pharmaceuticals 16.2 Chemical models & tools 16.3 Test- and essay organisms
17 Medicinal resources	Variety in (bio)chemical substances in, and other medicinal uses of, natural biota	Resources for fashion, handicraft, jewelry, pets, worship, decoration & souvenirs (e.g. furs, feathers, ivory, orchids, butterflies, aquarium fish, shells, etc.)
18 Ornamental resources	Variety of biota in natural ecosystems with (potential) ornamental use	
Information Functions	*Providing opportunities for cognitive development*	
19 Aesthetic information	Attractive landscape features	Enjoyment of scenery (scenic roads, housing, etc.)
20 Recreation	Variety in landscapes with (potential) recreational uses	Travel to natural ecosystems for eco-tourism, outdoor sports, etc.
21 Cultural and artistic information	Variety in natural features with cultural and artistic value	Use of nature as motive in books, film, painting, folklore, national symbols, architecture, advertising, etc.
22 Spiritual and historic information	Variety in natural features with spiritual and historic value	Use of nature for religious or historic purposes (i.e. heritage value of natural ecosystems and features)
23 Science and education	Variety in nature with scientific and educational value	Use of natural systems for school excursions, etc. Use of nature for scientific research

Table 3.4: Some examples of the functions, goods and services of natural and semi-natural ecosystems.

human populations and associated habitat degradation. Although not restricted to eelgrass, an estimated 18% of coastal marine and nearshore wildlife habitat in the Salish Sea had been destroyed by 1994 (Wright et al. 2012). Yet, eelgrass habitats perform key functions such as nutrient cycling, sediment stabilization, enhancement of biodiversity, and important gas exchanges (Orth et al. 2006). With the rapid declines in global and local eelgrass distribution, the benefits and ecological roles they play will only decline with them. A much greater effort is required for their protection by individuals, provincial/state governments, and federal laws.

Economic evaluation of ecosystem services strives to place a dollar value on the natural world. Although this approach does not capture the connection many people feel with the world around them, it does recognize nature's contribution to human well-being.

Although the economic value of ecosystem services to human well-being can be quantified and measured (Butler and Oluoch-Kosura 2006, Costanza et al. 1997, Daily 1997, de Groot et al. 2002, Harrison et al. 2010); this does not recognize nature's intrinsic worth or the essence of our personal connection to the natural world.

PHOTO: B. HARVEY