The Economics of Ecosystem Services and Biodiversity in Ontario (TEEBO)

A 2018 update with new knowledge and considerations

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Key Messages

- Biodiverse ecosystems supply goods and services that support human wellbeing.
- Many professions and sectors of the marketplace are taking an interest.

- Market prices tend to fail to reflect the economic value of natural capital.
- Non-market values are needed to understand the economic scarcity of nature.

- Land-use decisions can be more effective with non-market values.
- Non-market values can inform Balance Sheets and Economic Accounts.
- Economic Instruments can internalize non-market considerations.

- Information exists about ecosystem services in Ontario.
- Some policies and practices in Ontario are internalizing these considerations.

Key Concepts

Wellbeing is an aspirational goal that reflects various components of health, material standards of living, social connections and relationships, and the minimization of insecurity. The pursuit of wellbeing requires benefits from nature while also affecting the capacity of nature to provide benefits to humans.

Ecosystem goods are the products from ecosystems that humans use for food and fuel and as building materials. These goods are usually bought and sold in markets for a price, so they can be classified as commodities. Their price reflects their scarcity in the marketplace.

Ecosystem services are the unpriced benefits that flow from nature to humans. These services are unpriced because they are not exchanged in markets as commodities. Examples include the decomposition of and detoxification of human wastes, the dissipation of energy in stormwater surges, the recycling of nutrients, the attenuation of noise pollution, and the rejuvenation of mental health.

Natural capital describes ecosystems that provide ecosystem goods and ecosystem services. Applying the economic concept of capital to ecosystems reinforces the message that humans should conserve ecosystems so that they can provide benefits in the future.

Non-market values measure the economic importance of unpriced ecosystem services.

Economic value reflects the sum of **market value** and **non-market values**.

Executive Summary

This report aims to inform Ontarians about key economic issues involving ecosystem services and biodiversity in Ontario. These are considered together because their economic issues are similar. This follows the practice of the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES), of which Canada is a member.

Ecosystem services are the benefits that flow from nature to humans, including the decomposition of and detoxification of human wastes, the dissipation of energy in stormwater surges, the recycling of nutrients, the attenuation of noise pollution, and the rejuvenation of mental health. Biodiversity is the variability of life, such as genetic diversity, species diversity, and diversity within ecosystems. Ecosystem services and biodiversity are economically valuable because they supply scarce benefits that humans demand. These scarce benefits are unpriced, because they are not bought and sold as commodities. These unpriced benefits need to be protected because unregulated competitive marketplaces will tend to use them up.

Many professions and sectors of the marketplace are taking an interest in this subject. Businesses and investors are improving the ways that they measure and manage their interactions with ecosystems, with the aid of accounting professionals. Professional planners, engineers, and infrastructure specialists are improving their conservation of biodiversity and ecosystems, and the use of green infrastructure. Public health professionals are discovering how human health is dependent upon the health of biodiverse ecosystems. Ecological economists and other economists are working to recalibrate economic signals and policies for the sustenance of life on Earth.

Market prices fail to reflect the full economic value of nature. A solution is for economists to generate non-market values, using specific valuation techniques that quantify the importance of changes in biodiversity and ecosystem services. The resulting information helps to make land-use decisions more effective, balance sheets more complete, and economic accounts more comprehensive. All of this enhances efficiency and sustainability, especially when used with economic instruments. Economic instruments aim to more closely align economic self-interest with shared interests in the conservation of biodiversity and ecosystem services. Several instruments are available, including ones that affect information, prices, quantities, and legal liabilities, and behaviour.

Fortunately non-market values and economic instruments are increasingly prevalent in Ontario. This is helping several policies and practices that mandate their consideration.

1. Introduction

Biodiversity in Ontario is the portfolio of at least 30,000 species and their genetic information, living within a variety of ecosystems (Ontario Biodiversity Council, 2015a). Ecosystems that cover the province include forests, prairies, grasslands, lakes, streams, wetlands, and tundra. These provide many benefits to humans, and humans affect their capacity to provide benefits. Humans have increased their use and depletion of ecosystems with a result that biodiversity is increasingly scarce in Ontario and on planet Earth.

Ecosystems provide benefits that are called "ecosystem services". These include the purification of air and water, the moderation of stormwater damages upon infrastructure, the recycling of nutrients, and the rejuvenation of mental health. These ecosystem services are economically valuable, yet they tend to be un-priced because they are not tradable within marketplaces. As a result, their value is missing from many measures of economic performance, and absent from self-interested considerations within marketplaces. These omissions undermine the sustainability of ecosystems and biodiversity.

This report relates the economics of ecosystem services and biodiversity to an Ontario context. The report begins by relating biodiverse ecosystems to human wellbeing, with key concepts and terms that are used to communicate and to quantify this relationship. This relationship is situated within the context of market prices that fail to reflect the full economic value of natural capital. As a result, non-market values are needed to understand the scarcity of nature. With such values, land-use decisions can be more effective, balance sheets can be more complete, and economic accounts can be more comprehensive. The integration of non-market values can support – and result from – the use of economic instruments, which aim to align economic self-interest with the shared interests of conserving ecosystems and the biodiversity they contain. Fortunately economic instruments and non-market values are increasingly prevalent in Ontario, with some policies and practices that mandate their consideration.

This report updates an earlier 2012 report with the same title (Miller & Lloyd-Smith, 2012). The present report includes new information and sources, removes some outdated material, and adjusts the amount and ordering of some content. As before, this report omits the consideration of exotic invasive species, whose economic damages have been documented elsewhere (e.g. Marbek, 2010a, 2010b). As before, this report considers ecosystem services and biodiversity together, because they are complements to one another. This is a best practice following the global assessment of The Economics of Ecosystems and Biodiversity (TEEB) in 2010, and the practice of the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) since 2012.

2. Biodiverse ecosystems supply goods and services that support human wellbeing

What is human wellbeing?

Human wellbeing is an aspirational goal that reflects various components of health, material standards of living, social connections and relationships, and the minimization of insecurity. The specific end-point of wellbeing is contested because it reflects varying preferences and priorities for personal and community outcomes. Globally, the pursuit of wellbeing is often associated with the achievement of the United Nations Sustainable Development Goals (United Nations, 2015). More generally, the pursuit of wellbeing requires benefits from nature while also affecting the capacity of nature to provide benefits to humans. Nature provides materials and energy and services, which are used by humans as inputs to production and the metabolism of waste outputs. Nature also provides resilience to landscapes and oceans, which sustain life.

Nature is needed to support human wellbeing, because "humans cannot produce something from nothing" and "cannot produce nothing from something" (Farley, 2012). All economic production involves the transformation of materials and energy and services that are sourced from nature. Human activity is increasingly affecting the capacity of nature to provide goods and services, and to support the diversity of life on Earth. Many social and natural scientists question whether the current levels of human wellbeing can be sustained, with risks that future growth and development would be constrained. Concepts, tools, and techniques are needed to understand the relationships between nature and human wellbeing. This wellbeing-oriented approach has become more common in recent years, such as through the work of key scholars (e.g. Costanza et al., 2017), the updated UK National Ecosystem Assessment (2014), and the work of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES, 2018).

What are ecosystem goods and ecosystem services?

Biologically diverse ecosystems sustain human wellbeing by supplying *ecosystem goods* and *ecosystem services*. *Ecosystem goods* are the products from ecosystems that humans use for food and fuel and as building materials. These goods can be stockpiled and are usually bought and sold in markets for a price, so they can be classified as commodities. All other benefits that flow to humans from ecosystems are called *ecosystem services*. These services are unpriced because they are not exchanged in markets as commodities. Examples include the filtration of ultraviolet radiation, the decomposition of and detoxification of human wastes, the dissipation of energy in stormwater surges, the recycling of nutrients, the attenuation of noise pollution, and the rejuvenation of mental health. Ecosystem services can support the provision of ecosystem goods.

Ontario's Biodiversity Strategy (2011) followed an approach from the Millennium Ecosystem Assessment (2003) to differentiate between: *provisioning services* that provide products such as food, water and raw materials; *regulating services* of air purification, waste treatment, and the moderation of damages from storm-water; *supporting services* such as nutrient cycling and soil formation; and *social/cultural services* that provide aesthetic information and recreation and tourism.

Other distinctions exist, such as based upon differences between intermediate and final services (Boyd, 2012), or a cascade model that has ecosystem services cascading from ecosystem functions, and cascading onto benefits and values (Potschin & Haines-Young, 2011). Generally these details are unnecessary complications to communicating the concept and engaging new audiences. In Canada, there remains a tendency to lump ecosystem goods and services together, under the acronym of EGS, despite differences in the economic and policies issues of both (Miller, 2011). More recently, some are deliberately avoiding the commonly-used terms in this report, preferring "nature's contribution to people" (Pascual et al., 2017) or "nature's gifts" instead of services, and "systems of life" rather than biodiversity and ecosystems (Diaz et al., 2015).

Can ecosystem services be turned into commodities?

Ecosystem services are not commodities because they are not easy to commodify. They are flows that are difficult if not impossible to package, stockpile, and exchange. Some ecosystem goods, such as endangered species, could be commodities but they are currently forbidden from being exchanged by laws such as the Ontario *Endangered Species Act, 2007,* the Federal *Species at Risk Act, 2002*, and globally through the Convention on the Illegal Trade in Endangered Species. Nevertheless, human efforts to conserve an endangered species could be commodified by creating some sort of a claim to this effort – such as a certificate that could be exchanged with others who demand it. Some people may incorrectly interpret this as commodifying biodiversity, whereas it is commodifying a certificate that was generated from a specific type of human effort. Such a certificate does not imply ownership of the humans or endangered species involved in the outcome.

Humans can decide to create new commodities that relate to human efforts to affect the provision of ecosystem services. For example, humans can create a system that provides certificates to people if they undertake efforts to successfully increase a specific amount of carbon that is sequestered by the ecosystem services of an area of land. This system would not commodify the ecosystem service - it would commodify the human effort that enhanced the service. If the people holding the certificates were to exchange them with other people, the certificates would have a market price. This price would reflect the scarcity of certificates, considering their demand and supply. A new commodity would have been created to reward humans for managing ecosystem services. Details about this strategy, and other economic approaches, are described later in Section 8. This is just one way of rewarding pro-environmental behaviour, but is not in itself a way of commodifying nature - it would be commodifying human efforts to conserve nature.

What is natural capital and how can ecosystems be managed as natural capital?

The economic term *capital* is generally used to describe something durable that will provide a flow of benefits in the future. *Natural capital* is used to describe ecosystems that provide ecosystem goods and ecosystem services. Applying the concept of capital to ecosystems reinforces the point that as long as humans do not fully deplete ecosystems, then ecosystems can provide benefits in the future. The long-term pursuit of human wellbeing requires the sustainable management of natural capital for its capacity to provide ecosystem goods and ecosystem services in the future.

Ecosystems and their components, including biological and geological resources, can be managed as natural capital in order to provide benefits in the future. Fish stocks can be managed as natural capital to provide a flow of consumable protein over time. Forests can be managed as natural capital to provide flows of timber over time. The ozone layer can be managed as natural capital to provide the service of filtering ultraviolet radiation. If humans consumed too many fish or timber, or emitted too many ozone-destroying CFCs, they would deplete its originating natural capital fund, with a consequence of a lesser flow of services in the future. Natural resource management is therefore the management of human activity that affects the capacity of natural capital to provide benefits in the future.

How do natural capital stocks compare to natural capital funds?

It is often useful to distinguish between *natural capital stocks* that are the source of ecosystem goods and *natural capital funds* that are the source of ecosystem services. This distinction helps to emphasize differences in their measurement and management. Since natural capital stocks provide ecosystem goods, which are tradable commodities, the economic value of natural capital stocks are more easily measured using market prices. Natural capital funds provide ecosystem services which are unpriced, so the economic value of natural capital funds are not as easily measured. Therefore advocates of natural capital valuation and accounting should be mindful that the funds provide different challenges than the stocks; therefore the summation of both into an aggregated "value of natural capital" is probably not useful since each involves different management strategies.

Humans manage natural capital stocks by choosing the flow of ecosystem goods at a specific moment in time – such as how many animals to harvest or minerals to deplete. The harvest in one moment affects how much is available in the future – so humans can "save" a natural capital stock to allow for more to be consumed in the future. In contrast, humans cannot choose the flow of ecosystem services – humans can only choose whether to affect the capacity of the ecosystem to provide the flow. Humans cannot "save" the capacity of natural capital funds to be used more intensively at a different date. For example, humans cannot stockpile the noise attenuation benefits of urban trees to use it at a later time of their choice. Humans can only indirectly affect the flow by affecting the size of the tree canopy and its composition. More generally, humans affect the supply of services by affecting its originating natural capital fund, by choosing whether to diminish the fund by consuming its capital, or whether to grow the fund by investing in its capital.

Why is natural capital necessary for sustaining wellbeing?

Human wellbeing is sustained by natural capital because natural capital is needed to sustain other forms of economic capital, such as human capital and built capital. *Built capital* is the supply of buildings, infrastructure, and machines that provide the benefits of shelter, the outputs from machines, the movement of people and materials and wastes. *Human capital* is the supply of people and their knowledge, skills, and capabilities, which provides the benefits of paid and unpaid labour, understanding and resolving problems, leading people, and many other benefits. In this report, human capital is inclusive of social capital, and the term built capital is used rather than produced or manufactured capital. Different publications might use other terminology, but the concepts are usually identical.

Humans create built capital by using their human capital to transform ecosystem goods and services provided by natural capital. Built capital depreciates, meaning that it wears out over time. Built capital is sustained by offsetting its depreciation, through repairs and fixes that require materials and energy provided by ecosystems. Some ecosystem services help to protect built capital by slowing the rate by which it wears out (for example, the heat-attenuation services provided by living green roofs) or is damaged (for example, a riparian habitat's moderation of stormwater surges that results in less energy being transferred to infrastructure). Human capital is sustained by ecosystem goods that feed people, the services that purify the air they breathe and water that they need to consume. Human wellbeing therefore requires a mix of natural capital, human capital, and built capital.

How does biodiversity relate to ecosystem services?

Biodiversity is the variability of life. Biodiversity can be measured as the amount of variability within an ecosystem, among its constituent species, and the variability within each species such as its genetic information (United Nations, 1992). Biodiversity is not a service of ecosystems, nor are ecosystems the service of biodiversity. Biodiversity describes the elements of natural capital that provide ecosystem services. Biodiversity has declined on planet Earth at the same time that the flow of ecosystem services have been declining since ecosystems are being degraded (Watson et al., 2005). This correlation has resulted in a coupling of strategies to understand and remedy the decline of both, such as the global initiative The Economics of Ecosystems and Biodiversity (TEEB, 2011). The present report considers the decline of ecosystem services and biodiversity concurrently because both are subject to the same economic challenges, and potential opportunities for economic-oriented conservation strategies.

Would a recovery in biodiversity necessarily cause an increase in ecosystem services, or vice versa? The answer depends on the circumstances. Landscapes rich in biodiversity are believed to be better able to sustain ecosystem services over time (e.g. Parker & Cranford, 2010). Landscapes that supply high levels of ecosystem services tend to have high biodiversity (e.g. Hooper et al., 2005; Flombaum and Sala, 2008). Yet there are examples of low-biodiversity ecosystems providing high levels of ecosystem services and vice versa (e.g. Reyers et al., 2012). The relationships between biodiversity and ecosystem services are non-linear (Cardinale et al., 2012) and multi-scaled, with local-scale biodiversity affecting ecosystem functioning and stability, which in turn will alter the supply of ecosystem services at intermediate scales (Isbell et al., 2017).

A key insight from considering ecosystem services and biodiversity concurrently is that human actions to deliberately enhance one should be pursued in ways that maximize the opportunities for enhancing the other. For example, endangered species should be recovered by means that also enhance ecosystem services, and the rehabilitation of degraded ecosystems should include considerations for biodiversity. For this reason, Ontario's Biodiversity Strategy seeks to "integrate the economic value of biodiversity and ecosystem services into decision making" by noting that "biodiversity is the foundation upon which we derive benefits called ecosystem services" (Ontario Biodiversity Council, 2011).

3. Many professions and sectors are taking an interest

What about businesses and investors in the private sector?

Businesses and investors have several reasons to understand their interaction with biodiversity and ecosystem services in the course of routine and strategic decision-making. Often this is necessary to comply with conservation-oriented policies in Ontario. In some cases, businesses may discover greater efficiencies and productivities as a consequence of intentionally focussing on the inputs from ecosystems and waste outputs, as per the "Porter Hypothesis" (Ambec et al., 2013). Businesses often respond to investor pressures to voluntarily disclose dependencies and risks, such as in response to the Global Reporting Initiative, or other Environmental Social and Governance (ESG) criteria. Some are obligated to follow performance standards as an obligation of funding, such as required by the World Bank's International Financial Corporation (2012). Some are seizing opportunities to positively position their brand to consumers, such as through labelling and certification systems (with examples profiled in Section 8).

Many networks and initiatives have emerged globally and locally. Some are sector-specific, such as the Natural Capital Finance Alliance, and some are broader, such as the Natural Capital Coalition. This coalition includes Ontario-based TD Bank and other businesses, and has developed a Natural Capital Protocol to help businesses to "generate trusted, credible, and actionable information for business managers to inform decisions" (Natural Capital Coalition, 2015). This protocol has been piloted among many global corporations, and is supported by a Natural Capital Protocol Toolkit, which offers an online inventory of measures, computational tools such as calculators and models, reports, and frameworks.

Some businesses in Ontario were part of a corporate work-stream of a Canadian-based Natural Capital Lab (2015-2018), which aimed to apply the framing and scoping steps of the Natural Capital Protocol beginning with the financial sector (Purkis & Claesson, 2017). Some business operating in Ontario are members of the Canadian Business and Biodiversity Council, which amassed case studies of businesses that explicitly integrate considerations of biodiversity and ecosystem services (Canadian Business and Biodiversity Program, 2010). The council also surveyed its members about biodiversity data needs and gaps, and ways of filling the gaps (Canadian Business and Biodiversity Council, 2012).

What about accountants and their associations?

Accountants and their professional association are responding to demand from businesses and governments to measure and manage nature, in the context of sustainability.

Professional accountants in Ontario are members of the Chartered Professional Accountants association of Canada (CPA Canada), which is the amalgamation of formerly different provincial and national accounting associations representing various designations. The association is engaged in national and international initiatives to broaden the scope of accounting and management to include ecosystems and biodiversity under the broad header of sustainability, such that "CPA Canada supports improving Canada's natural capital stewardship" (CPA Canada, 2016). Since 2015, the CPA Magazine has featured articles about sustainability and natural capital, and even an article about alternative post-growth economies that might involve GDP degrowth (Lorinc, 2015). CPA Canada has profiled the Kering company's innovative "environmental profit and loss" statement, which considers the company's impacts upon biodiversity and ecosystem services in monetary terms, drawing from the TEEB valuation database (Kering, 2015).

Accountants are being challenged to update accounting and management protocols to deal with ecosystems and biodiversity that are not commodities. National and international accounting standards were developed when capital was more narrowly considered to be machines and buildings and market-valued land. As the consideration of biodiversity and ecosystem services becomes mainstream, so too are questions about how to include living natural capital assets. These considerations are especially relevant for public sector accounting, as evidenced by the considerations of the Municipal Finance Officers' Association of Ontario (e.g. Ratford, 2008) up to the Public Sector Accounting Discussion Group (e.g. 2016). CPA Canada hosts meetings to examine accounting issues, and recently discussed the extent to which the existing accounting handbook allows green infrastructure to be recognized in public sector financial statements (CPA Canada, 2017). Many of the major accounting-oriented corporations operating in Ontario market their offerings to include sustainability, including Deloitte, Ernst & Young, KPMG, and PricewaterhouseCoopers (PwC).

What about professional planners and architects?

Professional planners and architects are increasingly tasked to incorporate considerations of ecosystem services and biodiversity into infrastructure and land-use plans, development approvals, and the design of buildings and landscapes. The term "green infrastructure" seems to be used more frequently among planners than "natural capital". Recently updated provincial planning policy has signalled an intent to consider green infrastructure and to be mindful of the importance of biodiversity and ecosystem services (as detailed later in Section 10). Some towns are identifying their natural capital assets informally, such as Aurora (Kyle, 2013). The town of Oakville and the Region of Peel are engaged in a Municipal Natural Assets Initiative that was inspired by the town of Gibsons, BC, which formally sought to integrate nature into its asset management systems and onto its balance sheet (Municipal Natural Assets Initiative, 2017). The Canadian-based company Stantec includes natural capital in its capacity-building services, which included work for the Attawapiskat First Nation to identify and assess natural capital as a valued component in its community-based land use plan (Stantec, 2015).

Some clients are striving for best practices, aiming for low-footprint "passive buildings" or integrative "conservation subdivisions". Some seek certification through systems such as Leadership in Energy and Environmental Design (LEED) for buildings, or the Sustainable Sites Initiative (SITES) for landscapes. These performance-based certification systems work well to integrate multiple non-market considerations into a metric that can be marketed (Steiner et al., 2013). Some clients, especially those in the public-sector, seek participatory approaches to design and planning. This aligns well with opportunities for deliberative valuation methodologies that are usually promoted by ecological economists (and detailed in Section 5), and which could be integrated with participatory modelling. Planners can take advantage of spatial inventories of non-market values, such as the one covering Southern Ontario (Troy & Bagstad, 2009), and spatial modelling techniques that can specify the flow of non-market benefits across a landscape (e.g. Voigt et al., 2013).

The Ontario Professional Planners Institute certifies planning professionals in Ontario. The institute provides updates to its members through its Ontario Planning Journal. A recent issue themed "planning in the new millennium" featured perspectives of "millennial planners" that identified resilience to the effects of climate change and "ecosystem destruction" as key priorities for the future, with a perspective that "planners must have a progressive vision and active voice" (Chellew & Hertel, 2017). Early leadership in Ontario for the integration of ecosystem services and biodiversity in land-use planning was provided by the Natural Spaces Leadership Alliance, which commissioned the Canadian Urban Institute (2006) to produce its "Nature Cout$" brochure and report. This was featured in an issue of the Ontario Planning Journal with a theme of "valuing the environment" (Peterson, 2007).

What about engineers and infrastructure specialists?

Engineers are associated with creating built capital and assessing its condition. Nevertheless, some are integrating the consideration of regulating services from ecosystems to add resiliency to built capital, especially in the context of climate change. Some are considering "green infrastructure" approaches as cost-effective substitutes for routine approaches that can be called grey infrastructure. Some established infrastructure corporations are positioning their services in way that is favourable to biodiversity and ecosystem services. For example, the global infrastructure company AECOM advocates "putting nature at the heart of decision making" by using its offering of natural capital accounting, ecosystem accounts, and ecosystem service assessments (AECOM, 2015).

Infrastructure planning is increasingly required to integrate the considerations of biodiversity and ecosystems, as these become mandated by policy in Ontario. The *Endangered Species Act, 2007*, routinely comes into consideration for infrastructure projects in Ontario. As a result, engineers and conservation professionals are working together to identify baseline biodiversity and the effects and options that could affect this baseline. Many postings on the Environmental Bill of Rights registry relate to instruments under this Act, especially an "overall benefit" permit used in the context of infrastructure projects. This has some infrastructure specialists considering the potential to enhance natural capital for the benefit of biodiversity. The Ontario Infrastructure and Lands Corporation has noted that some of its "unmarketable" portfolio of lands may be useful for enhancing biodiversity, with an example of enhancements to the habitat of Eastern Meadowlark as part of a Toronto light-rail transit project (Infrastructure Ontario, 2016).

The option of green infrastructure is becoming mainstream in Ontario, particularly in the realm of green roofs. Toronto has a Green Roofs bylaw and offers design guidelines that identify best practices for "creating habitat and promoting biodiversity" (City of Toronto, 2017). There are now companies that specialize in this, with a Toronto-based non-profit industry association called Green Roofs for Healthy Cities. This organization and others have promoted green infrastructure, with a recurring "Grey to Green" conference held annually in Toronto. This conference has showcased the work of the Green Infrastructure Ontario (GIO) coalition, which aims to unite infrastructure specialists and planners and conservation professionals. Conservation professionals are often keen to champion the consideration of *living* green infrastructure, reminding people that the definition of green infrastructure includes living nature-based solutions and non-living green technologies such as permeable pavement and rain barrels. This effectively mirrors the distinction that natural capital includes living (biological) and non-living (geological) components.

What about public health professionals?

Health professionals aim to maximize human wellbeing and to understand its determinants. Some in the profession are particularly interested in the linkages between wellbeing and the health of biodiverse ecosystems. An Ontario initiative called EcoHealth Ontario is a collaborative of professionals in public health and medicine and allied fields. The collaborative includes Toronto Public Health, which commissioned a review of 106 studies of the linkages between greenspaces and mental and physical health outcomes, excluding the impact of greenspace upon physical activity (Zupancic et al., 2015). The collaborative called the conservation of biodiversity a "public health imperative" (Morrison et al., 2017) and prepared a high-level "policy toolkit" (Lura Consulting and Planning Solutions Inc, 2017) to integrate considerations into municipal-level public health and land-use planning. EcoHealth Ontario aims to transfer knowledge to Ontario from other jurisdictions, such as from a global state of knowledge review by the Convention on Biological Diversity and the World Health Organization (CBD-WHO, 2015).

Some scholars have suggested defining the ways in which nature benefits the mind as a "psychological ecosystem service" (Bratman et al., 2012). However this terminology is not established among health professionals nor is it widespread within the broader literature about ecosystem services. Research that links biodiversity and ecosystems to human health generally considers benefits that are psychological, cognitive, physiological, social, esthetic, and in the realm of increased resiliency and the potential to reduce the incidence of infectious diseases (Sandifer et al., 2015).

Most research seems to describe benefits in non-economic terms dealing with health outcomes. Some research has gone further to relate health outcomes to economic variables, such as averted costs, or equivalent gains in income. For example, the exposure of residents in Toronto to urban trees was related to health outcomes and the equivalent outcome from a change in income, since income is correlated with health outcomes. Kardan et al. (2015) found that a 4% difference in street tree density corresponded to an improved health perception equivalent to being seven years younger, or having $10,000 more in annual personal income and moving to a neighbourhood with that same increment in median income. That difference in street tree density was equivalent to an average of 10 more trees beside the street in a city block. The same difference in street tree density is associated with significantly fewer cardio-metabolic conditions, equivalent to being 1.4 years younger, or having $20,200 more household income and moving to a neighbourhood with that same increment in median income.

What about economists, especially ecological economists?

Economists have long been interested in the relationships between humans and nature that surrounds them. This interest was broad in the early days of economics, when its inquiry was called "political economy", yet it has since become narrower as the subject became increasingly specialized and formalized as economics. Today in Ontario and throughout the English-speaking world, some economists specialize in a sub-discipline of "natural resource economics" which includes the management of minerals and fuels, fisheries, forestry, and land management including parks and protected areas and hunting.

This scope includes the management of biodiversity and ecosystems, and their economic valuation. Some economists specialize in "environmental economics" which focusses on the economic problem of pollution and wastes, which in turn affect biodiversity and ecosystems. Economists in Ontario with either specialization are often members of the Canadian Resource and Environmental Economics (CREE) group.

Ecological economics includes the scope of natural resource and environmental economics, with a methodologically broader trans-disciplinary perspective, and a normative interest in the sustainable scale of humanity's metabolism of nature, and fair distribution, and efficient allocation. Ecological economics attempts to integrate considerations of ecology within economics. As a result, ecological economists are particularly interested in the economics of ecosystems and biodiversity. Earlier concepts of "nature's services" (Westman, 1977) and then "ecosystem services" (Ehrlich & Mooney, 1983) that were discussed among ecologists were introduced more broadly by ecological economists. The co-founder and inaugural president in 1988 of the International Society for Ecological Economics was Robert Costanza, who was the lead author of one of the most important publications about ecosystem services (Costanza et al., 1997). In 1993, the Canadian Society for Ecological Economics (CANSEE) was formed, with its inaugural president Peter Victor residing in Ontario. A 2015 content analysis of all articles from Canadian scholars published in the international journal *Ecological Economics* found "ecosystem services" to be the top keyword (Arruda & Dolter, 2016).

4. Market prices fail to reflect the full economic value of nature

How do markets affect prices?

The word *market* is shorthand for a marketplace, which is a physical place or electronic system that helps people to exchange things. Markets are more beneficial when there are more possibilities of exchange, which generally results when there are more interested buyers and sellers, with free will to enter or leave the marketplace regardless of whether an exchange was made, a good amount of truthful information about the things being exchanged, and a common medium of exchange and unit of account (which is usually fulfilled by using the same money). Markets with more of these attributes generate higher levels of economic efficiency, such that more people engage in exchange at lower costs. For this reason, many favour markets and market-like approaches for facilitating exchange.

Market prices result from the interaction of participants in a marketplace. Therefore, prices reflect various attributes of a particular marketplace. For example, prices reflect the relative power of demand from buyers versus supply from sellers; higher prices result when sellers have relatively more power; lower prices result when buyers have relatively more power. Market prices also reflect the management of natural resources, such as decisions about the amount to harvest to bring to market. It's possible that the quantity being supplied to the market is a quantity that cannot be sustained, such as if more fish are harvested than are being naturally replenished. A marketplace for fish may generate efficiencies of exchange, however it will not necessarily ensure a sustainable harvest. Other information informs harvest decisions. With all else constant, higher harvests of ecosystem goods will put downward pressure on their prices, while conservation will put upward pressure on prices. Nature is not a buyer or seller in markets, so it has no power to bargain with humans about the quantity of nature's ecosystem goods that are used, nor the amount of human wastes that it receives. Humans make decisions about how much nature to use and sustain, with these decisions affecting the amount of ecosystem goods that are supplied to marketplaces, which in turn affects their market price.

How can public policy affect market prices?

Market prices also reflect the extent to which all costs are contained within exchange prices. Any costs that are not included are said to be external costs, which are defined as *negative externalities*. Humans burden each other, and the biosphere, with negative environmental externalities in the forms of free pollution and the depletion of nature. Markets reward the generation of negative externalities because suppliers and demanders will personally gain when costs are externalized. Market prices therefore reflect the extent to which there are *market failures,* including the failure to fully internalize all costs. Such failures will generate economically inefficient levels of exchange.

Public policy has the potential to remedy some of these negative externalities by limiting their quantities or by requiring a compensatory payment. Remedies are identified and discussed later in Section 8, such as restricting the amount of externalities, or by imposing a cost upon the production of externalities. Market prices therefore reflect any effects of public policy upon the amount of costs that are externalized by a particular market that mediates exchange. Market prices also reflect the willingness of buyers to pay specific amounts, which depends upon their abilities to pay. For this reason, market prices reflect the distribution of purchasing power (disposable income inclusive of net borrowing). Markets ration the allocation of things that are exchanged towards those with a higher willingness to pay. Therefore markets may not generate outcomes that are deemed to be fair, even if the outcome is economically efficient. Altogether, an intent to promote efficient and sustainable and just outcomes will require multiple forms of successful public policy, since these outcomes are not automatically correlated.

Why do market prices fail to reflect the economic value of nature?

Economic value is a measure of the importance (to humans) of something that is scarce. Some of this value can be measured by market-prices, and some cannot; not all valuable things are exchanged in markets, and even those that are exchanged can be subject to market failures. Ecosystem services are economically valuable because they provide scarce benefits to humans. These benefits are not exchanged through markets, so their *unpriced* market value should not be used as an indicator of their economic value. Therefore, non-market measures of economic value are needed, as detailed in Section 5. These non-market values need to be considered with any market-priced values of ecosystem goods, in order to more fully understand the economic benefits from a particular ecosystem.

Prices of ecosystem goods will tend to understate their full economic value. Recall that market prices reflect the make-up of the marketplace, decisions about how much to harvest versus sustain for the future, and the presence of negative externalities after accounting for the influence of public policy. Furthermore, market-determined prices will reflect a minimum of the economic value enjoyed by transacting buyers and sellers, based on the preferences and constraints that each faced. To determine the full economic value of all market exchanges, one would need to include the value to the buyer and seller beyond the transaction price, which economists call the consumer and producer surplus, respectively. To understand the full economic value of market-priced ecosystem goods, it would be necessary to estimate the value that was enjoyed by consumers and producers beyond its transaction price. Generally the usefulness of gathering this extra information is less than the effort to figure it out. For this reason, market prices are usually relied upon to express information about *some* of the economic value of ecosystem goods.

How can nature remain unpriced even as it becomes scarcer?

Without protection, unpriced benefits from ecosystem services and biodiversity will remain unpriced until they are fully used up. Their increased economic scarcity will fail to be reflected by an increase in a market price. This is an important point that is often overlooked or misunderstood by conventional economic thought and policy, which generally assumes that market prices are an adequate indicator of economic value, and therefore an adequate guide to informing economic behaviour. Studies from Ontario and around the world reveal instances when the unpriced benefits from conserving specific ecosystems were more economically valuable than their conversion for market-priced benefits (e.g. Balmford et al., 2002).

If the economic benefits of ecosystem services and biodiversity were fully priced, then several changes might be expected to happen as they become increasingly scarce: entrepreneurs could be rewarded for finding more supply, consumers would be rewarded for conserving and (or) finding substitutes, and policy-makers would be inclined to review policies that affect supply and use. Instead, policy-makers, entrepreneurs, and consumers can be misled into thinking that there is no growing scarcity of ecosystem services and biodiversity, when in fact recent assessments have shown that there is a growing scarcity (Taylor et al., 2012). In the language of economics, this is often called "the new scarcity" problem in contrast to the "old scarcity" problem of a decline in the quality and quantity of ecosystem goods like timber and minerals (e.g. Simpson et al., 2005; Barbier, 2011).

Why do ecosystem services and biodiversity need to be protected?

The unpriced benefits from ecosystem services and biodiversity need some form of deliberate protection because unregulated competitive markets will deplete ecosystems. This happens for the same reason that the benefits are naturally unpriced: it is difficult to earn a private reward for conserving them when they also freely flow across the landscape to other people. When people can freely enjoy unpriced benefits, it is difficult for private entrepreneurs to profit from selling their benefits, or from finding ways to protect or enhance them. Deliberate protection involves governing the access and use of ecosystems, with about a dozen principles for the successful governance of so-called "common pool resources" (Ostrom, 2008). Success usually involves many overlapping spatial scales of governance; efforts to merge them usually result in less successful management. Because the spatial “benefits-shed” of ecosystem services does not usually coincide with political boundaries, some have proposed additional “ecosystem services districts “to support their governance (e.g. Goldman et al., 2007).

Few people will voluntarily pay someone to get something that they can already enjoy “for free.” This also means that the services could be destroyed or damaged “for free” because those who lose their benefits are not entitled to compensation. This combination of overuse and under-provision challenges the sustenance of ecosystem services and biodiversity. In the language of economics, ecosystem services suffer from “market failure” because their benefits are non-excludable and the consequences of their degradation will be externalized by unregulated competitive markets. In other words, ecosystem services are typically externalized in market transactions unless public policy is successful at deliberately internalizing the costs of their use and depletion and the benefits of their sustenance. This is no different in Ontario than it is in comparable jurisdictions.

How will their depletion affect economic productivity and wellbeing?

A growing scarcity of unpriced ecosystem services will impact upon an economy's *productivity*. Productivity is currently measured by comparing the value of economic production to the cost of inputs needed for that production. The benefits from ecosystem services and biodiversity are not directly measured as an input. However, a growing scarcity of ecosystem services and biodiversity could increase the (priced) costs of production. Producers might have to reconfigure their supply chains to use more inputs from places in the world that have a comparatively greater abundance of ecosystem services, for example water that is cleaner or cooler. Or producers might have to engineer a costly solution that mimics some benefit from nature, such as water purification.

Improved measures of productivity are needed that count nature's unpriced inputs, and the impacts of unpriced outputs like pollution. So far in Canada, this has only been assessed on an experimental basis by Statistics Canada (e.g. Harchaoui et al., 2002; Harchaoui and Lasserre, 2002; Dachraoui and Harchaoui, 2004). Outside of the statistical agency, there is some interest in exploring the concept further. A study by Hanna et al. (2010) forecasted the impact of a change in a few unpriced ecosystem services on the (priced) outputs of fruit, harvested wood, and some marine fish harvests in Canada. A 50% reduction in wild pollination of fruit in Canada would result in the loss of $53M of production in a $250M industry; this would increase the price of apples from $365 / tonne to $491 / tonne. The study describes ecosystem services as a “natural subsidy” of economic products.

More recently, the Smart Prosperity Institute launched a research project to consider natural capital and productivity. The project included an investigation into the shortcomings of existing measures and what would be needed by Statistics Canada to generate better measures (Smith, 2016). The project closed with a report prepared by the Centre for the Study of Living Standards that analyzed existing data for environmentally-relevant measures of productivity. That report focussed on industries that provide ecosystem goods, including forestry and agriculture and oil and gas. Conventional estimates of productivity were compared with less-conventional estimates, such as energy productivity, land productivity, and water productivity (Murray & Sharpe, 2016).

Why do ecosystem services deserve more attention than ecosystem goods?

The contribution of ecosystem goods, and other market-priced things, to human wellbeing is measured, and is managed by various sectors of society that rely upon these measurements. In contrast, unpriced ecosystem services have not been measured and managed as much, even though human wellbeing has always depended upon them. This gap was less significant earlier in history when there were fewer humans with lower standards of wellbeing and aspirations for growth. This gap is more significant now, and is expected to become more significant in the future. A 2018 assessment by the Intergovernmental Panel on Biodiversity and Ecosystem Services forecasted that 40% of the original biodiversity of the Americas will have been lost by 2050 under business-as-usual assumptions of a growing population and growth in market activity (IPBES, 2018).

Globally, the Millennium Ecosystem Assessment concluded that “nearly two thirds of the services provided by nature to humankind are found to be in decline worldwide. In effect, the benefits reaped from our engineering of the planet have been achieved by running down natural capital assets” (Watson et al., 2005). Nationally, the Canadian Biodiversity: Ecosystem Status and Trends Report concluded that “relevant ecosystem-level information is less available than decision-makers may realize” (Federal Provincial and Territorial Governments of Canada, 2010). For these reasons, non-market measures are needed.

5. Non-market values are needed to understand the economic scarcity of nature

What is economic valuation?

Economic valuation is an intentional determination of the importance to humans of something that is scarce. Recall that ecosystem services and biodiversity are scarce. Their economic importance cannot be deduced by the unpriced nature of ecosystem services and any externalized costs that impact upon other humans and the capacity of ecosystems to provide benefits in the future. Humans therefore need to intentionally estimate non-market values if they want to quantify their economic importance. This can be accomplished by various techniques, which are described later in this section.

Economic valuation can generate non-market values that measure the relative importance of scarce ecosystem services and biodiversity. Importance is a relative concept because economic value reflects the abundance of supply relative to its demand from humans. Changes in ecosystem services can arise from changes in the capacity of ecosystems to supply them, and (or) changes in their demand from humans. The valuation of these changes will reflect their importance in relation to a baseline quality and quantity. Economists call this *marginal* valuation, to signal that incremental changes are being valued, to reinforce the point that the estimated marginal values should not be applied to dramatic (non-marginal) changes. Values will also reflect other contextual attributes, including the characteristics of people doing the valuation, and the technique used to derive the non-market measure of value. Values are therefore context-dependent expressions of the relative economic importance of ecosystem services.

The intentional estimation of values can be compared with values that are implied by actions (or inactions) that involved trade-offs between priced and unpriced values. If someone paved over a biodiverse landscape, this implies that the biodiverse landscape was less valuable to the person than the value of the pavement less the costs of its installation and maintenance. If this was permissible without any requirement to offset the lost landscape, or to pay a fee for its conversion, this implies that the regulator commands a null value to the lost landscape. Intentional valuation helps to bring about greater transparency in the importance of ecosystem services and biodiversity to wellbeing.

When are biophysical measures of supply useful?

Measures of biodiversity and the quantity of services supplied by ecosystems can be measured in biophysical units, meaning biological or physical units. These units help to operationalize mitigation policies, especially the evaluation of conservation offsets.

Conservation offsets aim to sustain biodiversity and/or the capacity of ecosystems to supply services, by making comparisons between human-generated losses and gains. Empirical models from the natural sciences can help to measure the supply of ecosystem services that are used to support wellbeing, and to anticipate the effects of changes in human wellbeing upon the capacity of ecosystems to provide services. Measurements of this type are necessary for quantifying thresholds of natural capital resilience, related to the concept of critical natural capital (Ekins et al., 2003).

Biophysical measures include units of mass, such as Tonnes of carbon that are sequestered by units of landscape or biomass, which can be used to offset anthropogenic emissions such as from airline travel. Biophysical measures have also included units of energy, such as Kilocalories per day of temperature that can be avoided or dissipated by various landscape features, to reduce the net temperature rise in water systems that waste heat. Species richness and other metrics of biodiversity are sometimes used to measure impacts and make comparisons with mitigation efforts. Some measures can be observed, and some can be estimated or forecast using computational models. Biophysical measures of specific ecosystem services are usually expressed in different units, so they cannot be summed. One alternative is the accounting methodology of the ecological footprint and biocapacity, which converts the demand for – and supply of – various ecosystem goods and services into standard units of "global hectares" which can be summed and compared to inform the measurement of sustainability (Borucke et al., 2013). This is detailed further in Section 6.

When are monetary measures of non-market values useful?

Monetary measures of non-market value will always reflect human demand for a given amount of biophysical supply. In other words, the non-market value will reflect the scarcity of supply in relation to its demand. A higher demand for the same supply of an ecosystem service will generate a higher monetary value; the same demand with a reduced supply of an ecosystem service will also generate a higher monetary value. Non-market values can be used to substitute for the failure of market prices to reflect the economic scarcity of non-commodified ecosystem services and biodiversity. It takes effort to estimate non-market values since they are not as readily observable as are market prices.

Theoretically, non-market values could be internalized into decisions if decision-makers had to pay for the full consequences of losing non-market benefits of biodiversity and ecosystem services. The resulting outcome would be economically efficient, meaning that an optimal amount of exchange took place. If non-market values remain externalized, there will be more exchange than if all costs had been included in the transaction.

One caution is that even if an outcome could be made to be economically efficient, there is no reason to presume that such an outcome would be sustainable. An efficient harvest could still have resulted in a decline in the capacity of an ecosystem to supply services in the future. For this reason, the achievement of sustainability and efficiency requires the consideration of both – in the order of sustainability and then efficiency. Monetary measures imply trade-offs, so they should only be considered for trade-offs that are worth considering. There is no point estimating the monetary value for a trade-off that is impossible or improbable or objectionable, such as the presence or absence of planet Earth.

How can non-market values be calculated from market prices?

Various methods can be used to calculate non-market values from existing market prices. Economists use the expression *revealed preferences* to refer to methods that value an unpriced benefit based upon the actual spending on related goods or services in the market. These market-priced goods or services might include the premium paid to live near greenspace or the costs of travelling to experience rare nature. The prices of these market-priced goods or services reflect the level and distribution of economic affluence and the choices available within the marketplace. Specific methods include the *travel cost method*, *hedonic pricing*, *market price approaches*, or a *productivity approach*.

A *replacement cost* method involves the pricing of an unpriced benefit as the minimum cost of replacing it with a priced substitute. For example, this could include the costs of replacing biological pest control with chemical substitutes. This method is useful when there is a human-created substitute that provides an equivalent quantity and quality of the service at the least cost. This method does not imply that ecosystem services and biodiversity can be fully replaced with human-created substitutes, nor does it imply that there will always be an obvious replacement. Similar methods to replacement costs include the techniques of *avoided damage costs* and *substitute costs*.

Since actual spending does not measure full economic value, these revealed preference and replacement cost methods will tend to understate the full economic value of ecosystem services and biodiversity. They will reflect a hypothetical price that would have satisfied buyers and sellers, and not the full economic value of the transaction that would have included the consumer and producer surplus (as described earlier in Section 4). Nevertheless these methods generally require less effort than survey-based methods that are better able to express full economic value.

How can surveys be used to estimate non-market values?

Another set of methods that economists call *stated preferences* are used when there is no opportunity to use simpler methods that rely upon actual spending on related market-priced goods or services. Instead, a sample of people is surveyed to rate, rank, or price things that are unpriced in comparison to money (in the case of *contingent valuation*) or something else of value to them (in the case of *contingent choice*). This sample of people can be treated as consumers by asking for their individual and independent answers, or the sample of people can be treated as citizens by allowing them to discuss and debate their individual or collective decision. The sample's response might reflect a Willingness-To-Pay (WTP) to gain an unpriced benefit, or a Willingness-To-Accept (WTA) compensation for losing an unpriced benefit. Responses will naturally reflect the level and distribution of economic affluence of the sample of people. Care is taken to be sure that people are not overstating the amount that they would actually be willing to pay or accept.

All methods reflect a level of human understanding about the value of benefits from ecosystem services and biodiversity. Values obtained from contingent valuation will reflect the understanding of the sample of people who were surveyed, which in turn will reflect the understanding of the entire population from which the sample was derived. As humanity becomes more informed about the natural science of biodiversity, so too will its valuation of benefits from ecosystems.

Why might existing non-market values be transferred to new applications?

Each additional trade-off should ideally be valued anew, when and where it is considered, if it would involve a change in the baseline economic scarcity of ecosystem services and biodiversity. However, non-market valuation requires effort, especially if it involves creating surveys and applying them to samples of a population. As an alternative, decisions may still be reasonably informed by *transferring* the results from one valuation exercise to another one. This approach is often referred to as *value transfer*. Sometimes this is sufficient to inform a decision, and sometimes this can motivate a new valuation exercise.

Values can be transferred through time and (or) space; e.g. results from 2010 updated to 2012 and (or) from region X to region Y. Results can be transferred as point estimates or as mathematical functions, which relate point estimates to key factors such as the number of people affected by the benefit, its quality, and its relative scarcity. For example, Richardson and Loomis devised a single equation that can estimate the economic value of protecting threatened, endangered, and rare species in the USA (Richardson & Loomis, 2009). This equation was derived from 31 studies that produced 67 valuation estimates, generating a transfer error of 34-45%. It was applied to inform Environment Canada about the non-market value of conserving the polar bear in Canada (ÉcoRessources Consultants, 2011).

If people are generally informed about the economic benefits of natural areas and their relative abundance or rarity, then the monetary valuation of gains or losses will reflect their economic scarcity, which will reflect the perceived importance of the trade-off in relation to the baseline. For this reason, care must be taken when transferring values from one trade-off-scenario to another, to be sure that both scenarios involve gains or losses from a similar baseline. Eftec (2009) provides a useful overview set of guidelines for the use of value transfer in policy and project appraisal.

One must also ensure that the people in both scenarios have a similar level and distribution of economic affluence, since a willingness to pay is a function of ability to pay (as is a willingness to accept payment). When transferring estimates across currencies, it is more appropriate to use adjusted exchange rates, such as "Purchasing Power Parity (PPP)" rather than the actual market exchange rates because PPP better reflects the underlying willingness-to-pay and willingness-to-accept of individuals (Ready et al., 2004).

While value transfer is a relatively quick and inexpensive method for valuing ecosystem services, the results should be treated with additional caution. While all environmental valuation estimates are inherently uncertain, value transfer results in an additional layer of uncertainty. In addition, while per-hectare transfers of ecosystem service values are common in many ecosystem service valuation studies in Ontario and around the world, it is important to remember that the values accrue to people. Failure to adjust value estimates for population characteristics such as density and income or land characteristics such as availability of substitutes and ecosystem quality may reduce the value's accuracy.

Should ecosystem services be valued as a bundle or individually?

One ecosystem will typically provide several ecosystem services. The value of these services can be estimated as the value of the entire bundle. Or the value of the entire bundle can be estimated as the sum of each service – but only those whose value is not already counted or assumed by the value of another. This avoids the potential error of double-counting some services. This approach will be called a "sum-of-the-non-double-counted services" approach, as compared to the first "service-of-the-bundle" approach to valuation.

Whether one approach is better will depend upon the trade-offs being compared. If a meadow is being compared to its replacement with a parking lot, then it makes more sense to value the bundle as a unit because the choice is between its presence and absence. If a meadow is being compared to its replacement with pasture lands, or an afforested area, or a manicured park, then the trade-off is between the composition of this bundle, not its presence or absence. If a parking lot was an additional option, then only a sum-of-the-non-double-counted-services approach would work to evaluate the trade-offs among all the options.

In theory one would hope that both approaches yield the same result for the value of the entire bundle. In practice, the value of the whole is often less than the sum of its component parts when both are compared. People often perceive a greater value to protecting individual species within a landscape, than the entire landscape (e.g. Nunes & van den Bergh, 2001).

How should valuation deal with space?

Ecosystem services and biodiversity provide economic benefits over time and space. Many ecosystem goods can be stockpiled, and transported, such as minerals and fuel. But the benefits from ecosystem services cannot be stockpiled; the air purification benefits of a landscape cannot be conserved for one year to be used twice as much the following year, nor can these benefits be moved around. Consequently the units of their valuation are usually expressed as an amount per unit of time, and over an area of space.   More sophisticated spatial modelling can be used to understand the spatial flow of benefits (e.g. Bagstad et al., 2014). This approach was applied to understand the flow of sediment transport and water provision services from the ecosystems within Algonquin Provincial Park and the Lake of the Woods region in Ontario (Voigt et al., 2013).

The spatial scale over which to specify ecosystem services depends upon the geography of the trade-off being considered. If the value is described over a landscape that could be host to a number of smaller-scale trade-offs, then the value should be expressed per unit of area. For this reason, spatial value transfer is often used when creating general-purpose ecosystem accounts. This involves the conversion of a spatially-implied value to a spatially-explicit value; e.g. the original estimate of the value of X provided by the shoreline of Y is divided by the area of shoreline Y so that the value of X is now per unit of area. In theory, some parts of the shoreline would be more or less valuable than the average, but in the absence of more specific information from the original estimate, an average may be a reasonable approximation.

How should valuation deal with time?

In economics, one or many years of flow can be "capitalized" into a time-less stock of money that is equivalent in value from a "present value" perspective. This is typically done by discounting future values according to a mathematical formula that was developed for private financial analysis, where the time-value of money depends upon prevailing rates of return on private investments. Mathematically the same approach can be applied to environmental values, where a flow over time is capitalized to a time-less stock value. Many Ontario studies have applied this technique of discounting to one year's value of ecosystem services; e.g. Wilson (2008a), Kennedy and Wilson (2009).

It is preferable to keep ecosystem service benefits as a flow (e.g. $ per hectare per year), rather than converting them into a hypothetically equivalent stock. Above all, it is best to avoid converting one year's flow to a time-less stock; to do so would assume that its scarcity will not change over time. This is an unrealistic assumption given recent trends of increased scarcity in ecosystem services, e.g. the global Millennium Ecosystem Assessment (2003), the Americas assessment of the Intergovernmental Panel of Biodiversity and Ecosystem Services (IPBES, 2018), and the Mixedwood Plains Ecozone Ecosystem Status and Trends Report (Taylor et al., 2012). Even if the future scarcity of ecosystem services could be predicted, there are additional challenges particular to discounting, such as the functional form of the discount rate, the appropriate rate itself, and additional assumptions about equity (e.g. see Padilla, 2002). If the values of ecosystem services and biodiversity are being compared to other capitalized values, such as the value of built capital, then it is preferable to convert the capitalized value to a flow, rather than converting the value of ecosystem services to equivalent stock.

What best practices apply to non-market valuation?

Based on the insights from this section of the report, several "best practices" can be used to appraise specific studies about non-market values of ecosystem services and biodiversity.

- If a study considers market and non-market values together, such as the value of ecosystem goods and services, each component (of ecosystem goods and ecosystem services) should be distinguished, since the underlying theory and meaning of both sets of value are different.
- The results of economic valuation should identify whether the non-market values are full measures of value (from using stated preference methods) or partial measures of value (estimated by revealed approaches that estimate a hypothetical price as if it were exchanged with substitutes).

- All studies should communicate the appropriate use of the information they contain, or reference a document that provides guidance with respect to the use of the information.
- If the value of services is totalled, the total should not include double-counted benefits, such as one ecosystem service that is embedded within a sequential ecosystem service.
- A study espousing sustainability should identify how much natural capital is trade-off-able (or deemed to be critical natural capital) if the study is considering the monetary value of trade-offs.
- Trade-offs should relate to the spatial resolution of the study.
- A contingent valuation study should be attentive to the framing of whether the trade-off is presented as a gain or loss, in relation to the existing allocation or presumption of rights.
- If a study uses value transfer:
    - The original sources should be clearly referenced;
    - The original values should embed a similar scarcity of nature;
    - The original values should embed similar socio-economic circumstances;
    - Value estimate ranges should be preserved as ranges, not presented as a point estimate;
    - Adjusted exchange rates such as Purchasing Power Parity should be used to convert values between currencies.
- Services should be presented as temporal flows, meaning an amount per unit of time, rather than being converted to a time-less capitalized stock.
- The spatial flow of benefits should be characterized, if not also detailed in a Geographic Information System (GIS).

6. Land-use decisions can be more effective with non-market values

How can biophysical values be useful?

Sustainability-oriented land-use planning in southern Ontario typically involves the consideration of what is usually called a Natural Heritage System. There are various ways of realizing such a system, and various policies that apply depending upon the location of a system and the jurisdiction of the authority undertaking it. From an ecological economics perspective, the exercise of developing a Natural Heritage System is largely an exercise about understanding the biological capacity of a landscape, and different possibilities and constraints considering various objectives. Biophysical measures are needed to quantify a landscape's biodiversity and the capacity of natural capital funds that supply ecosystem services. With such measures, the biocapacity of a landscape can be determined, and compared to the demands of a given population in the form of its Ecological Footprint.

The Ecological Footprint is defined as a measure of the amount of biologically productive land and sea area needed to supply a person, or population, with settled areas, cropland, grazing lands, fishing grounds, forested lands that provide timber and fibre, and other areas that sequester greenhouse gas emissions (Borucke et al., 2013). In other words, the footprint is a measure of the land area needed to supply key ecosystem goods and the ecosystem service of carbon sequestration. An Ecological Footprint can be compared to a measure of biocapacity, which is the amount of biologically productive area that is available. One jurisdiction can effectively access another jurisdictions' biocapacity through cross-border trade of commodities that were derived from biocapacity, and through the open-access nature of carbon sequestration services that are included in the calculation of biocapacity.

An ecological footprint and biocapacity analysis was undertaken for Ontario in 2010 (Stechbart and Wilson, 2010) and again in 2015 (Zokai et al., 2015). To date, this approach has not consistently been used on a sub-provincial basis in Ontario, but it could be. To undertake such an analysis requires the same biophysical information that is needed in order to understand the non-market values provided by a given landscape's natural capital.

How can monetary values inform development decisions and associated fees?

Development is any transformation of the landscape, which can include its transformation into pasture, a playground, residences, and commercial areas. Development decisions include decisions about how much land to use for various uses, how the uses are to be realized such as the allowable type of buildings and associated infrastructure, and various rules that govern permits, fees, fines, land titles, and taxes. All of these prices that are set by development policy constitute price-based economic instruments, which are detailed later in Section 8. At the level of a Natural Heritage System, a key decision is the amount of development to allow and where to allow it. This is a decision about sustainability, which can be informed by the assessment of the biocapacity within a system.

Valuation can reveal the hidden economic costs of development in terms of the quantities and values of ecosystem services and impacts upon biodiversity. For example, an assessment of two development scenarios in Ontario's Rouge River watershed compared the impacts of development on ecosystem service values. The cost-benefit analysis estimated that a more sustainable development scenario would result in a net gain of $687 million when compared to a traditional full build-out scenario (Marbek, 2010c).

How can values inform the use of offsets to operationalize sustainability?

The quantification of ecosystem services and biodiversity can help to inform the evaluation of "offsets" that aim to lessen the net impacts of development. For example, the stormwater-buffering capacity of a particular green-field could be quantified in units of litres of water. The impact upon this capacity of a commercial development could be calculated, based upon design details such as whether the development would include a green-roof and permeable pavement, and any off-site solutions such as the rehabilitation of degraded wetlands to increase their water-holding capacity. If development policy mandated a "no net loss" of stormwater capacity, then the proposed development would need to account for how the loss will be fully offset. Such an approach employs macro-control with micro-flexibility, which is a principle of cost-effective environmental policy. For this reason, offsets are often used as part of a quantity-based economic instrument, detailed in Section 8.

Ontario and other comparable jurisdictions are increasingly employing concepts like "no net loss" or "overall benefit" to minimize the loss of ecosystem services and biodiversity. The European Union has a target of "no net loss of biodiversity and ecosystem services" by 2020 (European Commission, 2011). The Alberta Land-use Framework proposes land conservation offsets to "address biodiversity or natural value loss" (Government of Alberta, 2008). The Ontario *Endangered Species Act, 2007*, uses "overall benefit" as a criteria to permit development in regulated habitat. The Toronto and Region Conservation Authority continues to refine its protocol for determining "compensation" for ecosystem services as a way of achieving its natural heritage target (TRCA, 2009). The Lake Simcoe Region Conservation Authority (2017) has developed its own "ecological offsetting plan".

How can values support the prioritization of lands for conservation?

Valuation can help to prioritize the protection of landscapes that are vulnerable to development. Landscapes in Ontario can be newly protected by a variety of means, including restrictive covenants on their title and (or) the transfer of ownership to a conservation-oriented organization. To be effective, valuation should reveal the incremental gains from protection *beyond the baseline probability of loss or impairment* of ecosystem services and biodiversity. This baseline probability of loss is very important; a low probability of loss means the value of its protection is much smaller in comparison to a higher probability of loss. If a development application is being considered, then its probability of loss or impairment is known. If development is not being considered, then the probability of development could be forecast, to inform the prioritization of its protection. Probabilities might be assessed on the basis of land-use plans, which might include zoning. If there are too many uncertainties, probabilities cannot be determined, so possible scenarios would instead need to be used.

Organizations with an interest in protecting natural areas might find it useful to undertake a Cost-Benefit-Loss Analysis to help prioritize securement. This would integrate the costs of securement with considerations about the value of ecosystem services and biodiversity, multiplied by their baseline probability of loss (e.g. Newburn et al., 2005). Since the market value of land will naturally reflect any economic premium of its location, lands with the highest probability of loss tend to be the most expensive to secure. But this type of land might also provide a high economic value of ecosystem services and biodiversity given its proximity to people and infrastructure that would benefit from its services. Integrating these considerations would improve the effectiveness of conservation.

How can values inform the economic case for ecosystem rehabilitation?

Valuation can help to inform the benefits side of a business case for rehabilitating degraded landscapes. Rehabilitation costs money, so it can be helpful to describe its benefits in monetary terms as well. Valuation could inform the details of rehabilitation, such as making the area accessible to people for recreational purposes, or using bioremediation techniques over more traditional mechanical or chemical ones. To the extent that pricing the unpriced benefits of enhanced ecosystem services and biodiversity will reveal that rehabilitation is not an entire economic sacrifice, then this could be helpful to support action. To the extent that it would reveal economic gains that exceed losses, then this could complement the ecological case for rehabilitation.

Ecosystem rehabilitation is typically motivated by principles of justice rather than economic efficiency. For example, rehabilitation may be legally mandated as a remedy for past damages. Sometimes past damages are difficult to legally attribute to an entity that still exists in the present. In such cases, damaged ecosystems tend to become assumed by the public sector. In other cases, damages might have been generated by governments, such as from military operations in Ontario's north. In the public sector, the effort required to rehabilitate damaged ecosystems is typically juxtaposed against other competing public priorities. In such circumstances, economic valuation can help to inform decisions.

In the USA, Benefit Cost Analysis is mandated for projects that involve spending above a certain threshold. This type of analysis is meant to consider the market and non-market gains and losses that result from a decision, and in comparison with competing alternatives. Theoretically this analysis would recommend against projects whose costs exceed benefits. In practice, some environmental projects are still advanced on environmental and social grounds even if their economic costs are estimated to exceed the sum of their priced and unpriced benefits (Goodstein, 1995). In Ontario, Cost-Effectiveness- or Multi-Criteria-Analysis is more likely to be used to inform decisions, including whether ecosystem rehabilitation is preferable to other projects in the public interest. In all of these types of economic analysis, economic valuation of changes to ecosystem services and biodiversity would help to inform decisions.

How can values inform the management of existing conservation areas?

When lands are already protected from being traded-off against development, valuation can be helpful to communicate the economic benefits of ongoing protection and the relevance of monitoring and assessment programs. Narratives about the benefits might be more useful to communicate than monetary values, which imply a trade-off-ability and might confuse if there is no intention to trade-off its status as a protected area. However, there may be cases when the protected status of an area is deliberately re-evaluated, or is contemplated to be re-evaluated after a development scenario is proposed.

Protected areas often need to be defended against those who view them as a last-resort source of consumable natural resources or as a strategically opportune corridor for energy and transportation infrastructure. If the economic merits of such scenarios are to be entertained, then the decision should be equally informed about the value of the unpriced benefits of ecosystem services and biodiversity that would be lost.

Because protected areas tend to include very rare if not unique natural features, their economic value should be assessed first-hand rather than transferring an existing value from another application. Also the valuation methodology should reveal people's Willingness-To-Accept (WTA) compensation rather than Willingness-to-Pay (WTP) for protection, since the scenario is one of a loss, not a gain. People tend to be more loss-averse than they are averse to gains (Horowitz and McConnell, 2002).

7. Non-market values can inform Balance Sheets and Economic Accounts

What are economic accounts?

Ontario has "Economic Accounts" that are produced by the Ontario Ministry of Finance (2018). The accounts track the production and exchange of goods and services in the marketplace. Data for the accounts are sourced from Statistics Canada, which produces them following an international convention called the System of National Accounts (SNA) (United Nations, 2008). The convention includes rules for generating measures of investment, expenditures, income, and production, including Gross Domestic Product (GDP). The convention also includes rules for tabulating measures of wealth, from information about capital and other assets and liabilities. Because the convention is international, it helps to make comparisons between jurisdictions at the national level, and to be aggregated into global statistics, and to be used to generate sub-national statistics.

Even though the word "economic" is used to describe accounting that follows the SNA, the accounts should be understood as a more narrow system of *market* accounts. The accounts are based upon market-priced values with relatively few non-market estimates, such as the "imputed rent" paid by homeowners to themselves and other occupants. Similar to unpaid work done at home and other non-market activities, most of the economic benefits from ecosystem services and biodiversity are missing from economic accounts because they are unpriced. Attempts have been made to broaden economic accounts to include non-market values, but so far have resulted in additional accounts rather than revising existing ones.

What is a balance sheet?

A balance sheet reports on capital that is owned, such as buildings and other forms of built capital. A balance sheet also identifies other "assets" that are beneficial claims upon the future income or services provided by someone else. A balance sheet also identifies "liabilities" that are obligations to provide income or services to someone else in the future. The balance of assets, less liabilities, plus the stock of capital, can be summed to generate a measure of net wealth. The composition and changes of a balance sheet can inform an understanding about how wealth is trending, to inform an assessment of sustainability.

A balance sheet can be specified for a person, a household, a government, a corporation and any other legal entity. A national balance sheet is produced by Statistics Canada as an aggregation of all components of all balance sheets within the country. Balance sheets for government organizations in Ontario can be found in the Public Accounts.

In principle, natural capital funds could be included on balance sheets. And various dis-services such as environmental contaminants leaking from storage tanks, and degraded ecosystems could also be included as liabilities. However, balance sheets tend to be informed by market-priced values, following the same practice within the System of National Accounts. For this reason, only natural capital stocks that provide (priced) ecosystem goods are likely to be found on balance sheets. Since December 2015, Statistics Canada includes "natural resource wealth" in its National Balance Sheet Accounts but this only includes the market value of harvestable timber that is not yet harvested, plus saleable reserves of various minerals and fossil fuels (Statistics Canada, 2018). The Town of Gibsons BC has intended to include natural capital funds onto its municipal balance sheets, but has faced challenges such that it generated a multi-stakeholder Municipal Natural Assets Initiative project to further evaluate this (Municipal Natural Assets Initiative, 2017).

Why should non-market values be integrated into economic accounts?

The economic accounts command the attention of many decision makers because they provide "executive summaries of complex realities" (Jesinghaus, 1999). For this reason, many advocate the inclusion of non-market values to signal their relevance and importance, and to understand their complexity. Ecosystem services and biodiversity are complex; their indicators can generally be characterized as inaccessible, relying upon sparse data, and not linked to market-priced transactions. Consequently, there is a gap between the needs of policymakers and the current set of biodiversity measurements.

The impacts of economic activity upon ecosystem services and biodiversity are more significant than ever before. These environmental impacts have economic costs that are often not observed or reflected in the economy over the short term. Some organizations have cautioned that the impacts of economic activity on environmental systems are putting future economic growth and development at risk (e.g. OECD and IEA, 2011). This would ideally urge proponents of economic growth to be even more interested in reducing pollution and resource depletion to conserve biodiversity and ecosystems.

Society pays attention to what is measured and also how it is measured. Integrating information about ecosystem services and biodiversity into the economic accounts could support broader and more robust measures of wellbeing. This could provide a more accurate representation of the interdependence of economic and natural systems. Policy makers would no longer be able to view the economy and the natural world as two independent systems. Ecologically, it is important to know the state of the environment to highlight conditions, monitor trends, and assess impacts. As reviewed earlier in this report, the economic benefits from unpriced ecosystem services can be just as important as their priced goods, so they should be managed and accounted for accordingly.

What challenges the integration of non-market values into economic accounts?

The building blocks of the economic accounts are quantities (Q) and prices (P). Economic statisticians use the results of marketplace transactions, such as units sold and prices paid, to accurately, and relatively quickly, construct the national economic accounts. Aggregate values, such as measures of Gross Domestic Product (GDP) reflect the multiplication of each Q by its respective P. The distinction and independence between quantity and price is not always clear cut. For example, the calculation of the aggregate quantity of built capital may rely on present value calculations of net profits which employ an interest rate, which is a price (Victor, 1991).

For ecosystem accounts, there are additional challenges. In terms of Q, there is a need for a clear definition of the goods and services to be counted both in terms of quantity and quality. In terms of P, weights are needed to ensure the differences in the value of goods and services are reflected in the index. Clearly, the value of different ecosystem goods and services will largely depend on how they are defined, which underscores the importance of developing standard and robust quantified measures of ecosystem services.

Biodiversity poses some unique challenges for accounting frameworks. Our lack of understanding of many of biodiversity's key roles in ecosystem services makes it difficult to determine appropriate quantity and quality metrics (Qs), as well as applicable biophysical or economic weights (Ps). Biodiversity relates to the economic accounts in many ways: it is an environmental asset, it is an input into economic production, it is a component of ecosystems (which generate ecosystem goods and services), and it is an indicator of ecosystem condition (McDonald, 2011). Recognizing this diversity is important for developing ecosystem accounts. Biodiversity can be measured in terms of prices (such as value estimates derived from using nonmarket valuation techniques), quantities (such as tonnes or cubic metres), and qualities (such as indices of its condition, from 0-100) (McDonald, 2011). All three of these metrics provide important, and complementary, information for decision making.

What is the new System of Environmental-Economic Accounting?

An international convention called the System of Environmental-Economic Accounting (SEEA) was adopted by the United Nations Statistical Commission in 2012 as its first international standard for environmental-economic accounting. It was developed to use information and conventions from the System of National Accounts, so that it could profile linkages between them. As such, the “core framework” of SEEA is focussed on ecosystem goods, which SEEA calls “natural resources”, and emissions. Ecosystem services are explored through an “extension” called Experimental Ecosystem Accounting, which has been labelled as SEEA-EEA. Since this approach is an international convention, there are merits to considering this approach to make the accounts of any jurisdiction more genuinely “economic” by considering non-market values. Nevertheless SEEA and SEEA-EA are not the only means for creating ecological economic accounts and balance sheets.

Statistics Canada has implemented parts of SEEA in its Canadian System of Environmental-Economic Accounting (Statistics Canada, 2018). Since 2015, this system has been used to calculate a measure of “natural resource wealth” that appears on the National Balance Sheet Accounts, as the sum of the market-priced value of harvestable timber that is not yet harvested, plus saleable reserves of various minerals and fossil fuels. At this time, the publicly available national data cannot be queried for Ontario – so if Ontario were to develop its own timber accounts, it would need to engage Statistics Canada in order to access the data.

In 2011 Statistics Canada secured funding to develop a prototype ecosystem account system in close collaboration with various natural resource departments including Environment Canada, Agriculture and Agrifood Canada, Fisheries and Oceans Canada, Natural Resources Canada (Bordt, 2011; Bordt 2012). This required developing standard land cover, ecosystem, and ecosystem service classifications, collecting key biophysical data, creating indicators of ecosystem quality and researching appropriate valuation methodologies. This work is no longer ongoing, and concluded with a 2013 publication *Measuring Ecosystem Goods and Services in Canada* which made use of existing Ontario data about land-cover and ecosystem services (Statistics Canada, 2013).

8. Economic Instruments can internalize non-market considerations

What are economic instruments?

Economic instruments aim to more closely align economic self-interest with shared interests in the conservation of biodiversity and natural capital funds that provide ecosystem services. When successful, economic instruments correct market failures, by lessening the ability of markets to externalize costs and deplete ecosystems. The resulting outcome is greater economic efficiency, with the potential to enhance the sustainability of outcomes, and address distributional concerns, such as by having polluters and resource depleters pay, rather than other people who suffered the consequences of market failures. Generally, economic instruments target three different groups: *beneficiaries*, *damagers*, and *enhancers* whose actions can improve ecosystem services and biodiversity (Blom et al., 2008). Beneficiaries gain value from biodiversity, so they suffer losses caused by damagers, and gain value from the outcomes of enhancers. Enhancers are motivated to improve ecosystem services and biodiversity by incentives that ought to be provided by beneficiaries (to yield an overall gain) and by damagers (to remedy loss).

An instrument is deemed to be *economic* if it promotes economic efficiency and ongoing improvements. This is sometimes communicated as being "compatible" with markets, or being "market-based" (e.g. Adamowicz & Olewiler, 2016). In contrast, non-economic instruments remove decisions from the marketplace by prescribing how something should be done; such instruments are sometimes labelled as "command-and-control". Economic instruments can result in more cost-effective outcomes, meaning that less human effort is needed to achieve the same outcome, which means that more conservation could be achieved with the same effort. Just like musical instruments, the word *instrument* is used to communicate that great skills are required to use them, and there are many ways of using them, and their outcomes can vary depending upon the circumstances in which they are used. Similarly, there are many ways of categorizing economic instruments that are in use within Ontario.

What are information-based instruments?

Information-based instruments generate information about the environmental performance of specific products, or processes, or producers. This helps to increase the efficiency of markets by informing consumers and/or investors and/or producers and/or regulators. Businesses with superior performance can be rewarded as compared to businesses with inferior performance. For example, fisheries and the forest industry may have reduced direct impacts on biodiversity (as a result of more efficient or low-impact production processing methods) and biodegradable detergent may have reduced indirect impacts (due to a decreased pollution load). Tools for quantifying and valuing the environmental impacts of businesses are being developed. The UK-based firm TruCost has developed a process to include the unpriced damages of production, along the supply chain, of specific consumer products. This can inform consumers and allows companies to inform investors with "environmental profit and loss" statements (e.g. Kering, 2015).

Information about biodiversity impacts is captured by some eco-labelling and certification programs for ecosystem goods. The Marine Stewardship Council (MSC) is the world's largest and most recognized sustainable fishing scheme to provide eco-labelling and independently verified certification. In the forest industry, there are many certification standards and registration systems. All certification programs used in Canada require some level of conservation of biological diversity including maintenance of wildlife habitat and species diversity. Most forestry management units in Ontario are certified by one of many standards including the Canadian Standards Association (CSA), the Forest Stewardship council (FSC), and the Sustainable Forestry Initiative (SFI) (OMNR, 2014). The Cornerstone Standards Council (2015) developed a certification system for aggregates in Ontario. On a much smaller scale, the Credit Valley Conservation Authority has developed a system to certify "bird-friendly certified hay" to support the recovery of threatened grassland birds; included in this system is an exchange platform to connect buyers and sellers of hay and suitable land (Credit Valley Conservation, 2018).

How can liability-based instruments affect environmental outcomes?

Liability-based instruments create a legal obligation for environmental outcomes that would otherwise have been externalized. This obligation has the effect of internalizing the costs of damages and remediation, which thereby incentivizes prevention and other efforts to minimize risks and costs. Such instruments are often based upon the polluter-pay-principle which requires the pricing of damages and degradation of ecosystem services and biodiversity. With these damages priced, individuals who are liable could better understand the value of the damage and adjust their behaviours accordingly. As detailed in Section 10, courts in Ontario have considered non-market values in their deliberations and judgements. Liability-based instruments can also include the redefinition of property rights, such as adding a conservation easement on an existing land title, to make the property owner liable for uses that are not compatible with conservation.

While most of the early liability rules focused on air pollution, oil spills, and nuclear risks, more recent liability rules incorporate broader environmental concerns. Ontario's Environmental Bill of Rights is a liability-based approach that "protect, conserve and restore the integrity of the environment, to provide sustainability of the environment, and to protect the right of Ontario residents to a healthful environment" (Environmental Commisioner of Ontario, 2013). It does this by providing legal rights to residents to challenge policies and decisions and the rights to sue for some environmental-related damages, thereby making others liable for environmental outcomes. Several Acts in Ontario allow the government to require some form of "financial assurance" from proponents seeking authorizations that could generate a future environmental liability. The amount of assurance should ideally relate to the costs of mitigating a potential liability, as a way of internalizing its value onto the balance sheet of the proponent as a liability, and on the balance sheet of the regulator as a financial asset.

Federally, the Environmental Damages Fund accumulates fines, court orders, and voluntary payments, and expends the fund on projects that restore the natural environment and conserve wildlife. Priority is given to projects that operate in the same geographic region where the environmental damage occurred. An example is an environmental damage assessment conducted by Environment Canada for a fish kill event on Prince Edward Island. Economists quantified and valued the damage caused to the local recreational fishery in terms of the lost ecosystem service flow and expenditure. Compensation for the environmental damage was used to finance fish restoration projects in the area (MacDonald et al., 2002).

How do price-based instruments affect outcomes?

Price-based instruments intentionally affect the costs or benefits of some behaviour, for the purpose of influencing the amount of that behaviour. As detailed earlier, marketplaces reward the generation of negative externalities because suppliers and demanders will personally gain when costs are externalized. This problem can be managed by having suppliers or demanders pay a fee (in the form of a levy, tax, user fee, rent, or royalty) when they damage biodiversity or ecosystems. Or suppliers or damagers could be paid (in the form of direct payments, credits against taxes, and other subsidies) if they enhance the supply of biodiversity or ecosystem services. Success of price-based instruments relies upon being able to set a price that will generate the intended outcome.

Positive price-based instruments set a price at the minimum it takes to get an enhancer to generate the intended outcome. This minimum is known by enhancers, but not known by those setting the price. This minimum is the enhancer's net cost of making the change, which economists will say is the direct costs plus the enhancer's "opportunity cost" such as the foregone commercial benefits from using land for agricultural production rather than for serving as a wildlife sanctuary. This minimum can be estimated from the market prices and production costs of certain activities, however there are many unknowns that make this estimation challenging. It can also be estimated by using reverse auctions if there are sufficient numbers of potential bidders, as detailed later.

Negative price-based instruments set the price of a tax or fee at least equal to the estimated value of the damage. This relates to valuation and accounting, covered earlier in this report. Environmental taxes may be applied to damagers of ecosystem services and biodiversity to discourage specific pollutants or activities. For example, water charges can be applied to industrial water use to ensure the business is recognizing the value of water in its production decisions. For beneficiaries, a user fee or charge might be used for certain activities that are not damaging, but related; for example, visiting protected areas.

How can Payments for Ecosystem Services (PES) be used?

Payments for Ecosystem Services (PES) is a positive price-based approach that provides payments to enhancers of biodiversity or natural capital funds. Ideally, payments are conditional upon the successful enhancement of specific ecosystem services or components of biodiversity. To maximize economic efficiency, the payment system should minimize the cost of payments and their administration, while maximizing the generation of incremental non-market value. In practice, efforts to economise on administrative demands means that payments are often tied to a parcel of land or certain land use patterns, on the assumption that this relates to an enhancement of biodiversity or ecosystem services. The payment itself can be administered in a variety of ways such as a tax credit, an annual payment, or a one-time payment. Tax credits often prove to be more effective for motivating change than an equivalent value provided by another means. However tax policy is not usually set by ministries or agencies that are accountable for ecosystem services and biodiversity, so tax-based payments are rarely used despite eagerness from natural resource managers.

Across Canada and in Ontario, several PES systems have been developed and administered by farmers under the banner of Alternative Land Use Services (ALUS). In Ontario, the Norfolk ALUS pilot project was launched in 2007 and the Huron County Payments for Environmental Goods and Services (PEGS) pilot project was initiated in 2008. Both projects set a fixed annual payment to participating farmers based on average land rental rates, in exchange for farmers supporting the recovery of endangered species and spaces, such as re-establishing native tallgrass prairie habitat.

Between 2007 and 2009, Agriculture and Agri-Food Canada piloted 8 PES projects across the country (Campbell, 2010). Results were used to inform the department, and the country, about various aspects related to the design, effectiveness, and efficiency of PES systems applied to farmers and farmlands. Of note, tradable permits (a quantity-based economic instrument) tended to be twice as cost-effective as auctions (a way of informing price-based instruments) which were about twice as cost-effective as fixed annual payments (Agriculture and Agri-Food Canada, 2009).

How can reverse auctions inform payments under a PES?

Reverse auctions are one way of revealing the minimum price needed for a positive price-based instrument, such as the payment under a PES. In this type of an auction, potential enhancers compete for an incentive by under-bidding each other. The winning minimum bid will reveal the cheapest price that is needed to motivate at least one unit of an intended outcome. Economists support reverse auctions because they are very cost-effective. For the same reason, enhancers generally dislike reverse auctions because they would prefer to be paid a higher price.

Around the world, reverse auctions have been used for wetlands (e.g. Wetlands Reserve Program in the United States, BushTender in Australia), for water (e.g. EcoTender in Australia), for forests (e.g. Tasmania Forest Conservation Fund in Australia), and for general agricultural land (e.g. Conservation Reserve Program in United States). In 2009, a reverse auction for wetlands restoration was conducted in the Assiniboine River watershed in Saskatchewan (Hill et al., 2011). An environmental benefit index was used to rank the final bid price per acre based on the predicted incremental increase in hatched waterfowl nests. A total of 30 bids for 12-year term agreements were successful to restore 211 wetlands covering 211 acres at an overall price of $182,000. The average annual cost per acre was $119 with a range of $21 to $391. The large cost variability highlights the potential cost savings of using reverse auctions compared to uniform payments. A similar auction took place in 2012 and 2013 in the East Interlake Conservation District of Manitoba (Noga & Adamowicz, 2014).

How do quantity-based instruments affect outcomes?

Quantity-based instruments aim to directly affect the amount of biophysical benefits that are used, enhanced or damaged. This quantity of benefits can include specific ecosystem services, or other metrics that relate to them, such as the number of hectares of wetlands in a watershed that are newly protected or the quantity of phosphorous entering lake from controlled sources. Quantity-based instruments are used to affect the supply of biodiversity and ecosystems, usually for the purpose of sustainability. The amount sustained is affected by requirements (for regulations) or voluntary motivations (for incentives) to enhance them (by enhancers) or to pay for their use (by beneficiaries) or to pay for their damage (by damagers). The price of quantity-based instruments is not set; the price reflects dynamics including supply and demand for the quantity.

An accounting system can track who has done what to affect the quantity of benefits. Often there are permits or some other claim that relates to a specific quantity. Claims must be exclusive to just one person or organization, otherwise the quantity of benefits will not be successfully affected, and the instrument will not achieve its objective. Exclusive claims are often tradable. A monitoring and auditing system adds rigour to the accounting system so that it reflects true information. Quantity-based instruments can be used in various ways, depending upon the conservation objective of setting up a system.

How can trading systems support conservation?

Marketplaces can be created to support systems that allow quantity-based instruments to be traded. As long as there are enough potential market participants, trading can generate cost-effective outcomes. Buyers will choose the cheaper of two alternatives: undertake the action themselves, or buy the cheapest claim from someone else. Sellers will provide more outcomes in response to demand. The market price of traded claims will reflect the cost of an additional unit of conservation outcome.

As with all marketplaces, the success of a conservation-oriented marketplace will depend upon many factors, including the relative number of suppliers compared to demanders, the absolute number of participants, and the metrics used to define the conservation outcomes. Cost-effectiveness can be challenged by high transaction and administrative costs depending upon various factors including the costs of accounting, monitoring, and auditing trades. Careful design is required to reduce some of these costs and simplify the trading system.

Water quality trading is a common example of a trading system used in Canada (Voora et al., 2009) and around the world (Flombaum and Sala, 2009). The South Nation Conservation Authority in Eastern Ontario created a water quality trading system for phosphorous that covers both point and non-point sources. Landowners get credits for implementing best management practices on their land that reduce phosphorous leaching in the watersheds. Point source polluters can purchase these credits to offset their own phosphorous emissions, to meet their phosphorous targets. It has been estimated that technological control options would cost 10 times more than the trading system price of $390 to achieve the same reduction in phosphorous (Knight, 2010). This cost-effectiveness on the part of the payors has not lessened its appeal to payees, as 85% of landowners would recommend that other watersheds undertake a similar program (O'Grady, 2011).

This continues to be used to inspire the setup of new trading systems, including one being setup within the Lake Simcoe watershed by the Lake Simcoe Conservation Authority.

How can conservation offsets be supported by trading systems?

An intention to minimize the net loss of biodiversity and ecosystems is generally informed by a mitigation hierarchy. This hierarchy is a decreasing preference of: avoiding impacts, minimizing impacts, restoring or rehabilitating impacts on-site, and finally offsetting any residual impacts. This follows the approach that has been established in the science and policy of mitigating damages to aquatic or terrestrial ecosystems, or specific species (McKenney & Kiesecker, 2010). While human developments can often avoid and mitigate environmental impacts such as habitat loss and pollution, there will inevitably be some residual negative impact on ecosystems and biodiversity. While not always used concurrently, offsets and biodiversity banks can counteract these impacts. Depending upon the rules, offsets might be used to partially or fully offset losses, or to generate an overall gain if the offset overcompensates for a given loss. If a gain is created but not yet used to offset a loss, then it may be "banked" under a conservation bank or species bank system.

Biodiversity offsets are created from actions that provide measurable biodiversity benefits, such as protecting an existing habitat at risk or restoring a degraded habitat. Markets for biodiversity offsets are increasing in prevalence and size throughout the world as more jurisdictions mandate offsets (Bennett et al., 2017). The majority of offset policies and programs are in middle- or low-income countries (Gelcich et al., 2017). Among high-income countries, Australia is usually credited as a leading jurisdiction with high endemic biodiversity and a long history of using offsets and a formalized offset registry (May et al., 2017). The World Bank's International Finance Corporation requires its clients to apply a performance standard of biodiversity conservation, through the use of the mitigation hierarchy (IFC, 2012). A Business and Biodiversity Offset Programme (2009) was created through international collaboration to support the development of biodiversity offsets that achieve cost-effective and equitable conservation outcomes.

Ontario's *Endangered Species Act, 2007*, mandates the protection of endangered and threatened species and their habitat, on a species-specific basis. The Act conditionally permits actions that affect species and their habitat, such as if they would be offset in such a way as to result in "an overall benefit" to the species. One challenge to date with the implementation of this Act is the absence of a trading system in Ontario to facilitate the creation of benefits. Offset-seekers are typically land developers who have no idea how to provide benefits to species, other than a willingness to pay others to do this. Offset-providers are typically rural landowners and conservation organizations that have the capability to do good things for species, but need funding to make it happen. Currently there is no easy way for these two groups to meet. A trading system could help, such as the Species-At-Risk Benefits Exchange (SARBEX) proposed by Miller & Lloyd-Smith (2012).

Why are equivalence metrics needed to enable conservation offsets?

Equivalence metrics are used to define and evaluate the benefits of offsets and the impacts of damages that the offset seeks to lessen. This helps to operationalize the concept of no net loss, or an overall net benefit, by comparing gains against losses using a standardized measure. To be effective, metrics should enable decision-makers to compare changes over time, to allow comparability between offsets and losses and a baseline. Ideally, a metric would measure the impact of conservation actions on the likelihood (negative in the case of debits and positive in the case of credits) of the particular species surviving. In practice, surrogate measures are often used such as acreage of habitat or habitat quality. The ecological effectiveness of conservation offsets is heavily dependent upon the metric's unit of equivalence; critiques of offsets are often critiques specifically about the measure of equivalence. Perspectives on offsets have remained diverse, such that "it is both the dream and the nightmare of conservation" (Devictor, 2015).

The effective use of conservation offsets will involve the management of various aspects of uncertainty related to space and time (e.g. Overton et al., 2013 in the case of biodiversity offsets). Three important questions are: 1) How effective are the metrics of equivalence at representing the suite of ecosystem services whose value is to be sustained? 2) How likely are outcomes from the permitted actions? 3) How can actions (or outcomes) be determined to be additional to what would have happened anyway, to ensure that it is a true offset?

The United States has well-developed programs of wetland-mitigation banking, and conservation banking. It remains the largest share of the global market for compliance-driven programs (Bennett et al., 2017). Federal regulations require metrics that assess equivalence in terms of wetland acreage and function. However, the difficulty in assessing the functional values of wetlands has meant that, in practice, acreage alone serves as the most commonly used metric. For conservation banking, federal guidelines are flexible in determining the metric used to determine credits and debits because conservation banks include both species and habitat credits. Habitat acreage is a more commonly used metric.

How can nudging motivate voluntary pro-environmental behaviour?

The word "nudging" has been used to describe approaches to affect human behaviour by relying upon social norms and not monetary incentives and not coercion through legal or other means. This approach has gained an interest among social policy professionals, and has intrigued scholars interested in pro-environmental behaviour. Generally, "green" nudges play to the tendency of humans to desire an attractive self-image, and/or to emulate peer behaviour, and/or to set default choices (Schubert, 2017). The success of nudging relies upon the strength of pro-social norms, such as being motivated by an understanding of what conduct is expected of others, and what others expect of our own behaviour (Farrow et al., 2017).

Although some have favoured nudging as a form of "libertarian paternalism" as a substitute for monetary or coercive policy, nudging is a potential complement to other economic instruments. Nudging can pair with informational instruments, with some applications of nudging supplying additional information; some applications of nudging have used *mis*information such as overstating how many other people are participating (Goldstein et al., 2008). Some experimental results suggest that environmental information is not helpful to generating nudged outcomes, with the European Commission (2014) advising "don't mention the environment" when aiming to generate pro-environmental behaviour among audiences that are not environmentally oriented.

Behaviour-based instruments could be relevant to inducing small-scale, low-cost conservation outcomes that would otherwise be costly or impractical to achieve by monetary or legal means. To date, this is a relatively low-researched strategy, with about 10-times more publications in ecology and conservation biology related to the use of price- or quantity-based instruments, and 25-times more research related to the use of coercive mechanisms such as fines and physical exclusion of people such as using fences (Santangeli et al., 2016). These same researchers profile many low-cost actions that have generated high-impact returns to species in parts of Europe, such as buffer strips and uncultivated margins around pasture fields. In Finland, some research has revealed a role for nudging as a way of amplifying the pro-environmental behaviour generated by price-based systems (Matthies et al., 2016).

To generalize results to an Ontario context, behaviour-based approaches are more likely to be effective when the behaviour results in outcomes that are recognizable by others, and fits with existing normative expectations. The Environmental Farm Plan began 25 years ago without much in the way of monetary incentives, relying upon the voluntary effort of farmers to subscribe and comply with the program and be awarded a sign that reads "our farm has an environmental farm plan" (Schaer, 2016).

Which criteria affect the choice of a specific instrument?

Several criteria can influence the choice of an instrument. These include conservation effectiveness, economic efficiency, equity (including distributional effects), the impacts upon innovation, administrative feasibility, flexibility, the complementarity with other instruments and existing policy frameworks, and the impacts upon stakeholders and their support and participation in its selection and design. Research about the choice of instruments has revealed several general themes. No single instrument is superior along all of the criteria identified above.

Table 1 below identifies three different purposes for economic instruments: raising funds, informing markets, and recovering damage costs (Sawyer et al., 2005). In general, as the purpose of economic instruments moves from simply raising funds to recovering damage costs, more effort will be needed to administer the instrument and value the unpriced benefits. A tailor-made approach is ideal, with the choice, design and complexity of the instrument reflecting local conditions. The chosen approach will reflect trade-offs between criteria, such as economic efficiency versus administrative feasibility, versus efficiency, and versus equity. The approach may require shifting from one instrument to another as ecological and economic conditions change.

Table 1: Different purposes of economic instruments

	Primary Purpose of an Economic Instrument		
	Raising funds	**Informing markets**	**Recovering damage costs**
Reliance upon the valuation of unpriced benefits	Little	Moderate	High
Administrative Demands	Little	Moderate	High
Examples	Hunting licenses	Permits, payments, bonds	Damage assessments
	→ Increasing Effectiveness and Administrative Demands →		

One specific instrument is not likely to achieve all biodiversity protection and conservation goals. For this reason, "took kits" are often advocated, to contain a portfolio of instruments.

The diversity of activities, sources, and sectors affecting biodiversity often requires the implementation of a combination of policy tools. An insightful analogy is to think about economic policy. Economic policy can never be simplified to one policy instrument. Rather, its success relies upon a mixture of policy tools. The same holds true for biodiversity protection and conservation.

What affects the success of economic instruments?

A general lesson from the scholarly literature about economic instruments is the importance of anticipating interactions and compatibility. Instruments, funding, and policies controlled by one government department or one level of government will almost always have implications for existing policies enacted by another government department or level of government that target the same actor. A particular person or organization being influenced by instruments will also be influenced by other funding, and other policies of non-governmental bodies, such as industry associations. It is important to identify potential policy interactions in advance of considering economic instruments for the protection and conservation of ecosystem services and biodiversity.

Economic instruments are just one set of approaches. Other approaches include regulatory tools that compel actions or outcomes, and educational programs that raise awareness and support for the internalization of negative externalities within the marketplace. There are many complementarities between these approaches and economic instruments, and among various economic instruments as identified earlier. Historically, Canada has lagged behind the world in the use of economic instruments as policy options (OECD, 2004). Governments in Canada, including Ontario, have traditionally relied on subsidies, tax credits and regulations that uniformly command and control the behaviour of specific actors. An assessment by Kenny et al. (2011) for Sustainable Prosperity revealed a growing interest, and documented use, of economic instruments for biodiversity conservation and protection in Canada. More recently, that same institute identified an ongoing need for the greater use of economic instruments for species recovery in Canada, together with multispecies and ecosystem-based approaches, enhanced funding and funding mechanisms, and better use and dissemination of data (McFatridge & Young, 2018).

9. Information exists about ecosystem services in Ontario

How much information exists and where can it be found?

The most comprehensive and longest-running inventory of Ontario-specific information about the economic benefits from ecosystem services and biodiversity exists in the Environmental Valuation Reference Inventory (EVRI). EVRI is maintained by Environment Canada and is recognized as an important database of research publications. Even though the inventory has not been consistently updated with new information, a content analysis of its data undertaken in the first TEEBO report in 2012 is still informative. A key finding is that more information recorded in EVRI was generated after the year 2000 than before. This reflects the same pattern uncovered by global analysis of published research that is inventoried by other databases (e.g. Costanza et al., 2017): most formalized knowledge about ecosystem services and their economic valuation is from the 21st century.

EVRI accounted for more than 3,000 studies published up to the year 2010 from around the world, of which 84 related to assessments in Ontario (Miller and Lloyd-Smith, 2012). Ontario studies inventoried in EVRI tended to focus on the services of recreation and the regulation of air and water quality. Ontario studies tended to apply more to the southern and settled areas of the province. More than half of the Ontario studies (50 studies) were published between 2000 and 2010. Roughly two-thirds of the studies used primary valuation (54 studies) and one-third used the value transfer approach (30 studies). There has been an increasing trend towards more comprehensive assessments that include multiple ecosystem services. All of these assessments, and more recent ones discovered by the present report's author, can be assessed on a geographic basis, as follows.

What information is specific to the Far North?

Ontario's Far North is the northern 42% of Ontario's land mass, from the Manitoba border to James Bay and Quebec (OMNR, 2018a). This area is believed to be a significant global carbon sink, with about 12.5 million tonnes of carbon absorbed annually (OMNR, 2009). This ecosystem service of carbon sequestration is globally valuable. But the unit economic values of other ecosystem services are likely to be relatively less significant than in the southern parts of Ontario because they are less scarce in the Far North, with fewer beneficiaries demanding the services from a relatively greater supply of ecosystems. There are spatial inventories of the northern landscape, but its resolution is lower than southern land inventories and in the Area of the Undertaking. To date, that spatial inventory has not been linked to a database of ecosystem services and the economic value.

In 2008, the International Institute for Sustainable Development assessed the ecosystem services provided by the Pimachiowin Aki World Heritage Project Area, about 40,000 Km^2 straddling the Ontario and Manitoba border. This study qualified the geographical scale of the service flows, with an estimate that about 25% of the annual flows exclusively benefit the residents of the area (Voora and Barg, 2008). This study used a spatial value transfer approach, and the authors were appropriately cautious when transferring results from other research. The study identified other "potential" services that are appropriate to the landscape (such as carbon storage, water filtration), but whose values could not be applied to the area's smaller non-urban population. The study aimed to "initiate discussion" to support the area's designation for protection; it is not clear how the value of the ecosystem services would be different if the area was designated as a biosphere reserve versus if it was not.

Land-use planning in the Far North is underway as a pre-requisite for expanded resource extraction. The draft Terms of Reference for the Community Based Land Use Plan for the Attawapiskat First Nation included the consideration of natural capital (Stantec, 2015). Natural capital was considered as a "valued component" to be identified and organized into three broad categories. The categories distinguish between "sites that are considered suitable for protection" and "resources considered suitable for exploitation" and components that are "ecologically, economically, or culturally significant". After this categorization, the plan proposed to assess the components by means of an "ecological functional assessment" and then "resource valuation" to households and the regional economy, using "standardized resource valuation methodology". Without further elaboration, it is hard to assess how many "standardized" methods would suit the local context; a deliberative approach to contingent choice would seem to be more relevant than methods that derive non-market values from market prices. As of early 2018, the Attawapiskat plan has not yet been approved, while four other land-use plans have been approved but none of them explicitly identified natural capital.

What information applies to the Canadian Shield?

The Canadian Shield in Ontario that is south of Ontario's Far North is mostly Crown forest that is divided into management units (OMNRF, 2018b). This area includes settled landscapes and some ecosystems that are relatively unique, such as alvars, which limits the possibility of value transfer from other landscapes. Value transfer has been used to understand ecosystem services flowing from forested landscapes, with Sarker and McKenney (1992) informing one of the earlier assessments of non-market values for the Ontario Ministry of Natural Resources under its Forest Values Initiative. More recent information from Kant and Lee (2004) was derived using a novel non-market oriented stated preference technique to identify various forest values and to rank their preferences, among participants chosen from the forest industry, aboriginal communities, OMNR, and environmental Non-Governmental Organizations.

The most comprehensive and recent study within the area appears to be Voigt et al (2013) for the Ontario Ministry of Natural Resources and Forestry. This study used a proprietary modelling platform called ARIES to estimate the spatial flows of four ecosystem services from two case study areas: Algonquin Provincial Park and the Lake of the Woods region in Ontario. The study remains relatively unique in being the only one in Ontario that differentiates between the sources, sinks, and beneficiaries of ecosystem services, and makes these spatially explicit. The report generated maps that detail the theoretical service flows provided by an ecosystem, the amount of the flows that successfully reach beneficiaries, and the amount of flows that end at a "sink" location where they do not directly benefit people. This approach is particularly useful to understanding how ecosystem services from a protected area flows to off-site beneficiaries.

What information relates to Southern Ontario?

Most of Ontario's population and private land exists within the settled areas south of the Canadian Shield. Within this area, key ecosystem services have been described in relation to the landscape, and some coarse-level data exist as a starting point for project-specific considerations. Various studies have been published, with many using value transfer and some undertaking primary valuation. Some of the studies provide overlapping or cross-referenced information, but none of them employ the same accounting system so their estimated values cannot be compared across their overlapping geographies.

Some information has been generated using value transfer for specific geographies within Southern Ontario, especially the Greenbelt with a commonly-cited study by Wilson (2008a) with a recent revision by Green Analytics (2016) using more recent information and a refined methodological approach. Information has been generated for the landscapes within several watersheds, including the Lake Simcoe basin (Wilson, 2008b) and the watershed managed by the Toronto and Region Conservation Authority (TRCA, 2011). Credit Valley Conservation has commissioned a significant amount of research within its watershed, including a hedonic analysis of the impact of natural features upon property values (DSS Management Consultants, 2009), an value transfer inventory of ecosystem services across the watershed (Kennedy and Wilson, 2009), a contingent valuation to inform scenarios of wetland restoration (Lantz et al., 2010), and surveys to understand linkages between wellbeing and ecosystem services (Green Analytics, 2011). Many smaller initiatives have been undertaken by other organizations, including TD Economics and the

Nature Conservancy of Canada (2017) which assessed the Backus Woods and the Crane River by means of value transfer. Some value transfer assessments have been undertaken as course projects or graduate research, and some for specific advocacy purposes (e.g. Wilson et al, 2011).

Some information was generated for government. For example, Sverrisson et al. (2008) used contingent valuation to estimate the passive use values of hypothetical expansion of provincial parts and protected areas in southern Ontario. Marbek (2010a, 2010b, 2010c) generated information to inform Great Lakes policy undertaken by the Ontario Ministry of Environment. Rudd et al. (2016) used contingent choice to assess the economic value of conserving the channel darter, pugnose shiner, and lake sturgeon, to inform Environment Canada in its work under the Species at Risk Act.

The most comprehensive single source of southern Ontario information is from Troy and Bagstad (2009). This study related the existing landcover inventory SOLRIS to an inventory of ecosystem services and transferred values, with the result each 15 metre by 15 metre point on the landscape could be characterized by the services that it would likely have supplied. The service of "habitat refugium" was provided as a proxy for biodiversity; the report's discussion notes that biodiversity is an ecological indicator which, like many others, is not yet explicitly related to the levels of provision of ecosystem processes and their corresponding services. The report makes it easy for users to reference the originating studies that provide each point estimate of a service-from-landscape estimate, and to assess the richness or coarseness of data that characterizes the average of this estimate. The spatial data in a GIS (Geographic Information System) can be requested from the Ministry through Land Information Ontario.

What about the Great Lakes and their basin?

A wide array of benefits provided by the Great Lakes ecosystem have been quantified and valued. To date, the focus of Great Lakes valuation literature has been on the benefits of cleaning up polluted sites and the benefits of recreational activities such as swimming, boating and fishing. The most comprehensive compilation and assessment of this information is found in the report "Assessing the Economic Value of Protecting the Great Lakes Ecosystem" which served as a literature review for three related economic analyses (Marbek 2010a, 2010b, 2010c, 2010d). This literature review assessed over 100 studies that collectively contribute to a better understanding of the economic benefits from the Great Lakes. The report also provides an overview of the main findings, gaps and implications for using this information (Marbek 2010a). The three applied economic analyses focused on sustainable watershed development (Marbek 2010c), wetland and stream system protection and restoration (Marbek 2010d), and aquatic invasive species prevention and control (Marbek 2010b).

More broadly, there are several easily digestible documents that assess the state of knowledge of the economic value of water resources in Canada (Renzetti et al., 2011). A document produced for the Canadian Council of Ministers of the Environment provides guidance on the use of water valuation in decision-making in Canada (CCME, 2010). More scoped to Lake Erie was a review of concepts, data sources and methods of ecosystem services to inform the management of algal blooms (Smith, 2014).

The economic valuation of large aquatic ecosystems such as the Great Lakes requires careful consideration. Several unique challenges are posed by issues of scale and fluidity of the resource, as well as its bi-national status and international significance as a waterbody. In discussing the different economic values associated with water, it is important to note that water provides a multitude of ecosystem goods and services. People value the attributes and services they receive from water, not necessarily the water itself.

What information has informed the assessment of sustainability?

In 2005, a "conservation blueprint" exercise was undertaken within the Great Lakes basin, which covers much of Ontario (Nature Conservancy of Canada and Ministry of Natural Resources, 2005). The baseline aquatic and terrestrial biodiversity was assessed on an eco-region basis over the Canadian portion of the Great Lakes basin. A suite of sustainability-oriented targets was assessed, and used to estimate the conservation needs that would close the gap between targets and the baseline. This research was the basis for a cost-benefit analysis of habitat protection and restoration that was undertaken to inform the Ontario government about a Great Lakes strategy (Marbek, 2010d).

An ecological footprint and biocapacity analysis was undertaken for the Ontario Biodiversity Council in 2010 (Stechbart and Wilson, 2010) and again in 2015 (Zokai et al., 2015). The methodology of this type of analysis was described earlier, as a way of assessing a jurisdiction's demand for some of the benefits from natural capital, in comparison with its available supply of biocapacity. Applied to Ontario, the studies estimated that Ontario's ecological footprint is close to being to the amount of biocapacity within the provincial boundary of Ontario.

10. Some policies and practices in Ontario are internalizing these considerations

Which acts or regulations mandate the consideration of ecosystem services?

The term "ecosystem service" and its synonyms is not found in any Ontario Act or Regulation. The term "ecological" is found in 17 Acts, with 11 Acts referencing "ecosystem" and 33 referencing "valuation". There are relatively Acts that integrate these considerations, such as a reference to "recreational value" in the *Wilderness Areas Act, 1990*, and the *Crown Forest Sustainability Act, 1994*, and one reference to "ecological values" in the *Far North Act, 2010*. In that Act, the term is not defined, but is mentioned as one of two possible considerations of the Minister to make an order to allow a person to undertake developments in an area without a community based land use plan. Regulation 140/02 under the *Oak Ridges Moraine Conservation Plan* uses the phrase "ecological value" and defines it to include the consideration of biodiversity and "ecological features and ecological functions".

There are no references to "natural capital" and no references to a distinction between market and non-market or external(ized) value. However Ontario Regulation 588/17 under the *Infrastructure for Jobs and Prosperity Act, 2015*, defines a "municipal infrastructure asset" to include a "green infrastructure asset" that is defined as "consisting of natural or human-made elements that provide ecological and hydrological functions and processes and includes natural heritage features and systems, parklands, stormwater management systems, street trees, urban forests, natural channels, permeable surfaces and green roofs". Since ecosystem services are derived from the interaction between humans and ecological and hydrological functions and processes, this definition allows for the consideration of natural capital as municipal capital, as long as it is "directly owned by a municipality or included on the consolidated financial statements of a municipality".

The phrase "ecosystem services" does not need to be written in law in order to be considered in the administration and interpretation of law, as detailed later in this section about legal cases. Thus it is not obvious that ecosystem services or natural capital would benefit from its own legislation. But the words and phrases used within laws signal an intent to consider certain types of knowledge. For this reason, there may be merits to including relevant phrases in new or updated legislation, even if it is just in the preamble. Another option would be to clarify definitions about "economic" value and benefits and growth to signal an intent to consider externalized values.

A recent assessment of Canadian law noted an absence of any reference to "ecosystem services" at the federal or provincial level, although there are at least a dozen federal laws that incorporate "environmental valuation" or "use and non-use values" to signal the consideration of non-market values in determining fines (Pasten et al., 2018). No such concept appears in regulations considering environmental penalties under the *Environmental Protection Act*, the *Water Resources Act*, the *Crown Forest Sustainability Act*, or the *Fish and Wildlife Conservation Act*. Many regulations that consider penalties include the phrase that the penalties "shall not be punitive in nature" or in the case of Regulation 222/07 under the *Environmental Protection Act*, the Director may reduce the amount of the penalty if the magnitude of the penalty is considered "punitive". If there were opportunities to include non-market values, Ontario data could be used to inform this. Besides penalties, data could also be used to inform or reform fees associated with the consumption of ecosystem goods and services, such as charges for the water taken by a water bottling facility, which is currently fixed at $0.0005/L in Regulation 176/17 under the *Ontario Water Resources Act, 1990.*

What legislation mandates the consideration of biodiversity and sustainability?

Some Ontario legislation explicitly considers "biodiversity" or "biological diversity". Examples include the *Crown Forest Sustainability Act, 1994*, *Provincial Parks and Conservation Reserves Act, 2006*, *Endangered Species Act, 2007*, *Far North Act, 2010*, *Great Lakes Protection Act, 2015*, *Invasive Species Act, 2015*, and Regulation 282/98 updated in 2004 under the *Assessment Act* insofar as it clarifies "conservation land." In these instances, biodiversity is not characterized in economic terms; the word "economic" exists in the Acts but is used in a way that it conveys the market economy without signalling that non-market values should be considered in order to determine "economic benefit".

The term "sustainability" is found in 40 different acts and regulations, about half of which would be classified as economic policy (e.g. *Regulatory Modernization Act, 2007*) as distinct from environmental policy (e.g. *Aggregate Resources Act, 1990*). References to sustainability tend to exist in more recent policy. The transcribed debates of the Ontario Legislature reveal few references to the concept of an economic value of ecosystem services and biodiversity; committee hearings reveal only a few references from expert testimony. All considered, perhaps it is not surprising that existing legislation does not signal much in the way of *ecological* economic intentions.

Two recent Acts reveal some potential tensions arising out of the integration of various considerations. The *Infrastructure for Jobs and Prosperity Act, 2015*, explicitly notes that "planning and investment should minimize the impact of infrastructure on the environment and respect and help maintain ecological and biological diversity, and infrastructure should be designed to be resilient to the effects of climate change". The Act's consideration of infrastructure does not allow for natural or living infrastructure, since infrastructure is defined as "physical structures and associated facilities". Nevertheless its regulation 288/17 prescribes that asset management planning for municipal infrastructure can include "green infrastructure" as detailed earlier. The *Climate Change Mitigation and Low-carbon Economy Act, 2016*, explicitly includes, in its preamble, an aspiration to "drive economic growth" despite scholarly skepticism within the ecological economics community as to the merits of advocating for both economic growth and emissions reductions.

Which existing Ontario policies could benefit from non-market considerations?

Public policy is much broader than what is written in Acts and regulations. At the present time there is no consolidated and searchable inventory of the strategic, program, and operational or administrative policy that is additional to the acts and regulations of the crown. To the extent that these forms of policy are more adaptive, then one should expect there to be more use of the terms or concepts of ecosystem services and biodiversity. Indeed there are many documented examples of policies that are well positioned to use existing information and ideally to also support the generation of new data.

All Ontario Ministries subject to the *Environmental Bill of Rights, 1993*, have a Statement of Environmental Values that are to be used to inform the way decisions are made (Government of Ontario, 2018). The statement of MNRF includes "natural resources should be properly valued to provide a fair return to Ontarians and to reflect their ecological, social and economic contributions". Included in the statement of the Ministry of the Environment and Climate Change is that it "considers the effects of its decisions on current and future generations, consistent with sustainable development principles". To operationalize both of these statements requires the use of non-market values.

The Ontario government created a multi-stakeholder Ontario Biodiversity Council in 2005 to promote the understanding of biodiversity and to steward Ontario's Biodiversity Strategy. The updated biodiversity strategy includes a target that "by 2020, programs and policies are in place to maintain and enhance ecosystem services" (Ontario Biodiversity Council, 2011). To report on progress, the Council asked its secretariat in 2014 to survey policy experts at 14 ministries that were part of the Ontario Public Service Biodiversity Network. The survey asked to "identify strategic and program polices in which maintaining or enhancing ecosystem services is explicitly included as a main objective/goal" and to "identify those that include consideration of ecosystem services (e.g., mitigation/compensation for ecosystem services, use of ecosystem service valuation methods or economic instruments)" (Ontario Biodiversity Council, 2015b). Thirteen ministries responded, identifying a total of six policies, which collectively "safeguard our water, as well as protect important ecosystem services through effective land use planning and support climate change mitigation through carbon sequestration". These low numbers are likely to rise, since more explicit references have been made in the last few years.

Which new Ontario policies identify the consideration of ecosystem services?

The Ontario Ministry of Natural Resources and Forestry has recently signalled an interest in considering ecosystem services and the natural capital that provides them. The Ministry's climate adaptation strategy called *Naturally Resilient* notes that the Ministry "is exploring applications of natural capital accounting and the value of ecosystem services" in order to "better understand the economics of climate change from a natural resources perspective" (Ontario Ministry of Natural Resources and Forestry, 2017a). The strategy defines ecosystem services, although it also uses the phrase "ecological services" in describing its goal to increase awareness and communicate why biodiversity matters.

The Ministry's wetland conservation strategy has a vision that "Ontario's wetlands and their functions are valued, conserved, and restored to sustain biodiversity and to promote ecosystem services for present and future generations" (2017b). Of note, the wetlands strategy also incorporates a quantity-based sustainability criterion of "no net loss" and a longer-term objective of "net gain". Its future implementation could benefit from economic instruments. The Ministry also explicitly considers "natural capital and ecosystem services" in its reporting on the state of Ontario's forests, although its status and trend are unknown with its reporting that data is inadequate (2016). The Ministry's Natural Heritage Reference Manual includes an explicit consideration of ecosystem services as a consideration in the development of natural heritage systems (Ministry of Natural Resources, 2010).

In 2017, a *Growth Plan for the Greater Golden Horseshoe* was prepared and approved under the *Places to Grow Act, 2005*. The plan notes that the subject lands "provide essential ecosystem services" and include natural areas that support biodiversity (Ontario Ministry of Municipal Affairs, 2017). The plan mandates the consideration of low-impact development and "green infrastructure" which is defined in the *Provincial Policy Statement, 2014*, as "natural and human-made elements that provide ecological and hydrologic functions and processes" which can include "natural heritage features and systems, parklands, stormwater management systems, street trees, urban forests, natural channels, permeable surfaces, and green roofs" (Ontario Ministry of Municipal Affairs and Housing, 2014). Green infrastructure is meant to be considered within stormwater management planning to increase the resiliency of communities. One notable omission is any signalling of the use of economic instruments as a means of generating the planning outcomes. For example, the emphasis upon stormwater management could have benefited from a mention (or requirement) that municipalities modify the structure of their stormwater fees along a polluter-pays approach, such as reflecting the size or degree of impermeability of lots and coupled with deductions for green infrastructure that provides an ecosystem service of stormwater mitigation. Such an approach has been used in Waterloo for a few years and is now in use in Peterborough and some other municipalities.

Have legal judgements considered non-market values and concepts?

The economic value of ecosystem services has been considered by the Supreme Court of Canada. In the 2004 case of British Columbia v. Canadian Forest Products Ltd, the court noted "the question of compensation for environmental damage is of great importance" and for this reason, "a claim for environmental loss, as in the case of any loss, must be put forward based on a coherent theory of damages, a methodology suitable for their assessment, and supporting evidence" (Supreme Court of Canada, 2004). The court reviewed some of the theory and methods of expressing the economic value of unpriced benefits, as presented by the government of British Columbia. The court was not convinced that the government had evidence to suggest it had accounted for the benefits, but rather assumed a somewhat arbitrary premium. Legal commentators suggest that the ruling has nevertheless "laid the blueprint" for future claims of damages against the unpriced economic benefits from nature in this "novel area of environmental litigation" (Davis & Company, 2004). This judgement has been cited in a few cases at lower level courts, including the granting of a claim for environmental damages (Pasten et al., 2018).

A recent assessment of legal cases found evidence that the concept of ecosystem services was considered in cases before the Ontario Municipal Board and a judicial review considered by the Ontario Superior Court of Justice (Pasten et al., 2018). The Ontario Municipal Board has accepted, without elaboration, evidence regarding the loss of ecosystem services in both cases that the authors reviewed. As one example, the board dismissed the appeals of a developer whose Toronto-based development was not approved because it would have resulted in a "net loss of ecosystem services" despite a proposed mitigation effort of a "green roof" on the proposed condominium, plus incremental tree seeding (Ontario Municipal Board, 2013). Ontario data regarding ecosystem services has yet to be incorporated into judgements.

11. Conclusions

The economics of ecosystem services and biodiversity is mostly about the economics of value that is neither reflected in markets, nor in the economic accounts that inform jurisdictions about their economy, nor in the self-interested economic motivations of people and organizations. These gaps threaten the diversity and abundance of life on the planet. These gaps allow the consumption of natural capital to continue unaccounted for, and mask the contributions that ecosystem services and biodiversity make to economic wellbeing. In turn, this contributes to the decline of the diversity and abundance of life on the planet. Furthermore, these gaps challenge the productivity and sustainability of economies, and challenge the cost-effective achievement of wellbeing.

All these gaps can be lessened by the quantification and economic valuation of ecosystem services and the benefits from biodiversity. In turn, this information can be integrated into the economic accounts of jurisdictions to better inform economic measures, strategies, and policy – including the use of economic instruments to better align the motivations of people and organizations with goals of biodiversity conservation.

In the last six years since the original publication of TEEBO, many new provincial, national, and global developments have emerged to reflect an increasing interest in the economics of ecosystems and biodiversity. Ontario has some new policies that explicitly signal an economic consideration of ecosystems and biodiversity. Information about this consideration has grown, and so has the use of economic instruments.

Nationally, Statistics Canada has included "natural resource wealth" in its quarterly balance sheets since 2015, although this statistic is not updated quarterly, and reflects just part of the wealth derived from ecosystems. This followed an initiative called Measuring Ecosystem Goods and Services in Canada (MEGS) which published a report in 2013 and could be a useful framework for additional work in the future (Statistics Canada, 2013). Environment Canada released a Toolkit for analysts undertaking an "ecosystem service assessment" which presumably should become more commonplace as ecosystem services become more widely considered in environmental assessments (Value of Nature to Canadians Study Taskforce, 2017).

Globally, the Intergovernmental science-policy Platform on Biodiversity and Ecosystem Services (IPBES) was formed, with its first global assessment released in March 2018 (IPBES, 2018). The System of Environmental-Economic Accounts (SEEA) was updated in 2012 to include extensions of "experimental ecosystem accounts" to respond to high demand for considering non-market accounts. A new scholarly journal called *Ecosystem Services* was launched, and is now publishing more research on this subject than other journals including *Ecological Economics*, which had previously led a lot of research.

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13. Appendix of key statements derived from this report

Biodiverse ecosystems supply goods and services that support human wellbeing

- Human wellbeing requires benefits from nature and affects nature's capacities
- Ecosystem Services are unpriced benefits flowing to humans from nature
- Human efforts to conserve and enhance ecosystem services could be commodified
- Ecosystems can be managed as Natural Capital to sustain their benefits
- Natural capital Stocks provide ecosystem goods; Funds provide ecosystem services
- Natural Capital is needed to create and sustain Human Capital and Built Capital
- Biodiversity describes natural capital that provides ecosystem services

Many professions and sectors are taking an interest

- Businesses and investors in the private sector
- Accountants and their associations
- Professional planners and architects
- Engineers and infrastructure specialists
- Public Health professionals
- Economists, especially Ecological Economists

Market prices fail to reflect the full economic value of nature

- Market prices reflect the make-up of markets and decisions about sustainability
- Market prices omit external costs, but public policy can affect this
- Economic value includes market-priced value plus external non-market value
- Nature can remain unpriced even as it becomes scarcer through depletion
- Ecosystem services and biodiversity need deliberate protection
- Their depletion will affect economic productivity and wellbeing
- Ecosystem services deserve more attention than ecosystem goods

Non-market values are needed to understand the economic scarcity of nature

- Economic valuation helps to intentionally measure the importance of nature
- Biophysical measures of supply can help to sustain nature
- Monetary measures of non-market values can help to inform efficient trade-offs
- Some non-market values can be revealed from market prices
- Some non-market values need to be determined by surveys
- Existing measures can be transferred to new applications
- Valuation can be applied to a specific ecosystem service or bundles of them

- Ecosystem services flow across geographies
- Measures of ecosystem service flows should not be capitalized as time-less stocks
- Several best practices apply to non-market valuation

Land-use decisions can be more effective with non-market values

- Biophysical values can inform the measurement of a landscape's Biocapacity
- Values can inform development decisions and associated fees and plans
- Values can inform the use of offsets to operationalize sustainability
- Values can support the prioritization of lands for conservation
- Values can help to inform the economic case for ecosystem rehabilitation
- Values can inform the management of existing conservation areas

Non-market values can inform Balance Sheets and Economic Accounts

- Economic Accounts generate statistics about the marketplace of a jurisdiction
- A Balance Sheet is an inventory of assets and liabilities and owned capital
- There are advantages to integrating non-market values into economic accounts
- Integration is challenged by missing prices and a pluralism of quantities
- A new System of Environmental-Economic Accounting is available

Economic Instruments can internalize non-market considerations

- Various economic instruments can be used to lessen market failures
- Information-based instruments inform the marketplace to influence its outcomes
- Liability-based instruments extend legal obligations to environmental outcomes
- Price-based instruments affect market prices, to influence market outcomes
    - E.g. Payments for Ecosystem Services (PES) is a price-based approach
    - E.g. Reverse auctions can be used to inform payments under a PES
- Quantity-based instruments affect market quantities, to influence outcomes
    - E.g. Trading systems can support quantity-based approaches to conservation
    - E.g. Mandated conservation offsets benefit from trading systems
    - E.g. Equivalence metrics are needed to enable conservation offsets
- Social-norms-based instruments motivate voluntary pro-environmental behaviour
- Multiple criteria affect the choice of a specific instrument
- The success of instruments depends upon their interactions and compatibilities

Information exists about ecosystem services in Ontario

- More information was generated after the year 2000 than before

- Some information is specific to the Far North
- Some information covers the settled areas on the Canadian Shield
- Most information is about the settled areas south of the Shield
- The Great Lakes basin has been more of a focus than the lakes themselves
- Some information was generated to inform a sustainability assessment

Some policies and practices in Ontario are internalizing these considerations

- No Ontario Acts or Regulations mandate the consideration of ecosystem services
- Some legislation mandates the consideration of biodiversity and sustainability
- Some existing Ontario policies could benefit from non-market considerations
- Several new Ontario policies identify the consideration of ecosystem services
- Some legal judgements are considering non-market values and concepts