

Isolated Habitat Valuation

Prepared for the Prairie Conservation Forum

by François Blouin

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1- Acknowledgements

The author would like to acknowledge and recognize the work of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) in developing “The Assessment of the Diverse Values and Valuation of Nature” (IPBES 2022a). An important amount of information related to the valuation of nature and valuation methods presented in the current report was derived from this significant body of knowledge intended to inform decision-making and policy options for a diverse range of stakeholders. We extracted what we felt relevant for the purpose of this assignment, but the reader is encouraged to consult the assessment itself (IPBES 2022a) for an in-depth perspective on the various valuation methods and approaches and their application.

2- List of Acronyms

Acronym	Definition
ABMI	Alberta Biodiversity Monitoring Institute
ALUS	Alternative Land Use Services
ARIES	Artificial Intelligence for Ecosystem Services
BAP	Biodiversity Action Plan
BD	Biodiversity (indicator)
BMU	German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
CESI	Canadian Environmental Sustainability Indicators
ES	Ecosystem Services
ESP	Ecosystem Services Partnership
EU	European Union
GDP	Gross Domestic Product
GIS	Geographic Information System
GT	Graph-theoretic (method descriptor)
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
Int. \$	International Dollars
ISF	Institute for Sustainable Finance
InVEST	Integrated Valuation of Ecosystem Services and Trade-offs
LR	Landscape Resilience
LUCI	Land Utilisation Capability Indicator
LULC	Land Use / Land Cover
MA	Millennium Ecosystem Assessment
NCP	Nature's Contributions to People
NC	Natural Capital
NCC	Nature Conservancy Canada
NB	Nature Braid

Acronym	Definition
NGO	Non-Governmental Organization
NEA	National Ecosystem Assessment
NEAFO	National Ecosystem Assessment Follow-On
PCAP	Prairie Conservation Action Plan
PCF	Prairie Conservation Forum
PIE	Probability of Interspecific Encounter
PAGE	Pilot Analysis of Global Ecosystems
SL/SS	Single Large / Several Small
SLOSS	Single Large or Several Small
SROI	Social Return on Investment
SVI	Social Value International
TEEB	The Economics of Ecosystems and Biodiversity
UK	United Kingdom
UN	United Nations
USEPA- SAB	US Environmental Protection Agency - Science Advisory Board
USD	United States Dollars
WTW	Where To Work
WTD	What To Do
WWF	World Wildlife Fund

3- Introduction

The Alberta Grassland and Parkland Natural Regions (hereafter, the Prairie Region) cover 23.6% of Alberta land area and supports a rich diversity of species (Alberta Parks 2015). However, the Prairie Region is the region of the province most impacted by human development, including agriculture (most important), transportation, and energy, urban, rural, and industrial development. Collectively these anthropogenic drivers have contributed to the loss, fragmentation and degradation of native prairies. Today, about 37% of the Prairie Region remains as natural cover and supports over three quarters of Alberta’s species at risk (ABMI 2016, Raven *et al.* 2022). With conversion to other land uses, what remains occurs as a few larger interconnected blocks of native vegetation and a patchwork of smaller isolated patches of various configurations in a largely agricultural matrix (ABMI 2016, O2 2017).

The Prairie Conservation Action Plan’s (PCAP) **vision** is to ensure that “*The biological diversity of native prairie and parkland ecosystems is secure under the mindful and committed stewardship of all Albertans*” (PCF 2021). To achieve this vision, the 2021-2025 iteration of the PCAP proposes three long-term **environmental outcomes**: 1) *maintain large native prairie and parkland landscapes*; 2) *conserve connecting corridors for*

*biodiversity; and 3) protect isolated native habitats. Approaches and actions are suggested to achieve each of these outcomes. Outcome #3 comprises three different **approaches**: a) define 'isolated' habitats/ fragments; b) Identify locations of isolated native prairie habitats; and c) identify the value or values of these isolated parcels. The following review is designed to address approach #3.*

The PCF was interested in knowing the value or values of isolated parcels of natural habitat and as such, was interested in finding out what methods existed to value nature, and which ones would be appropriate to assess the value of isolated habitats. This scan and literature review is intended to unravel valuation systems that look at, but are not limited to, ecological goods and services, economic drivers, inherent value of native habitats and the biodiversity they support, cultural and social values, etc. Identifying these different values and valuation systems for different uses of native prairie land can expose areas where conflicts might arise if land management changes were to happen and where the greatest needs are for protection and stewardship of isolated native prairie habitats. While each person holds their own set of values and personal interpretation of nature and their relationship with nature, this review looks at valuation of nature, including biodiversity and ecosystems, from a collective or societal perspective.

4- Definitions

Some background and definitions are important to convey prior to addressing the various approaches and methods used to value natural habitats:

An **ecosystem** can be defined as a “*dynamic complex of plant, animal, and microorganism communities and the non-living environment interacting as a functional unit*” (MA 2005a). **Ecosystem functions** represent the habitat, biological or system properties or processes of ecosystems (Costanza 1997). In his book *Small is Beautiful*, economist E.F. Schumacher (1973) argued that modern economics treats natural resources, such as fossil fuels, minerals, and the environment's capacity to absorb pollution, as a renewable income source (i.e., expendable), a view he saw as unsustainable and economically illogical, because its depletion is treated as profit rather than a loss of a permanent asset. He introduced the concept of *Natural Capital*, which he described as the stock of renewable and non-renewable natural resources that forms the basis of our economy and society. According to the System of Environmental-Economic Accounting (SEEA nd), the underlying premise of that concept is that “*since the environment is important to society and the economy, it should be recognised as an asset that must be maintained and managed, and its contributions (services) be better integrated into commonly used economic frameworks*”.

The 2005 Millennium Ecosystem Assessment (MA 2005a) integrated the concept of Natural capital and developed a typology for flow of environmental assets to humans. They, and subsequent scholars, defined **Natural capital** as the biotic (living things and non-living organic matter) and abiotic (air, water, minerals, land, oceans) components of nature and ecosystems (referred to as “assets” in environmental accounting) that interact through processes to provide a flow of goods and services, which make life possible (Mace *et al.* 2015, Smith *et al.* 2017, Leach *et al.* 2019, SEEA nd). It is the planet’s *stock* of natural assets and the ecosystem services that are derived from them (UNEP FI nd). These **ecosystem services** (ES)¹ have been categorized by the Millennium Ecosystem Assessment (MA) (MA 2005a) as:

- *provisioning services*, including but not limited to food, water, timber, and fiber,
- *regulating services* that impact water quality, climate, floods, wastes, diseases,
- *supporting services* such as nutrient cycling, carbon capture, soil formation and photosynthesis and,
- *cultural services* that offer recreational, spiritual and aesthetic benefits.

While in some cases, the flow of ecosystem services may be seen as constant, the stock of natural capital may be depleted beyond an ecological threshold or tipping point, whereas further pressure can cause significant, lasting and often irreversible shifts in the structure and function of ecological systems leading to direct and indirect negative impacts on biodiversity and human well-being (Mace *et al.* 2015, TEEB 2010a). Without a clear knowledge of the values (monetary and non-monetary) of nature and the goods and services that it provides, we cannot understand what we have, what we are gaining or losing, and the full short and long-term implications of the policy and management choices and decisions we make on nature itself, our economy, our society, and on us as social human beings.

The term **value** can be used to express two different meanings. On one hand, it is a judgement that refers to importance, worth or usefulness, a preference or a measure (e.g., species richness) or indicator (e.g., price). On the other hand, it addresses “held values, principles or beliefs and moral duties” (such as the values instilled by one’s parents or community of people) (Díaz *et al.* 2015, Pascual *et al.* 2017, IPBES 2022a, Gould *et al.* 2023). The two notions are interconnected, as the held values of individuals or groups contribute to the cultural makeup of a society, which in turn, determines what is perceived as important, beneficial or useful for a *good quality of life* (Díaz *et al.* 2015).

¹ The term “ecosystem services” (ES) is used throughout this document instead of “ecosystem goods and services”, in accordance with the Convention on Biological Diversity and other important international initiatives. The “goods” aspect is recognized as being part of the “provisioning services” category of ES.

Broadly speaking, valuation of nature can be used to improve human welfare, ecological sustainability and eco-social justice. More specifically, it can “*support decisions about alternative projects or policies; inform the course of (collective) action; aid in the design of policy tools and instruments; assess and even strengthen human-human and human-nature relations*” (Termansen et al. 2022). Characterising the values of nature and their importance to people increases the attention they receive and the probability of having them integrated in the decision-making process at all levels (Termansen et al. 2023).

Valuation of nature is the “*intentional process in which agreed upon methods and approaches are applied to reveal the values individuals or communities (including indigenous people) hold about nature, nature’s contributions to people, and human-nature relationships*” (IPBES 2022b). The values of nature are elicited and articulated through **Valuation methods**. They involve an array of data collection techniques, data analysis and result interpretation within a decision-making context to gather information about value. **Valuation approaches** are the guiding principles and beliefs that form the basis for specific methods. They determine how a method is applied and how its results should be interpreted (Termansen et al. 2023).

5- How Nature is Valued

Throughout human history, different cultures around the world have established multiple ways of understanding and relating to nature, leading to a large array of values of nature (IPBES 2022b). Specific values are “opinions or judgements of the importance of specific things in particular situations and contexts” (Anderson et al. 2022). They can be grouped into *instrumental, intrinsic and relational values*.

1. **Instrumental values:** Natural entities and processes that are important to achieve some human end or to satisfy human preferences (Pascual et al. 2017). The importance of nature is assessed through its provision of benefits to humans and support of human economic well-being and subsistence (Anderson et al. 2022). Examples include provision of raw materials, food, pollination services, water filtration, etc. Instrumental values are particularly well-suited for economic assessment as they are more easily quantifiable, both conceptually and technically. (Anderson et al. 2022). Instrumental values of nature to human well-being was the focus of nearly three quarters (74%) of valuation studies in a literature review (Termansen et al. 2022).
2. **Intrinsic values:** These are values inherent to nature expressed independent of people’s judgments. They represent “other-than-human” entities (e.g., an organism) that are worth protecting as “ends in-and-of themselves” (Anderson et al. 2022,

Pascual *et al.* 2017). These values embody moral obligations towards other living things, are foundational to conservation efforts and can strengthen environmental protection and policy outcome. Biophysical indicators are often used to express intrinsic values, but their social evaluation requires qualitative and participatory methods (Anderson *et al.* 2022). Intrinsic values of nature to human well-being was the focus of 20% of valuation studies in the literature (Termansen *et al.* 2022).

3. **Relational values:** Emphasize the non-instrumental, meaningful and desirable, often reciprocal, human relationships - with nature and among people via nature (e.g., a specific landscape, species, or forest). Relational values also recognize human-nature interactions that are components of a grounded, fulfilling and dignifying existence (eudaimonia), including mental and emotional health, virtues and attitudes of care and responsibility towards other people and other-than-human beings (Anderson *et al.* 2022, Chan *et al.* 2016). They reflect some aspects of cultural identity, social cohesion, social responsibility towards others and moral responsibility toward nature (Pascual *et al.* 2017). By acknowledging these values, we can ensure a meaningful inclusion of diverse groups in environmental stewardship and decision-making, leading to social-ecological relationships that provide fulfilling lives for present and future generations (Chan *et al.* 2016). Relational values of nature to human well-being was the focus of only 6% of valuation studies in the literature (Termansen *et al.* 2022).

6- Nature Valuation: Programs, Assessments and Tools

6.1- International:

Several national and international programs and assessments have been undertaken over the years, and various tools have been developed to value nature and ecosystems services. In the western scientific world, the ecosystem services concept has been the dominant framework to explain the relationship between humans and nature. It began to appear in the 1980's ecological literature as an economic-based language for describing to decision-makers how ecosystems and processes underpin human existence and well-being (Anderson *et al.* 2025). In 2005, the **Millenium Ecosystem Assessment (MA)** drew on this concept of capital essential to human well-being to create a new conceptual framework to assess the condition of the world's ecosystems, the drivers and the consequences of ecosystem changes for human well-being (MA 2005a). It identified ES and classified them into four major types (provisioning, regulating, cultural, and supporting; see "definitions" above), and stressed the importance of demonstrating the economic value of ecosystems services and developing techniques for representing stocks of ecosystem services in

national accounts (Maechler and Boisvert 2024). While it integrated different types of values and valuation methods (mainly economic), the values expressed in the assessment were largely biophysical (MA 2005a, MA 2005b, Termansen *et al.* 2022, Maechler and Boisvert 2024).

The Economics of Ecosystems and Biodiversity (TEEB) is a global initiative that aims to make the *economic* value of nature and its services visible to decision-makers, to demonstrate the increasing cost of ecosystem degradation and loss of biodiversity and to bring together experts from the fields of ecosystem science, economics and development policy to capture those values in decision-making and find solutions for a sustainable future (TEEB 2010a). They identified “direct use” values, those associated with provisioning services (e.g., crops, livestock, fish, wood), and “non-use” values, or the non-consumptive values of nature such as recreation, spiritual or cultural importance of a place, a landscape, or a species). They emphasized that there is no single valuation process that can be applied to every situation, but they offered a three-step framework to guide individual needs and circumstances. They provided practical guidance on how to apply the framework, along with illustrations and examples using a series of case studies from local and regional levels. They indicated that valuation is best applied to assess a subset of ES which are affected by alternative management options, rather than by attempting to assess the full range of ES. As part of this initiative, TEEB did a review of the main economic methods for valuing ES, which they described along with their advantages and limitations in TEEB (2012). In another assignment under the same initiative, de Groot *et al.* (2012) extracted 1350 value (of ES) estimates from 300 case study locations and analysed the mean economic value of 22 ES for 11 biomes, including the grasslands (comprising the North American prairie), which they calculated to be 2,871 Int. \$/ha/year (2007-year)².

From the TEEB initiative, a business component evolved and led to the *TEEB in Business and Enterprise* report. The report urged corporations to integrate natural capital into their “corporate planning, accounting and reporting” (TEEB 2010b as cited in Maechler and Boisvert 2024), requiring its prior valuation. This TEEB business component morphed into an independent network, the (Maechler and Boisvert 2024). The Natural Capital Coalition vision is “*a world where business conserves and enhances natural capital that safeguards thriving societies and prosperous economies*”. To achieve this vision, the Natural Capital Coalition developed a ***Natural Capital Protocol***, which is “*a standardized framework to*

² The international dollar, or the Geary–Khamis dollar, is a hypothetical unit of currency that is used to standardize monetary values across countries by correcting to the same purchasing power that the U.S. dollar had in the United States at a given point in time. Figures expressed in international dollars cannot be converted to another country's currency using current market exchange rates; instead, they must be converted using the country's PPP (purchasing power parity) exchange rate. 1 Int.\$=1 USD (de Groot *et al.* 2012)

identify, measure, and value direct and indirect impacts (positive and negative) and/or dependencies (of business) on natural capital” (Natural Capital Coalition. 2016). In the protocol, valuation is defined as including qualitative, quantitative, and monetary approaches, or a combination of these. The protocol does not explicitly list or recommend specific valuation tools or methods. However, it describes the main valuation techniques (15) and helps the user select what is most appropriate for their assessment. These techniques include qualitative, quantitative, monetary and value transfer methods.

In 2011 & 2014, the United Kingdom produced an independent and peer-reviewed **National Ecosystem Assessment (UK NEA)** and the following **UK NEA Follow-on (UK NEAFO)** for the entire UK. Its goal was to raise awareness of the importance of the natural environment to human well-being and economic prosperity with a mandate to enable the identification and development of effective policy responses to ecosystem service degradation (UK National Ecosystem Assessment 2011, 2014). They introduced a framework that builds on the findings of the MA (MA 2005), the TEEB (TEEB 2010a) and more recent conceptual advances to incorporate measures of human well-being, including economic (monetary), health and shared (social) values (UK National Ecosystem Assessment 2014). They identified two broad approaches to valuation of ecosystems and biodiversity: 1) intrinsic/inherent values and 2) instrumental/extrinsic values (including use and non-use values), to which they took an anthropocentric perspective. They took on a broad-ranging review of ES from all of UK’s natural habitats, considering the goods and services they generate and their resultant values where possible, using methods described in Bateman *et al.* (2011a) (Bateman *et al.* 2011b). This review also included an assessment of the UK’s semi-natural grasslands (Bullock *et al.* 2011).

Since 2008, the German government has been promoting climate action and biodiversity conservation in the “Global South” through the International Climate Initiative. As part of this initiative, the **ValuES** project was created in 2014 to support practitioners, advisors and decision makers in government and non-government organizations in the integration of ecosystem services into decision-making and planning processes. This is achieved by developing instruments and training courses, providing technical advice and facilitating planning and decision-making processes. Knowledge-sharing is also promoted via regional workshops and participation in global discussion forums. ValuES offers a six-step approach on how to recognize, demonstrate and capture the value of ecosystem services in order to integrate it into development planning. It also integrates a “*Methods Navigator*” to determine the broad theme (policy area) being addressed and the purposes of the assessment, which helps choose suitable methods and tools for assessing ecosystem services from the “*Methods Database*”. Case studies show experiences from different applications and study processes (BMU nd).

Between 2012 and 2017, the EU-funded **OpenNESS** (Operationalisation of Ecosystem Services and Natural Capital) translated the concepts of Ecosystem Services (ES) and Natural Capital (NC) into operational frameworks that provide practical and tailored solutions for informing sustainable land, water, and urban management in different locations and scales. Working closely with decision makers and stakeholders, the project developed and tested operational frameworks and tools through 27 real-world case studies across Europe (most) Argentina, Brazil, India and Kenya (Harrison *et al.* 2018, Oppla 2025). The case studies applied different biophysical, socio-cultural and monetary valuation methods to operationalise the ecosystem service concept towards sustainable land, water and urban management. The project compiled 43 specific ES assessment methods, categorised into 26 broad method groups, which were proposed as possible options for application in the case studies. A survey of the reasons why the case study teams selected particular methods was conducted and a set of linked decision trees was developed to provide guidance to researchers and practitioners in choosing ecosystem service assessment methods that are suitable for their context (Harrison *et al.* 2018).

The **United Nation's System of Environmental-Economic Accounting – Ecosystem Accounting (SEEA EA)**, is a “*spatially based, integrated statistical framework for organizing biophysical information on ecosystems, measuring ecosystem services, tracking changes in ecosystem extent and condition, valuing ecosystem services and assets and linking this information to measures of economic and human activity*” (United Nations 2024). The framework aims at making visible the contributions of nature to the economy and people and at providing a better accounting of the impacts of economic and other human activity on the environment than otherwise captured in standard economic accounts. It offers a structured approach to assessing how human activity and the economy depend on and impact ecosystems across the world (United Nations 2024). The framework is built on five core ecosystem accounts that use spatial data and information about the functions of ecosystem assets and the ES they produce. They are 1) ecosystem extent and 2) ecosystem condition accounts, which are compiled in physical terms (e.g. hectares, tons), ecosystem services accounts, which can be compiled in 3) physical and 4) monetary terms, and 5) the monetary ecosystem asset accounts, which records in monetary terms the opening and closing “stocks” of all ecosystem assets within an areas, along with the reductions and additions to those stocks from ecosystem degradation and enhancement, respectively (UN SEEA nd(a)). In using monetary terms, SEEA argues that the contribution of ecosystems to the well-being of society can more easily be understood by decision-makers and integrated with other existing national accounts for policy planning (UN SEEA nd(a)).

The SEEA EA uses a typology that includes five categories of monetary valuation methods for ES, which are consistent with the exchange value concept of the System of National

Account³. They describe ten valuation methods based on market price, revealed preference (direct/indirect) and modelling (NCAVES and MAIA 2022).

The SEEA EA can be compiled at the national, subnational (e.g., state/province, river basin, protected area, city, etc.) and across terrestrial, freshwater and marine areas. It can also engage in “thematic accounting” where data are organized into specific policy-relevant themes such as biodiversity, climate change, protected areas, forests and oceans that are central to the global sustainability agenda (UN SEEA nd(a)).

ARIES (or ARtificial Intelligence for Environment & Sustainability) started in April 2007 at the Gund Institute for Ecological Economics of the University of Vermont, United States as an ecosystem services assessment platform. Now based out of the Basque Centre for Climate Change (BC3) in Bilbao, Spain, ARIES has broadened its focus to become an AI-powered integrated, open-source modelling platform for environmental sustainability. It provides open, safe, and accurate methods for sharing and linking scientific models, empowering stakeholders to make better-informed decisions regarding the most complex sustainability issues of our time and drive positive change (BC3 2025, UN SEEA nd(b)). Shortly following the adoption of the SEEA standard by the United Nations in March 2021, the **ARIES for SEEA Explorer** was made available in order to accelerate SEEA’s implementation worldwide on the UN Global Platform. The ARIES for SEEA Explorer application can generate ecosystem accounts for any user-specified terrestrial area in the world (such as a country, administrative region, watershed, etc.), by using freely available global remote-sensing derived data and models, and rapidly computes these accounts online, using a web browser. The current Explorer functionalities are restricted to assessing ecosystem *extent* (based on the IUCN Global Ecosystem Typology), *condition* (for forest ecosystem types), and *selected ecosystem services* in physical and monetary units using basic models as a starting point (UN SEEA nd(b)).

The **International Union for the Conservation of Nature (IUCN)** is the world’s largest and most diverse environmental network of government and non-government organisations, with the mission to “*influence, encourage and assist societies to conserve the integrity and diversity of nature and ensure that any use of natural resources is equitable and ecologically sustainable*” (IUCN nd). In addition to being a trusted repository of best practices, tools and international standards, IUCN implements a large and diverse portfolio of conservation projects worldwide. IUCN developed a guide to make accessible the main concepts and methods of economic valuation of the monetary value of goods and

³ The application of exchange value concept of the System of National Account allows comparisons of ecosystem services and assets with the values of products and assets recorded in the national accounts (NCAVES and MAIA 2022).

services rendered by natural ecosystems in West Africa: “**Economic valuation of ecological functions and services of natural ecosystems: guide on the use of simple methods**” (Somda and Awaïss 2013). Designed for all actors involved in the economic valuation of ES, the guide allows quick understanding of the most commonly used economic valuation concepts and methods applied by natural ecosystem evaluators. Albeit not comprehensive, it enables non specialists of environmental economics to understand the basic principles and to further engage in the application of economic valuation of ecosystems.

Since it was introduced in the 1980’s, the ES concept has grown extensively to relate different facets of nature to people’s good quality of life (IPBES 2022b). However, Muradian and Gómez-Baggethun (2021) argue that the ES framework has evolved to reflect a western culture “stock-and-flow” system in which ecosystems are “stocks” of renewable and non-renewable resources, that provide flows of services (benefits) to humans, described by Maechler and Boisvert (2024) as “commodification” of nature. As such, it separates humans from nature and puts humans above the natural environment. In this *anthropocentric* and utilitarian worldview, the valuation processes aim at estimating the economic and non-monetary contributions of nature specific to human well-being (Muradian and Gómez-Baggethun 2021).

Other worldviews and knowledge systems have also been recognized by the **Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services** (IPBES). The IPBES is an independent intergovernmental body established in 2012 to provide policymakers with objective scientific assessments on the state of the planet’s biodiversity, its ecosystems, and the contribution they make to people in order to inform policy development (Díaz *et al.* 2018). It advocates the need to pluralize values and valuation processes (Maechler and Boisvert 2024). This pluralization stems from the different cultures, languages, religions, knowledge systems and interpretations of human-nature relationships. In its ambitious effort to be more inclusive and representative in its assessment of biodiversity and ecosystems, the IPBES introduced the concept of “nature’s contributions to people” (NCP; Díaz *et al.* 2018). It builds and expands on the concept of ES to recognize the cultural and spiritual impacts of biodiversity, in ways that are not restricted to a discrete cultural ecosystem services category as in the Millennium Assessment (MA 2005) but instead incorporates diverse world views of human-nature relations that may overlap several of the original four MA categories (see above).

The IPBES identified 18 nature’s contributions to people. They were classified under three broad categories: material NCPs, non-material NCPs and regulating NCPs (Table 1; IPBES 2018). These, along with other biodiversity indicators were assessed for their state of

knowledge, importance values and trends in 2018 in “**The regional assessment report on Biodiversity and Ecosystem Services for the Americas**” (IPBES 2018). The assessment comprised South America, Mesoamerica, North America and the Caribbean and addressed terrestrial, freshwater, and coastal biodiversity and covers current status and trends, going back in time several decades, and future projections, with a focus on the 2020-2050 period. The assessment also analysed the direct and underlying causes for the observed changes in biodiversity and in nature’s contributions to people, and the impact that these changes have on the quality of life of people. Different governance options and policies to reduce biodiversity loss and support sustainability were provided (IPBES 2018).

Table 1. Nature’s contribution to people (NCP). Adapted from Figure SPM 5 in IPBES (2018).

Material NCP	Non-Material NCP	Regulating NCP
Food and Feed	Learning and inspiration	Maintenance of options
Materials and assistance	Supporting identities	Climate regulation
Energy	Physical and psychological experiences	Regulation of freshwater quantity, flow and timing
Medicinal, biochemical and genetic resources		Regulation of freshwater and coastal water quality
		Regulation of hazards and extreme events
		Habitat creation and maintenance
		Regulation of air quality
		Regulation of organisms detrimental to humans
		Pollination and dispersal of seeds and other propagules
		Regulation of ocean acidification
		Formation, protection and decontamination of soils and sediments

In its 2022 “**Methodological Assessment Report on the Diverse Values and Valuation of Nature**” the IPBES distinguishes three main types of world views: *anthropocentric* (human-centered), *bio/ecocentric* (nature-centered) and *pluricentric*, recognizing that there is a large amount of variation and overlap within and among them (Anderson *et al.* 2022). *Anthropocentrism* in its core is largely based on instrumental values, but a “weak” anthropocentrism further acknowledges our essential relationships with nature and other-

than-human life (relational values). This latter type of anthropocentrism integrates both instrumental and relational values. The *bio/ecocentric* worldviews recognize the inherent or intrinsic value of living things, ecosystems and ecosystem processes as respectable and worthy of consideration in decision-making. The emerging *pluricentric* worldviews align with relational values, emphasizing the reciprocal, interdependent, intertwined, and embedded relationships between humans, other-than-human beings, and nature's elements and processes (Anderson *et al.* 2022).

IPBES conceived a typology to define nature's values in a universally intelligible and accepted way across cultures and academic traditions. This core set of concepts integrates four overlapping layers metaphorically depicted as the layers of an onion: 1) *worldviews*, 2) *broad values*; 3) *specific values*, and 4) *value indicators* (Pascual *et al.* 2023). People's *worldviews* correspond to the different ways people conceive and interact with the world expressed through knowledge systems (bodies of knowledge, practices and beliefs associated with culture and language) (Pascual *et al.* 2023). They shape broad values (also known as "human values" or "held values" or "principles"), which represent the life goals, general guiding principles and orientations towards the world. They include freedom, prosperity, health, justice, security, belonging, etc. Broad values provide meaning and context to specific values and practices about human-nature relationships (Anderson *et al.* 2022). The fourth layer, the value indicators are the quantitative measures and qualitative descriptors of nature values, as revealed by the various nature valuation methods. Value indicators are typically biophysical, monetary or socio-cultural (Pascual *et al.* 2023).

Each of these layers takes on a specific meaning and reveal a particular set of values depending on how people perceive their relationship with nature. When people see themselves as *living from* nature, they consider nature as provider of resources to sustain their livelihoods, their needs and their wants; revealing instrumental values. People who see themselves as *living with* nature also recognize its life-supporting processes in connection with other living things, which have the right to thrive independently of people's needs, thus emphasising both intrinsic and relational values. When *living in* nature, people value nature as settings for their lives, practices and cultures, underscoring relational values. When *living as* nature, people embody and perceive nature as a physical, mental and spiritual part of oneself, emphasizing broad values of oneness, kinship and interdependence (IPBES 2022, Pascual *et al.* 2023)

The ***Economics of Biodiversity: The Dasgupta Review*** is an initiative commissioned by the UK's HM Treasury in 2021 to produce an independent, global review on the Economics of Biodiversity. Led by economist Professor Sir Partha Dasgupta of Cambridge University

assisted by a multi-disciplinary Advisory Panel, the review finds that the current global economic model that leaves nature as an externality has been steadily eroding the regenerative natural capital and biodiversity, and this must be addressed to avoid a collapse of the ecosystem services that supports it. It reframes economic thinking to include biodiversity as a natural asset. It urges countries to de-emphasize GDP as an index of progress, which excludes depreciation of assets and instead to focus on a National Wealth measure that includes an accounting for Natural Capital (Dasgupta 2021). This concept of National/Comprehensive Wealth is therefore intrinsically related to sustainable economic development (Hamilton & Hepburn 2017 *cited in* Termansen *et al.* 2022). This implies that natural capital should be valued and monitored over time so as to be integrated into this measure of comprehensive wealth (Dasgupta 2021, Termansen *et al.* 2022).

In 2009, the **US Environmental Protection Agency – Science Advisory Board** (USEPA-SAB 2009) created a Committee on Valuing the Protection of Ecological Systems and Services to “offer advice to the Agency on how EPA might better assess the value of protecting ecological systems and services”. Their “***expanded and integrated approach***” to ***ecological valuation*** considered measures of value of ecosystems and their services based on preferences (for alternative goods and services) and on biophysical elements of potential public importance. Preference-based values included: 1) attitudes or judgments, 2) economic values, 3) community-based values, and 4) constructed preferences. Biophysical values included: 1) bio-ecological values and 2) energy-based values. They identified 17 different methods in the various categories such as economic methods, but also measures of attitudes, preferences, and intentions; civic valuation; decision science approaches; ecosystem benefit indicators; biophysical ranking methods; and cost as a proxy for value (USEPA-SAB 2009).

In 2006, the **US Department of Agriculture, Forest Service** along with numerous cooperators developed ***i-Tree***. I-Tree is an open-access suite of freely available software and web-based tools designed to assess the benefits and values derived from individual trees or entire forests in both urban and rural areas. i-Tree encourages users to create healthy, sustainable, and resilient forest landscapes across the urban to rural continuum. Originally designed to work in the United States, the tools have expanded to have a global reach with professional and non-professional users. i-Tree developers continue to develop tools with the ultimate goals of assessing:

- Local forest conditions;
- Ecosystem services and values derived from forests;
- Local risks to forest and human health;

- How changes in forest structure will lead to changes and trade-offs among; ecosystem services and values'
- Best locations, tree species and planting rates to optimize ecosystem services and values through time and across space to enhance human health and well-being.

One of the tools, “*i-Tree Eco*”, also provides an avian habitat suitability (currently limited to 9 bird species), which has been adapted for Canada (Nowak *et al.* 2018).

Based out of Stanford University, California, the **Natural Capital Project** (NatCap) is a collaboration with the Royal Swedish Academy of Sciences, the Stockholm Resilience Centre, the Chinese Academy of Sciences, the University of Minnesota, Natural Capital Insights, The Nature Conservancy, and World Wildlife Fund. NatCap aims to improve the well-being of all by helping people, governments, and corporations incorporate the value of nature into decision-making (NatCap nd). Scientists and software engineers at NatCap designed ***InVEST***[®] (Integrated Valuation of Ecosystem Services and Tradeoffs), a suite of free, open-source software models used to map and value the goods and services from nature (Anonymous 2023). InVEST combines land use and land cover (LULC) data with information on the supply (biophysical processes) and demand of ecosystem services to provide a service output value in biophysical or economic terms (Sharps *et al.* 2017). Models are grouped into two primary categories: 1) supporting and final ecosystem service models and 2) additional tools to support service analysis. Supporting ESs include crop pollination, habitat quality, habitat risk assessment. Analyses can be conducted to address questions at the local, regional or global scale. InVEST often employs a production function approach to quantifying and valuing ecosystem services (Natural Capital Project 2025). InVEST has recently been repackaged into ***InVEST Workbench*** with an updated user interface.

There are hundreds of projects and groups involved in improving our understanding, modeling, valuation and management of ES and natural capital. Launched in 2008, the **Ecosystem Services Partnership (ESP)** brings together and coordinates the work of over 3000 ecosystem services scientists, policy makers and practitioners who work together in over 40 Working Groups and a large number of national networks from more than 90 countries (ESP 2025). The network provides a platform to facilitate communication, coordination and cooperation, and to build capacity with the goal of enhancing the science, policy and practice of ecosystem services for conservation and sustainable development. The ESP is supporting the development of ***comprehensive and practical guidelines (ESP Guidelines) for integrated ecosystem services assessment***. They aim to analyse and capture the benefits of landscape restoration, nature conservation and sustainable ecosystem and land management from an ecological, social and economic

point of view (De Groot *et al.* 2018). The draft guidelines consist of a 9 steps conceptual framework that connects the so called “4 Returns” of investing in nature conservation, ecosystem restoration and sustainable landscape management: return of natural capital, social capital, financial capital and inspiration. The document presents and describes 80 assessment methods, tools and models relevant to ES assessment that can be used at different steps of the guidelines (De Groot *et al.* 2018).

The ***Nature Braid*** (NB; formerly LUCI/Polyscape) toolset provides a suite of high-resolution GIS-based ecosystem services models relevant for a range of users at multiple scales and levels of decision-making. It can be used by local councils, community and stakeholder groups, farmers and land managers and policy makers for applications around sustainable development, conservation, sustainable tourism, restoration, and policy-making. NB allows the user to determine the spatial distribution, supply, and opportunities of the individual ecosystem services. Different scenarios of land use or land management can be explored to determine the impact on ecosystem services. A trade-offs tool allows to identify areas already providing services and areas with opportunities to improve services. Among the nine models described, NB includes agricultural production, habitat provision and land use/land cover accounting. The web site mentions that datasets from the United Kingdom, Europe, and New Zealand are currently supported by NB out-of-the-box, with support for a broader range of datasets to be added in the future (Nature Braid nd).

6.2- National:

The ***Canadian System of Environmental-Economic Accounts - Ecosystem Accounts***. Ecosystem accounts are based on the System of Environmental-Economic Accounting - Ecosystem Accounting (SEEA-EA; see above) framework, which was adopted as an international statistical standard by the United Nations Statistical Commission in March 2021. This framework complements, and builds on, the accounting for environmental assets described in the United Nations System of Environmental-Economic Accounting Central Framework (SEEA-CF), which was adopted as an international standard in 2012.

Ecosystem accounts are a structured compilation of information on ecosystem assets that include, for example, forests, agricultural areas, wetlands and other ecosystem types. Ecosystem accounts present information about both the extent and condition of ecosystem assets, as well as on the flows of ecosystem goods and services from which society benefits. These assets and their flows can be measured in both physical and monetary terms, but monetary ecosystem asset accounts are not a focus of the work currently being undertaken at Statistics Canada. Ecosystem accounts can also include

thematic accounts on several topics, such as urban and ocean areas, biodiversity, carbon and protected areas. Selected statistics on these themes are available. Work to date in this area is summarized in recent editions of the report *Human Activity and the Environment* (Statistics Canada 2022) and is the focus of new efforts as part of the development of the *Census of the Environment* (Statistics Canada 2023).

Building and expanding on the work of the report on *Human Activity and the Environment: Accounting for ecosystem change in Canada* (Statistics Canada 2022), the **Census of Environment** (CoE) will be the first-ever **national register of Canada's ecosystems**. It is designed to help track the size and condition of ecosystems such as wetlands, coastal areas and urban forests over time. The CoE will also highlight the services these ecosystems provide (for example, clean air, food, recreation) and how they benefit human well-being and the economy. The goal of the CoE is to deliver a full picture of the complex relationship between ecosystems and the economy, society, and human well-being via the **Census of Environment portal** (Statistics Canada 2025). This portal is under development at the time of this report. It will provide the statistical and spatial framework necessary to help track Canada's performance towards meeting international goals to protect the planet and achieve a more sustainable future. It will include collection and integration of data, access to regional data and will follow internationally-accepted ecosystem accounting standards and will maintain high standards of data governance and engagement (Statistics Canada 2024). The Census of Environment portal is available at <https://www.statcan.gc.ca/en/census-environment> where users can find the latest releases, data publications, reference material, mapping tools and can download relevant geospatial files (Statistics Canada 2025).

In Canada, a study about the **Value of Nature to Canadians** was initiated in 2009 with the objective of identifying the social, economic, and ecological significance of nature to Canadians in urban, rural, and wilderness environments in support of government policy and decision-making. It resulted in the development of a national approach to ecosystem services (ES) assessment and an interdisciplinary **toolkit for completing and using ES assessment**. The toolkit was developed with the intent to be a “step-by-step guide to complete a robust, comprehensive ES assessment” for all levels of governments, consultants, researchers and professionals in the areas of environment and natural resources management. The toolkit addresses valuation in economic and socio-cultural terms as a component of an ES assessment. It identified 24 major valuation methods, grouped under six monetary techniques (specific to economic valuation) and three non-monetary techniques (applying mainly to socio-cultural valuation). It also explained the considerations for either economic or socio-cultural valuation and provided links to

factsheets about different kinds of methods or tools for ES valuation (Value of Nature to Canadians Study Taskforce 2017).

The ***Canadian Environmental Sustainability Indicators*** (CESI) program was created in 2004 to report on the state of the environment by providing information and data to track Canada's performance on key environmental issues on air, biodiversity, climate, water, and waste and contaminants. The indicators allow decision-makers to track progress towards policy objectives and make informed decisions that support environmental sustainability. The information is used by policy makers, non-governmental organizations, academics, media and the public to better understand and evaluate Canada's state of the environment. CESI's environmental indicators provide national, and some regional and international, environmental trends. Interactive maps are also available to visually explore environmental indicator results at the local and regional scale. The biodiversity module includes indicators related to wildlife species, conserved areas, habitat and sustainable use of natural resources (forests and fish stocks) (Environment and Climate Change Canada 2025).

Nature Conservancy Canada collaborated with **Carleton University** to create a ***Conservation Planning Toolkit***. The toolkit helps conservation practitioners identify priority areas for conservation and land stewardship by considering species at risk, critical habitat, cultural values and cost-effectiveness. It includes three main tools: Where To Work (WTW), What To Do (WTD) and Landscape Resilience (LR). These tools use artificial intelligence and computing power to conduct real-time conservation analysis and compare multiple scenarios, incorporating complex data such as species distributions and climate change projections. The ***WTW tool*** creates spatial analysis using a large number of reliable Canadian datasets on various species, climate, soils, hydrology, and more, as well as metrics and mathematical optimization algorithms to reveal prioritization sites based on criteria specially chosen by the users to fulfill their mission to protect biodiverse and ecologically valuable land. The ***WTD tool*** assists in determining the best conservation actions to take within priority areas, evaluating stewardship activities such as installing fences or removing invasive species and assessing the potential impacts of these actions. The ***LR tool*** is designed to evaluate the resilience of different landscapes or project areas to help support decision-making in optimizing the contribution of conservation efforts to landscape resilience and nature's ability to thrive. Still under development, the LR tool helps identify areas that are resilient yet unprotected, making them prime candidates for area-based conservation efforts. It also assists in identifying degraded areas where restoration activities could provide significant benefits (NCC 2025).

In Ontario, the Credit Valley Conservation, Toronto and Region Conservation Authority, and Lake Simcoe Region Conservation Authority developed the **Natural Assets Carbon Assessment Guide and Toolbox** to guide the correct use of methods, tools, and resources to standardize estimations of two types of ecosystem services, carbon sequestration and carbon storage, across Greater Toronto Area and Lake Simcoe Region. Natural assets were defined as trees, forests, wetlands, grasslands, and manicured open spaces. The guide provides: i) per area, carbon sequestration and storage rates and additional information required to conduct assessments of carbon storage and sequestration for various local land cover types, including forests, wetlands, grasslands, and manicured open spaces and, ii) guidance regarding which tools, methods, and resources should be used to estimate carbon sequestration and storage for different natural assets (e.g., wetlands vs. grasslands), spatial scales (e.g. individual trees, forest stands, and patches of forest across a landscape), and project objectives and scenarios (e.g. restoration projects or protecting existing forests) (CVC, TRCA, and LSRCA 2022). The Toronto and Region Conservation Authority (TRCA) mentions that collaborative projects are currently underway to update carbon storage and sequestration rates in the guide for forests and wetlands. TRCA also indicates that they support municipalities by developing reliable methods to quantify and value ecosystem services for a variety of natural assets. They are exploring carbon storage, water runoff reduction, improved air quality, and more (TRCA 2025).

7- Nature Valuation: Methods

The IPBES report on the diverse values and valuation of nature is the first global and government-endorsed assessment on values of nature (IPBES. 2022a). It is the work of nearly 100 experts from around the world, assisted by about 200 contributing authors, along with significant input of indigenous and local knowledge. It integrates the screening of 32,248 peer-reviewed papers on valuation methods and a systematic detailed review and analysis of over 1,163 georeferenced studies applying specific valuation methods between 2010 and 2020. The report investigates valuation methods from the disciplines of economics and ecology that are largely informed by western worldviews but also explores valuation procedures and practices that look at nature and human-nature relations, including through the lenses of Indigenous People and Local Communities (IPBES 2022b, Termansen *et al.* 2022, Pascual *et al.* 2023).

IPBES identified and classified over 50 different methods to assess nature's values that have been applied in diverse socio-ecological contexts around the world in the last four decades of valuation research and practices. While multiple credible systems of method classification have been developed (see discussions in Brondízio *et al.* 2010, Chan *et al.* 2012, Gómez-Baggethun and Ruiz-Pérez 2011, Jax *et al.* 2013, National Research Council

2005, Pascual *et al.* 2010, Reid *et al.* 2006), including those from environmental economics (Freeman *et al.* 2014), and have their merits within their disciplinary context (economics, political science, anthropology, conservation biology, etc.), their application across disciplines and traditions, including those of indigenous people and local communities, is limited (Termansen *et al.* 2022). To overcome this limitation, IPBES grouped valuation methods into four main discipline-neutral “*method families*”, each including quantitative and qualitative valuation systems that are associated with biophysical, economic and socio-cultural approaches. Methods within families share the same value sources and as such, also share similar ways of eliciting value and many of the same limitations, irrespective of the discipline they were derived from (Termansen *et al.* 2022). In this report, we will adhere to the four valuation method families developed by the IPBES. Refer to Appendix 1 (supplementary material) for a list of methods associated with the four method families. The characteristics of the four families of valuation methods are presented in Table 2.

Three of the four valuation (of nature) method families are distinguished from one another by where they gather their information from (components of nature, people’s statements and people’s behaviour), while the fourth family integrates and synthesises values from multiple sources drawn from methods that spans the other three families to facilitate understanding and improve decision making (Termansen *et al.* 2022).

1. *Nature-based valuation*: “*assess the biophysical world in order to measure and characterise nature and components of nature to make nature’s contribution to people and the importance of nature-in-itself visible to decision-making*” (Termansen *et al.* 2022). These are methods for collecting and analyzing environmental data to support resource management decisions. They include direct (e.g., wildlife/vegetation surveys, camera trapping, soil or water sampling, etc.) and indirect (remotely sensed) observations on ecosystem or species, or on landscape, topography, soil, water and air and expert consultations (e.g., Delphi methods, participatory resource mapping, interviews) (Table 2, Appendix 1). Indigenous people and local communities may also conduct direct and indirect assessment of nature using their own methods, such as *ad-hoc* observations or targeted territory patrols (Termansen *et al.* 2022).

Four main (but not necessarily mutually exclusive) approaches comprising several methods are recognized by IPBES in this family. They include Direct Measurements, Stakeholder Consultations, Spatial Analysis and Mapping, and Modeling (Termansen *et al.* 2022, Appendix 1). The majority (68%) of the 1163 studies from IPBES’ global review of literature on valuation methods were nature-based

valuations (Termansen *et al.* 2022). ABMI’s “Status of Biodiversity in the Grassland and Parkland Regions of Alberta” report (ABMI 2016) is a good example where various approaches (direct measurements, spatial analysis and mapping and modeling) were used to generate the assessment.

2. *Behaviour-based valuation*: Also known as “revealed preference methods”, it “quantifies or qualifies the importance of nature for people based on what people do with/in nature” using both economic and non-economic indicators (Termansen *et al.* 2022). This may include records of time and efforts spent for nature, resources and money spent to experience nature or observations of rituals and traditions (Table 2, Appendix 1). Direct observations of people or indirect information from databases or descriptions of behaviours are used to derive this information (Termansen *et al.* 2022). The values elicited by this family are considered more robust and less biased by participants and interpreters. Behaviour-based valuation made up 12% of studies from IPBES’ global review of literature on valuation methods (Termansen *et al.* 2022).
3. *Statement-based valuation*: “Quantifies or qualifies the importance of nature for people based on what people express when asked about what they value and why” (Termansen *et al.* 2022). Information about statements include priority scores, narratives, or willingness to pay (or receive money) for changes in aspects of nature or human-nature relations. Valuations in this family are primarily derived from direct interactions with individuals or groups through surveys, interviews or group discussions (Table 2, Appendix 1). Methods from this family can reveal the worldviews and motivations behind how people value nature. They are especially useful to determine the value of non-market and non-use aspects of nature (Termansen *et al.* 2022). Statement-based valuation made up 11% of studies from IPBES’ global review of literature on valuation methods (Termansen *et al.* 2022).

A study to elicit the monetary value of a rare non-charismatic endemic species (giant Palouse earthworm; *Driloleirus americanus*) as an attribute within a larger multi-attribute valuation of the threatened and highly fragmented Palouse Prairie grassland ecosystem (Decker and Watson 2016) is a good example of statement-based valuation. Using a choice experiment method, area resident participants were asked to make trade-offs among 12 choice tasks representing three discrete choices of five grassland attributes and a conservation cost attribute. One of these attributes was the presence (or absence) of the giant Palouse earthworm, and another one was the cost (they would be willing to pay per year) for the conservation

of Palouse Prairie. The annual willingness to pay per household for the giant Palouse earthworm was estimated at about \$20.

4. *Integrated valuation*: “Combines several sources of information (whether from the same methods’ family or across families) on the importance of nature for people with the goal to integrate them towards a decision-making process” (Termansen *et al.* 2022). The integration process can happen through integrated modelling, deliberative processes or aggregation procedures to bring together value estimates with the goal of creating a comprehensive and aggregated accounting of the diversity of values and knowledge stemming from different stakeholders. Integrated valuation methods sit on the boundary between valuation systems and decision-support tools, but their inherent valuation features still dictates which and how values inform decisions. The approaches are varied and include *integrative* methods such as modelling and scenario building to summarize information for decision-making through the exploration of the interactions between ecosystem processes and human and environmental drivers, but also *decision-making tools* for project and policy evaluation (e.g., cost-benefit analysis, multi-criteria decision analysis, participatory rural appraisal and deliberative decision making (Table 2, Appendix 1) (Termansen *et al.* 2022). Integrated valuation made up 9% of studies from IPBES’ global review of literature on valuation methods (Termansen *et al.* 2022).

Examples from this method family include the Canadian ES Toolkit and the modeling work of Otto *et al.* (2022) in the grasslands of North and South Dakota. The Canadian Ecosystem Services Toolkit was developed by the federal, provincial, and territorial taskforce on the Value of Nature to Canadians to incorporate the use of ES assessments into various government applications. The toolkit is interdisciplinary, bringing together biophysical and social sciences, economics, and traditional and practitioner knowledge (Value of Nature to Canadians Study Taskforce 2017). It is designed to be implementable at the federal, provincial, territorial, regional, watershed or municipal scale. Otto *et al.* (2022) used a production function to quantify the relationship between the market value of grasslands to commercial beekeepers and the importance of grasslands for birds of conservation concern in North and South Dakota. Their models estimated beekeeping annual revenue increased by \$7525 USD and grassland bird abundances increased 2 to 7% per 10-km² increase in grassland area. Through this study they demonstrated both the market value of grasslands to commercial beekeepers and the non-market benefits of grasslands in supporting migratory birds.

Table 2. Characteristics of the four families of valuation methods (Termansen et al. 2022; also see Appendix 1) (Reproduced with permission under the terms of IPBES 2022).

	methods	methods	methods	methods
				
What is assessed?	Nature, physical or ecological components of nature	What people express when asked about the importance of nature	What people do in nature, for nature, with nature, to, as nature	Different outputs from one or more methods, to support decision-making
How is information about values generated?	Measuring nature and its functions through several methods such as remote sensing, field observations, consulting experts, etc.	Asking people (interviews, questionnaires), analysing other expressions (e.g., narratives, discussions, art, etc.)	Observing people, assessing records of people's behaviour (e.g., park visits, policy choices, (non-)market exchanges, etc.)	Synthesising, comparing, contrasting, deliberating, consolidating or aggregating diverse values for decision-making or decision support
Which values are elicited	Mainly intrinsic and instrumental values	Instrumental, intrinsic and relational values	Mostly instrumental values	Instrumental, intrinsic and relational values
Examples of value indicators	Species richness, CO2 stored, ecological indicators	Preferences for nature's contributions to people, subjective well-being indicators, narratives of human-nature relationships, required compensations	Time spent, share of household income, prevalence of disease, price of land, use of plants	Strength of support or objections to policy options, welfare gains or losses from projects
Examples of methods and approaches	Biodiversity assessment, ecosystem services mapping, Delphi method	Group discussion, Q-methodology, choice experiments, valuation interviews	Participant observation, travel cost method, cost-based method, livelihood dependence, photo-series analysis	Natural capital accounting, cost-benefit analysis, multi-criteria decision aid, integrated modelling, deliberative decision methods
Type of stakeholder inclusion	Most methods do not include stakeholders, though some inclusive approaches exist (e.g., based on local ecological knowledge)	Most methods include stakeholders to some extent (e.g., surveys) and inclusion is often integral to the method (e.g., participative approaches)	Most methods have limited stakeholder inclusion (e.g., analysis of market accounts) but some include diverse stakeholders	Some methods can be non-inclusive (e.g., desktop multicriteria decision analysis MCDA) but often, inclusion is key to the decision support aspect (e.g., participatory scenario building)
Examples of typical valuation "products"	Biodiversity indices, maps of priority areas for policy/management action, improved understanding of the importance of components of nature	Ranked importance of components of nature or nature's contributions to people, (monetary) value of protection of biodiversity-rich areas, explanations for why people value nature	Ranked importance of components of nature or nature's contributions to people, quantified changes in values nature or nature's contributions to people, explanations for why people value nature	Ranked policy options, evaluation of socio-economic and environmental impacts of policy options, improved understanding of conflicts/shared values of nature
Limitations/ concerns	Impact on people assumed but not assessed, dependence of nature is not assessed by the people dependent on the resources	Concern about reliability of statements, power disparity can reduce the validity of group-based methods, representativeness in selection of respondents	Requires conceptual and empirical understanding of the relationships between behaviour, nature and its contribution to well-being, challenging to reveal in-depth understanding of motivations behind behaviour	Aggregation of values across groups of people can reduce representation of values, combining multiple value types creates incommensurability concerns

Nature-based, statement-based, behavioural and integrated methods can be used to elicit and make sense of the diverse values of nature. Each valuation method family has its characteristics, strengths and limitations and may be better suited for certain objectives than others (Table 2). However, by combining complementary methods, their limitations can be lessened, and a more diverse set of values can be elicited. Expert consultation from diverse disciplines can help select the appropriate combination of methods to produce the most useful results for the decision being made (Termansen *et al.* 2022).

8- Choosing a Valuation Method

The choice of valuation methods in support of decision-making should be guided by **three key considerations**: their *relevance*, their *robustness*, and the *resources* they require for their implementation (thereafter referred to as the “3Rs”). The *relevance* factor determines the extent to which the methods and approaches used elicit the values that matter under different decision-making contexts. The *robustness* factor comprises two aspects: i) the ability to convey values reliably and consistently (involves assessing the replicability, the consistency and the precision of results); and ii) the legitimacy of the process in terms of the representativeness of stakeholders, both in the values that are included in the process and in the considerations given to the different people or groups impacted by the decision that it is intended to inform. Finally, the *resource* factor applies to the time, data availability and capacity (financial, technical and human resources) required to design and conduct the valuation (Pascual *et al.* 2023, Termansen *et al.* 2022). However, valuation systems rarely meet the three key considerations simultaneously.

According to Termansen *et al.* (2022), there are no perfect valuation methods or silver bullets that match methods to purpose and contexts. The purpose of the valuation will narrow down the methods that would be suitable, and the context of the assessment will further determine what works and doesn't work. Trade-offs between the “3Rs” must often be made, wherein an increase in relevance and robustness typically translates into a need for more resources and largely influences the feasibility of applying any given method (Pascual *et al.* 2023). Moreover, depending on how comprehensive the valuation is intended to be, it may be desirable to combine multiple complimentary methods.

The IPBES recommends five steps to help guide valuations. These include (1) constructing a legitimate process; (2) defining the purpose of valuation; (3) scoping the valuation; (4) selecting and applying valuation methods; and (5) articulating the values into decision-making (IPBES 2022b).

- Step 1- *Construct a legitimate process*: Identify who (people, social groups, communities) depends on nature and will potentially be affected positively or

negatively by the changes; what are their levels of dependence on nature; what are their levels of influence and power on the decision about nature; which groups of people (and non-human being) need to be distinguished; whose values need to be represented; which people/groups/communities need to participate in the valuation process and; which processes and inclusiveness measures need to be achieved?

- Step 2- *Define the purpose of valuation*: Decisions from step 1 help to establish the goals and purposes of the valuation, which can be stated, communicated towards or deliberated together with the relevant people, groups or communities in a transparent manner. Questions to be asked to clarify this step include why is the valuation being conducted; which decision type(s) is the valuation anticipated to inform; how will the results influence these decisions and who will be involved in decisions regarding these questions? The latter may involve adapting step 1.
- Step 3- *Scoping the valuation*: Decide on the values to be covered by the valuation. This includes deciding on broad and specific value types that are important to the people/groups identified in step 1; keeping those that are relevant to the purpose of the valuation (step 2) and removing those that are not relevant or not relevant enough to the people/groups considered. The kinds of expertise needed, along with the available resources (time, financial, technical) need to be determined realize valuations for these value types.
- Step 4- *Selecting and applying valuation methods*: With a clear process, purpose and scope, valuation method(s) can be selected and applied. This will be influenced by the inherent features of existing methods and the trade-off considerations needed based on available resources (step 3). It is important at this stage to involve experts from different disciplines to avoid disciplinary bias and assess the potential approaches and methods from different perspectives and traditions, so as to recognize or represent the full extent of value diversity entailed by the purpose.
- Step 5- *Articulating the values for decision-making*: A successful valuation exercise should have its results inform and improve the decision for which it was designed. The actors commissioning the valuation, the diverse actors involved in it and the valuers share the duty to responsibly and effectively integrate the value information in the decision process.

In working toward the PCF's long-term environmental outcome of protecting isolated native habitats (PCF 2021), the following considerations grounded on the above IPBES 5-step guidelines could be taken when developing a valuation process. The process is iterative and adaptive and may involve returning to previous steps as new knowledge or information is shared and decisions are made:

PCF Step 1- **Construct a legitimate process**: Deciding on protecting parcels of isolated native prairie habitat may impact (positively or negatively) several stakeholders. They may include either private or public landowners and land managers who directly depend on them to make a living. Some parcels may have indigenous values associated with them, which may be taken into consideration in the valuation process. Natural resources planners at various levels of government as well as non-government organization (NGOs) involved with land securement and stewardship could also be brought to the table to address the needs of priority species and habitats and their beneficial management.

PCF Step 2- **Define the purpose and intended use of the valuation output**: Some of the questions to be asked here and potential answers are (Termansen *et al.* 2022):

- *Why is the valuation conducted?* In the case of isolated habitats, it may be to determine which patches of habitat are the more valuable from the perspective of the stakeholders identified in Step 1.
- *Which decision types does the valuation aim to inform?* Which parcels of land need to receive greater attention from a conservation and stewardship's perspective to prevent their loss or increase their suitability for the various values identified (e.g., biodiversity, local traditions, nature appreciation, etc.).
- *How will valuation results target these decisions?* The valuation process may involve some form of multi-criteria ranking of habitat patches with decisions to be made as to the threshold below which little or no effort is afforded toward their conservation/stewardship, and above which various efforts could be deployed on an incremental basis.
- *Who will be involved in decisions regarding the above questions?* Likely resource managers will have an important role to play in this aspect, but other key stakeholders (from Step 1) could make strategic contributions.

PCF Step 3- **Scoping the valuation**: The set of values to include are decided at this stage. Value types from the stakeholders identified at step 1 would be considered here. Biophysical (intrinsic) values are likely to be considered at this step. These may include the diversity of priority species (for Isolated Habitats Mapping project; Taylor 2022), high priority landscape, the status of species and the status of native habitat as determined in the *Status of Biodiversity in the Grassland and Parkland Regions of Alberta* report (ABMI 2016), connectedness (see Han *et al.* (2022) below), etc. Instrumental (e.g., grazing) and relational (e.g., aesthetics, recreational and cultural/spiritual) values could also be included here. The 3Rs (*relevance, robustness, and the resources [time, financial, technical]*) and the kinds of expertise needed to realize valuation for these value types should be determined at this step.

PDF Step 4- **Selecting and applying valuation methods:** Multiple methods would likely be of consideration for isolated habitats valuation. There are many ways to assess biophysical values that could be used for isolated habitats. A multi-species biodiversity index could be developed from the Isolated Habitat Mapping project (Zanshin Environmental Networks Inc. 2023). ABMI's (2016) methodology used to determine the biodiversity intactness and effective mesh size indices (exercise already completed) could be integrated into this step. The concept of connectors and stepping stones from Han *et al.* (2022) would be worth investigating to integrate in the valuation process. The range health score may indicate the state of certain ecosystem services (Adams *et al.* 2016). The vegetation structure components of the rangeland health could provide an index of bird abundance (Hendersen and Davis 2014). At this stage, open-minded experts from different disciplines may be required to look at the inherent features of existing methods, to assess the pros and cons of the different methods, to afford representation of the different stakeholder values and to assist with determining what trade-offs need to be made respective of the 3Rs identified in Step 3.

PCF Step 5- **Articulating the values for decision-making:** At this step, an action plan could be developed prioritizing selected activities (e.g., conservation, habitat stewardship, restoration, etc.) on isolated habitat patches according to their assessment "values" so as to achieve the PCF's long-term environmental outcome of protecting isolated native habitats.

9- Valuations Specific to Natural Habitats, Native Grasslands and Isolated Habitats

Several studies in the literature used various approaches to natural habitat valuation, including valuations that are specific to native grasslands and/or isolated habitats. Depending on the objectives, they used either monetary or biophysical measures/indicators in their assessments, which involved looking at instrumental or intrinsic values. They are described below.

9.1- Valuation Studies about Natural Habitats

The Institute for Sustainable Finance (ISF 2024) conducted a [partial assessment of Canadian wetlands' value, looking at two ecosystem services: water filtration services and carbon sequestration services](#). The accuracy of models of wetland land cover was determined to be generally poor, which limited their estimates of total wetland area. They deferred to the System of Environmental-Economic Accounting - Ecosystem Accounting (SEEA-EA; see above) to determine their choice of methods. They focused on valuing wetland services that have a directly observable market price, which was limited to the two

ES afore mentioned. Using the benefit or value transfer method, they estimated that wetlands provided natural services worth around \$225 billion per year, equivalent to around 10 percent of GDP. They also investigated potential areas of capital sourcing for preserving natural assets such as wetlands. These include Green bonds; Environmental Impact Bonds, payment for ecosystem services models; Voluntary Carbon Markets (VCMs), biodiversity credits (similar to carbon credits), blended financing models and tax incentives. They found that Canada severely lacks an understanding of its current stock of natural capital (including but not limited to wetlands). They indicated that a major area of focus for ISF will be to develop more accurate estimates of total coverage of wetlands and other beneficial ecosystems, combined with thorough evaluations of their derived services.

Külling et al. (2024) conducted a comprehensive spatial assessment for 15 Nature's Contributions to People (NCP) and one biodiversity – distribution of threatened species – indicators (BD) in Switzerland. Indicators values were computed using a combination of mapping and modelling methods. They found significant trade-offs and synergies in the spatial repartition of these indicators. In particular, an analysis performed on the 16 indicators revealed the existence of four bundles showing a heterogeneous repartition over the Swiss landscape. They concluded that various significant relationships existed between NCP and biodiversity indicators in Switzerland, emphasizing the importance of informed conservation approaches considering both NCP and biodiversity supply.

In 2023, **EcoMetrics** conducted an analysis of the market and non-market value of the environmental, economic, and social benefits created by a four-farm pilot implementation of the “Alliance for Water Stewardship standard” in the Lake Winnipeg Basin in Manitoba. The Project Partners engaging in this work were two environmental groups, ALUS Canada and The Water Council, and four agri-food supply chain companies. EcoMetrics was tasked to characterize the co-benefits that could be expected to result from the intended water stewardship practices, in order to establish which water stewardship practices -if implemented- would drive the most value for the environment, communities, and the value chain. EcoMetrics incorporated the guiding principles of Social Value International's (SVI) Social Return on Investment (SROI) Methodology in their assessment. They used a meta-analysis and benefits transfer approach to assign economic values to outcomes. They looked at “current conditions” (prior to adoption of practices) and changes anticipated from “implementation of proposed water stewardship practices” over the next 25 years and measured the difference (delta). Values were assigned for two management strategies: 1) cropland stewardship strategies (improved nutrient management, water use and tillage on cropland), and 2) enhancement of edge-of-fields and marginal farmlands (restoration or preservation of riparian buffer zones, inland wetlands, planting of hedgerows [windbreak and pollinators], preservation of green space). Values were presented by stakeholder,

including Environment & Producers, Producers, General Public and Local Governments. The “Habitat and Biodiversity” outcome of enhancing edge-of-field and marginal farmlands was estimated to produce a net value of nearly \$16 million dollars over 25 years for the Environment & Producers group (Piñero *et al.* 2023).

9.2- Valuation Studies Specific to or Including Grasslands

Mulrooney and Jones (2023) used a benefit transfer approach to produce an initial estimate of the potential economic value of ecosystem services and natural capital associated with the terrestrial and marine environments in [Canada’s federal system of national parks and national marine conservation areas](#). Landsat satellite data were employed to determine asset extent, and ES values were taken from the scientific literature with applicability to the Canadian context. Eight land cover types (or “asset” types) were recognized: barren lands, forested lands, [grasslands](#), shrublands, water, wetlands, snow and ice, and marine. Ecosystem service values were assigned to the extent of each asset type in each protected area. [Grassland environments had an annual service value at between CA\\$ 6 billion and CA\\$ 32 billion \(medium estimate of approximately CA\\$ 19 billion – in 2020 CAD\)](#). Values for 12 ES were also provided.

DeLoyde and Mabee (2023) used previously published data post-2005 to [ascribe values \(in monetary terms\) of provisioning, regulating, cultural, and supporting ecosystem services for different land cover classes, including grasslands, in southern Ontario](#). Data describing land cover classification from two time periods were used to understand changes on the landscape before and after protected areas were designated. [The tool presented is capable of monitoring discrete categories of ecological services as well as overall values to provide useful ecological indicators for environmental planners and land managers](#). Their findings illustrate the effectiveness of using ecosystem service values to assist planners and land managers in making land management decisions with regard to maintaining protected areas for the long term, versus the conversion of protected areas into urban development. Data for grasslands came from three studies: Wilson (2008, see below), Troy and Bagstad (2009), and Spatial Informatics Group (2013).

Otto *et al.* (2022) used a production function to [quantify the relationship between the market value of grasslands to commercial beekeepers and the importance of grasslands for birds of conservation concern in North and South Dakota](#). Their models estimated [beekeeping annual revenue increased by \\$7525 USD per 10-km² increase in grassland area and grassland bird abundances increased 2% to 7% per increase in grassland area](#). Through this study they demonstrated both the market value of grasslands to commercial beekeepers and the non-market benefits of grasslands in supporting migratory birds.

Wilson (2014) took a similar approach as Wilson (2008; see below) to [assess the economic values for the ecosystem services provided by natural capital within the B.C. portion of the Peace River Watershed](#), ahead of a major hydroelectric development project (Site C) in the Peace River Valley. Spatial land cover data were used to identify land cover ecosystem types and land use for the study area, including grassland. Ecosystem types and land use were then used to identify the ecosystem services (ES) provided by the area's natural capital. The ES values reported in the study were mostly direct- and indirect-use values and the approaches taken to assess them were provided.

The [Ontario](#) Ministry of Natural Resources commissioned **Spatial Informatics Group** in **2013** to [investigate two different approaches to quantifying and assessing ecosystem services in and around several provincial parks in Ontario](#). In one approach, they used the platform ARIES (see above) to quantify the spatial connection between ecosystems and their beneficiaries, looking at the type of service and assessing the physical flows of benefits over space. They tested this framework as a proof of concept on two case study areas, for four different ecosystem services. The other approach used a “value transfer” analysis for a different region. The value transfer analysis resulted in the development of a detailed and customized land cover typology that included 18 classes with valuations and one class for all other land that didn't have existing or expected valuation. The valuation estimates used for the value transfer approach were similar to those in the Southern Region Study by Troy and Bagstad (2009), but with a number of modifications, including updating values to 2011 Canadian dollars. Grasslands were represented by the [“Grassland/pasture/hayfield” class](#), which is the same class as in Troy and Bagstad (2009). [It was estimated at \\$399/ha/year for eight ecosystem services](#), which translated into a total value of \$3,990 per year for the provincial parks and conservation reserves assessed (Voigt *et al.* 2013).

ÉcoRessources Consultants (2013) developed a [tool to generate estimates of the value of nature's benefits to society arising from the restoration of ecosystems and habitats on ALUS \(Alternative Land Use Services\) farmlands](#) in Canada. As part of a primary step in ALUS' marketing strategy, the tool was developed with the goal of demonstrating the value of ES to potential investors, communities and customers to support potential investments in its program. The tool estimated the economic values of suites of ecological services from five restoration project types by using accepted benefit transfer approaches. These project types included wetland, streamside vegetation, [grassland](#) and forest restoration. Grasslands were assessed for two counties, Norfolk (ON) and Vermillion River (AB), and estimates were largely derived (with modifier) from those of ES for grasslands and forests by Christie *et al.* (2011; below). [Their \(conservative\) value was assessed at \\$1/acre/year in Vermillion River and \\$37/acre/year in Norfolk](#), presumably due to the difference in

population density which was 31 times higher in Norfolk resulting in greater scarcity of grasslands (ÉcoRessources Consultants 2013).

Christie et al. (2011) undertook a valuation research study to estimate the economic value of changes in biodiversity and associated (non-market) ecosystem services expected to result directly from the delivery of the [UK Biodiversity Action Plan](#) (UK BAP). They assessed 1) the marginal value of ecosystem services associated with the UK BAP, 2) the levels of ecosystem services delivered by different UK BAP habitats, and 3) the marginal value of the UK BAP conservation activities: across the UK as a whole; within different regions of the UK; and across different BAP habitats and species. They examined two scenarios: i) “*Current spend*” - maintain current level of BAP provision, and ii) “*Increased spend scenario*” - above and beyond the *current spend* scenario, where the BAP is fully implemented. A choice experiment study (public valuation) was used to estimate the economic value of seven ecosystem services associated with the UK BAP. Of the 19 broad habitat types assessed, grasslands were represented by [lowland calcareous grassland](#), [lowland dry acid grassland](#), [upland calcareous grassland](#) and [improved grassland](#). The total marginal benefits (aggregate value) of the ecosystem services delivered by the UK BAP under the “*current spend*” scenario for the entire UK was £174.37m/year and the total marginal benefits (aggregate value) under the “*increased spend*” scenario was £92.63m/year for the three grassland habitat types (Christie et al. 2011).

Troy and Bagstad (2009) conducted a [spatially explicit ecosystem service valuation for southern Ontario to inform policy-makers wishing to incorporate ecosystem service values into their decision-making](#). They used a proprietary database system and query engine along with the spatial value transfer-based methodology. It provided estimates of the yearly flow of ecosystem service values per land cover type for southern Ontario and illustrated the geographic variation in these values. [The land cover type grassland/pasture/hayfield was described as “likely areas for pasture or hayfields, or identified native grasslands outside of urban areas” was estimated at \\$353 \(2008 CAD\)/ha/year for the entire study region and included eight ecosystem service types.](#)

The [British Columbia Grasslands Conservation Council](#) (GCC) commissioned **Wilson (2009)** to 1) [conduct a review of the ES valuation studies about grasslands in North America](#), 2) [conduct a review of payment for ecosystem services including conservation programs and carbon trading systems related to grasslands and rangelands](#), 3) [provide opportunities for further research on conservation incentive and ES valuation for grassland conservation in BC](#), and 4) [provide three priority actions for GCC’s future work on natural capital and conservation incentives](#). Wilson (2009) identified ten global, national, state and

regional economic assessment studies on the value of ES related to grasslands, some of which are mentioned below.

Wilson (2008) used various data sources to [quantify the natural capital value \(in monetary terms\) of the non-market ecosystem goods and services provided by Lake Simcoe's watershed](#), a section of which is located in [Ontario's Greenbelt](#). This project involved identifying and classifying the extent of the different land uses and ecosystem types across the Lake Simcoe basin in order to assess the ecosystems, functions and their respective services. [Grasslands were one of the ecosystem types](#), which included perennial crops and pastures (because some ALUS farmlands allow grazing).

Dodds et al. (2008) [determined the economic value and the relative benefits for eight categories of ecosystem goods and services associated with native and restored lands in six ecoregions across the conterminous United States](#). They found that wetlands (48%) and Great Plains (10%) had the greatest remaining native areas. With 23 million hectares remaining as native and 10 million hectares restored, [the Great Plains ecoregion's ecosystem goods and services were valued at \\$1574 billion per year \(in 2004 US dollars\), with \\$384 billion of that corresponding to restored areas](#). Using various approaches, they provided estimates for eight ecosystem services for the six ecoregions. For the Great Plains, commodities (native and tame grasses harvested) represented the highest value at \$3853/ha/year and biodiversity (e.g., pollination) was estimated at \$46/ha/year. Native and restored Great Plains lands supplied the largest economic values of biodiversity per unit area of the terrestrial ecoregions. They considered that restored lands offered 31% to 93% of native land benefits (70% for the Great Plains) within a decade after restoration and concluded that conservation should be the first priority, but that restoration programs across broad geographic regions can have substantial value.

In their two-year study, **Costanza et al. (2008)** [assessed the economic value of New Jersey's ES and natural capital](#). They used three different approaches to derive their monetary estimates: value transfer, hedonic analysis, and spatial modeling. They organized their study by different land cover types. [Pasture/grassland land cover type was valued at \\$77-2004 USD per acre per year](#) for the gas/climate and water regulation and soil formation, waste treatment, pollination, biological control and aesthetic and recreation services they provide.

De Witt and Blignaut (2006) were contracted to [assist with assessing the economic value of grassland ES in South Africa](#). They provided a broad overview of existing monetary valuation studies of grasslands in South Africa, sufficient to inform proposal development to the Global Environmental Facility. They also developed comprehensive physical and monetary grassland accounts for South Africa. They determined that the Grassland biome

of South Africa covered an area of 336,544 km². They estimated the value of the flow of ecosystem services in South African grasslands to be in the order of 9.7 billion rand per annum, or 29,000 rand per km².

Olewiler (2004) explained the importance of valuing nature. The services provided by Canada's natural capital are described using four case studies. Case studies illustrate that governments may be making inefficient choices in allocating land to uses that destroy and degrade natural capital. Society may therefore have to look for more expensive substitutes or to forego these services at a loss to our well-being today and into the future. The case studies include the Lower Fraser Valley in British Columbia, the Grand River watershed in southern Ontario, the Upper Assiniboine River Basin in east-central Saskatchewan and western Manitoba and the Mill River watershed in western Prince-Edward Island. The Lower Fraser Valley's natural capital valuation includes goods and services provided by grasslands and rangelands, for which conservation is valued at \$232 per hectare per year. This value was transferred from **Costanza et al. (1998)** in their global assessment of ecological services.

The **Pilot Analysis of Global Ecosystems (PAGE)** project was intended to provide an overview of ecosystem condition at the global and continental levels for five major categories of ecosystems: 1) agroecosystems, 2) coastal ecosystems, 3) forest ecosystems, 4) freshwater ecosystems, and 5) grassland ecosystems. It documented the extent and distribution of the five major ecosystem types and identified ecosystem change over time and analyzed the quantity and quality of ecosystem goods and services. PAGE also attempted to assess the capacity of ecosystems to continue to provide goods and services, using measures of biological productivity. PAGE is a predecessor of the Millennium Ecosystem Assessment (MA 2005) (White *et al.* 2000). As part of PAGE, **White et al. (2000)** investigated grassland ecosystems to present quantitative indicators and qualitative information on the condition of the world's grasslands. Grassland condition was defined in terms of the current and future capacity of these ecosystems to provide goods and services important to humans. Goods and services included food, forage and livestock, biodiversity, carbon storage and tourism and recreation. Measure indicators, conditions and trends and information status and needs are presented for each category of ecological goods and services.

Also see **Herrera et al. (2017)** and **Decker and Watson (2016)** below.

9.3- Valuation Studies Specific to Isolated Habitats

Deane and Riva (2025) investigated whether equal areas of smaller and larger habitat patches provided equivalent habitat value and how might this change over time and under

differing matrix conditions. They developed an indicator of relative habitat value based on a species-individual null model and used the indicator to compare sets of patches ordered in small-to-large and large-to-small orders, building hierarchical Bayesian regression models to test the role of time since patch creation and contrasting matrix conditions. They assessed habitat value for 85 metacommunities inhabiting fragmented landscapes from around the world (1354 patches, >4500 species). **They found that, in long-fragmented, light matrix landscapes, small and large patches apparently offer comparable per-unit-area habitat value. Conversely, under a harsh matrix, larger patches retain slightly greater habitat value.** They speculated that a ‘colonization credit’ might occur within smaller patches after the initial loss of fragmentation-sensitive species in disturbed landscapes. Overall, analyses supported the need to maintain and enhance total habitat area—regardless of configuration—for biodiversity conservation, especially in long-fragmented landscapes with light matrices.

Wang et al. (2024) used the *stepping-stone* and *complex network theories* to simulate the ecological network in highly urbanized areas of southeast China, evaluate the centrality of each “ecological source” (patches with the highest habitat quality) and “stepping-stone” (patches of high ecological flow density and high habitat quality) and analyse the network robustness under different damage scenarios. **They then identified the optimal strategy and key patches for maintaining ecological connectivity.** They also evaluated whether the key patches were protected by China’s new policies: Ecological Protection Red Line (EPRL) and the Three Lines One Permit (TLOP). Results indicated that 1) the ecological network was composed of 53 ecological sources and 291 stepping-stones, with 591 links between them; 2) **the network stability can be optimally maintained by prioritizing the protection of stepping-stones with high centrality, and 3) the 53 ecological sources and 51 stepping-stones with the highest centrality can ensure the stable operation of the ecological network, that is, they are key patches for ecological corridor maintenance.**

Riva and Fahrig (2023) analysed 71 datasets (a global compilation of metacommunities hosting 4351 taxa in 1149 patches) and 425 scenarios (i.e. combinations of dataset×habitat amount that included at least two sets of patches involving 9954 sets of patches) to **compare species richness and evenness across sets of patches with equal cumulative area, but different sizes and numbers of patches.** They tested two predictions: for multiple sets of patches totalling the same habitat area: 1) species richness and species evenness will increase with increasing mean patch size across sets of patches, that is, when habitat is less fragmented; 2) the positive relationship between species richness or species evenness and mean patch size [Prediction (1)] will be weaker in scenarios with a higher species turnover. To achieve the former, they measured species richness (S) and species evenness, measured as Hurlbert's probability of interspecific encounter (PIE), following

Chase *et al.* (2020; see below). Then, they modelled the effect of mean patch size of a set of patches on each of S and PIE. To achieve the latter, they partitioned beta diversity using incidence-based (Jaccard dissimilarity) and abundance-based (Ruzicka dissimilarity) metrics. They also tested whether the diversity in small patches was inflated by generalist species spilling over from the matrix into small patches. To achieve this, they re-evaluated Prediction (1) (above) including only declining species (thus excluding generalist species that are not declining or are increasing). They concluded that ecosystem decay (as observed for small patch sizes in Chase *et al.* 2020) did not extrapolate to the landscape scale. As opposed to Prediction (1), they found that species richness actually decreased with increasing mean patch size across sets of patches (when habitat was less fragmented). The same relationship was found when evaluating only declining species, indicating that the increase in total species richness with decreasing mean patch size was not due to spillover of generalist species from the matrix into small patches. Consistent with Prediction (2), they found that when considering an equal total habitat area, higher species turnover in a metacommunity contributes to the higher species richness across sets of several small than few large patches. They suggest that “we should take advantage of all opportunities to protect and restore habitat, regardless of patch sizes”.

Riva and Fahrig (2022) analysed 32 datasets from around the world comprised of 603 patches and 2290 taxa using a classical SLOSS (single large patches or several small patches) comparison for each dataset to determine whether the current conservation emphasis on large over small patches is valid. In one curve, the number of species and total area are accumulated from smallest to largest patch, and in the other curve they are accumulated from largest to smallest patch. If the largest-to-smallest curve lies above the smallest-to-largest curve, then SL > SS. If the reverse occurs, then SS > SL (SL = single or a few large patches; SS = several small patches). If the curves cross, the SLOSS comparison is inconclusive (SL = SS). Results: 1) sets of small patches harbor more species than large patches even when considering only species of conservation concern. 2) sets of small patches harbor more species than large patches even when the small patches are very small compared to the large patches. Therefore, higher extinction risk in small than large patches does not decrease the cumulative value of small patches for biodiversity. Their results confirm and reinforce the results of other studies that demonstrate the disproportionately high value of small patches for biodiversity conservation, providing managers, practitioners, community groups, and individuals with evidence supporting their efforts to protect or restore small areas of habitat.

Szangolies *et al.* (2022) used an individual-based, spatially-explicit community model to analyze the diversity of mammal communities in landscapes consisting of a few large habitat islands interspersed with different amounts and sizes of small habitat patches.

Within these heterogeneous environments, individuals compete for resources and form home-ranges, with only risk-tolerant individuals using habitat edges. Results show that when risk-tolerant individuals exist, small patches increase species diversity. A strong peak occurs at approximately 20% habitat cover in small patches when those small habitats are only used for foraging but not for breeding and home-range core position. Additional usage as stepping stones for juvenile dispersal further increases species persistence. Overall, [their results reveal that a combination of a few large and several small habitat patches promotes biodiversity by enhancing landscape heterogeneity](#). These small patches add value to landscapes by serving as foraging areas and stepping stones and diversifying the environment.

Han et al. (2022) used the [forest in Kalajun-Kuerdening, Xinjiang, China](#), as a case study, [to assess the potential role of small patches in landscape connectivity, and to determine which of these sites should be prioritized for conservation/protection](#). They ranked the patches according to their importance in maintaining overall connectivity. They used the following metrics of connectivity proposed: the probability of connectivity index, normalized equivalent of connected area, and the number of components. Thirteen patches were classified as critical and fourteen as important patches for landscape connectivity, which they proposed should be recognized as priority sites. Based on their contributions to maintain overall connectivity, [seven small \(<5 ha\) patches and fifteen small patch clusters were identified as connectors between large patches, which could be used as stepping stones by some species. Some small patches provide critical habitat and protection for species with small home ranges and short dispersal distances and thus were prioritized for both conservation and management of landscape connectivity](#).

Chase et al. (2020) analysed 123 studies of assemblage-level abundances of focal taxa taken from multiple habitat fragments of varying size [from around the world to evaluate the influence of passive sampling \(species are lost in proportion to their abundance and distribution in the natural habitat with habitat loss\) and ecosystem decay \(more species are lost than would have been expected simply through loss of habitat alone\) on biodiversity loss](#). They found that across all studies, [ecosystems and taxa, biodiversity estimates from smaller habitat fragments contained fewer individuals, fewer species and less-even communities than expected from a sample of larger fragments, supporting the ecosystem decay hypothesis](#). They calculated several biodiversity indices that reflect different aspects of the total and relative species abundances, as well as aspects of sample completeness. They used hierarchical generalized linear models to examine the relationship between biodiversity indices and fragment size.

Wintle et al. (2019) undertook a [global synthesis of the relationship between the conservation value of habitat patches and their size and isolation](#), based on 31 systematic conservation planning studies [across four continents](#). They found that that small, relatively isolated habitat patches of high shape complexity in fragmented landscapes tend to be of higher conservation value according to a complementarity and representativeness criterion than a similar-sized habitat patch within contiguous tracts of intact vegetation of low shape complexity. This means that [small, isolated patches are inordinately important for biodiversity conservation](#). Their results provide a powerful argument for redressing the neglect of small, isolated habitat patches, for urgently prioritizing their restoration, and for avoiding simplistic application of island biogeography theory in conservation decisions. The conservation value of a given landscape unit (raster cell) was defined in terms of its conservation priority rank, as determined by a Zonation analysis based on a “marginal loss” function, that is based on the proportion of remaining species distributions contained within each cell. Based on vegetation mapping, patches of habitat generally comprised areas of natural forest, woodland, shrubland, or [grassland](#) embedded in a matrix of human-modified agricultural land thought to be unsuitable for the species included in each case study.

Herrera et al. (2017) investigated the potential [contribution of small habitat patches as stepping stones for maintaining overall landscape connectivity for many species inhabiting fragmented landscapes](#). They used connectivity metrics based on a graph-theoretic approach to (i) quantify the connectivity of [grassland patches](#) in a sector of the [Pampa region in Argentina](#) using a range of dispersal distances (from 100 to 10,000 m) representative of the scale of dispersal of different species; (ii) identify the most relevant patches for maintaining overall connectivity; and (iii) study the importance of small patches (defined for different area thresholds of 5, 20, and 50 ha) as connectivity providers in the landscape. They found that [grassland patches](#) were in general poorly connected at all distances, but some of them [played a critical role as stepping stones, yielding significant connectivity gains for species that move large distances](#) for the three area thresholds considered. They recommended 1) to preserve grassland patches with the highest potential as stepping stones to promote landscape-level connectivity and 2) to pay more attention to the conservation of key small patches, since usually they are those more vulnerable to land clearing for agriculture.

Decker and Watson (2016) conducted a [study to elicit the monetary value of a rare non-charismatic endemic species \(giant Palouse earthworm; *Driloleirus americanus*\) as an attribute within a larger multi-attribute valuation of the threatened and highly fragmented Palouse Prairie grassland ecosystem](#) (covering central Idaho, southeastern Washington, and northeastern Oregon) using a statement-based valuation approach. They employed a

choice experiment method where area resident participants were asked to make trade-offs among 12 choice tasks representing three discrete choices of five grassland attributes and a conservation cost attribute. One of these attributes was the presence (or absence) of the giant Palouse earthworm, and another one was the cost (they would be willing to pay per year) for the conservation of Palouse Prairie. [The annual willingness to pay per household for the giant Palouse earthworm was estimated at about \\$20.](#)

Ovaskainen and Hanski (2003) [investigated ways of classifying the different types of measures that can be used to characterize “patch value”](#) for the dynamics and persistence of a metapopulation living in a network of many fragments. They argued that the question “What is the value of a particular habitat patch in a patch network” cannot be properly answered until what is meant by “patch value” is first defined. They investigated four alternative quantitative measures of the “value” of an individual habitat fragment: the contribution of a fragment to the metapopulation capacity of the network, to the equilibrium metapopulation size, to the expected time to metapopulation extinction and the long-term contribution of a fragment to colonization events in the network. They showed that [the value of a fragment depends not only on the properties of the landscape but also on the properties of the species. Most importantly, variation in fragment values between the habitat fragments is greatest in the case of rare species that occur close to the extinction threshold](#), as these species are likely to be restricted to the most favorable parts of the landscape.

Fisher and Lindenmayer (2002) [analysed the conservation value of small patches in terms of bird species diversity in two landscapes of southern Australia.](#) Their results show that in the Tumut landscape, patch sizes ranged between 0.5 and 97.6 ha; 30 species of birds (37%) were observed in patches of up to 1 ha, and 74 species (91%) were found in patches of up to 10 ha. In the Nanangroe landscape, patch sizes ranged from 0.4 to 15.6 ha, and 74 species of birds (75%) were found in patches smaller than 1 ha. [In both landscapes, small patches contributed strongly to species accumulation curves.](#) They concluded that while large patches are needed by many species to maintain viable populations, [it is important to recognise the complementary value of small remnants.](#) They further indicated that it is necessary to examine the value of small habitat patches, so they are not removed simply because they are small, and hence implicitly assumed to be worthless. In addition, due to their lower costs, small scale restoration programmes using small patches as a starting point are more likely to be implemented in the short term than large scale projects that can be very expensive.

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