WASHINGTON STATE
Academy of Sciences
Science in the Service of Washington State

Report on Net Ecological Gain

Prepared for the Washington State Department of Fish and Wildlife

July 2022

WSAS Committee on Net Ecological Gain

Seattle, WA

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INTRODUCTION

The Washington Department of Fish and Wildlife (WDFW) requested that the Washington State Academy of Sciences (WSAS) inform its work on the development of a net ecological gain (NEG) standard for public projects as part of the response to a proviso contained within Engrossed Substitute Senate Bill 5092 (2021).

WSAS convened a committee of scientific and technical experts to conduct this work. The scope of work for the committee was to develop a definition, goals, objectives, and performance metrics for the net ecological gain standard, assess how sufficient existing standards have been in achieving endangered species recovery, and make recommendations about monitoring and indicators for no net loss and net ecological gain. The scope of work was divided into two report chapters.

The committee completed two separate report chapters and transmitted them to WDFW. This document contains the two reports in their entirety; the content of the chapters should still be cited separately.

The first report chapter synthesizes the committee's perspectives on a proposed definition for net ecological gain, considerations for defining net ecological gain, and goals and objectives for achieving net ecological gain. The committee interpreted the charge as producing a definition of net ecological gain that would be relevant to Washington State, as well as providing examples of specific goals and objectives for how the definition should be applied to ecosystems or projects.

The second report chapter focuses on (1) assessing whether and why existing standards of ecological protectiveness, such as no net loss (NNL) standards, have been sufficient or insufficient to protect ecological health and achieve endangered species recovery and (2) providing recommendations for developing: performance metrics for the NEG standard, indicators to assess NNL and NEG, establishment of a monitoring system, and incorporation of climate science predictions into NNL and NEG standards. The committee also presents suggestions for subsequent activities that may facilitate next steps toward successful implementation of NEG in Washington State.

The committee hopes that this report serves as a useful reference for Washington State agencies, tribes, and legislators.

WSAS COMMITTEE ON NET ECOLOGICAL GAIN

Ronald Thom (*Chair*)

Dr. Ron Thom is Staff Scientist Emeritus in the Coastal Sciences Division of the Pacific Northwest National Laboratory, where he led the Coastal Ecosystem technical group at the Marine Sciences Laboratory until retirement. His research is focused on ecosystem restoration and adaptive management in coastal and estuarine ecosystems. Dr. Thom has directed approximately 200 multidisciplinary ecological studies and authored five book chapters, around 100 peer reviewed papers, and hundreds of reports. He also served on numerous professional committees and panels; including chairing the Technical Advisory Committee of the EPA's Puget Sound Estuary Program, serving on the Expert Regional Technical Group to restore ecosystem health and salmon in the Columbia River Estuary Ecosystem Restoration Program, being a member of an EPA Science Advisory Board panel to review the Great Lakes Restoration Program, and serving on a National Academy of Science, Engineering, and Medicine panel on recovery of the Gulf of Mexico coastal ecosystem following the 2010 Deepwater Horizon oil spill. Dr. Thom was appointed by the Washington Governor to the Northwest Straits Commission and serves as a Senior Science Advisor to the Puget Sound Partnership. Dr. Thom is an elected Fellow in the American Association for the Advancement of Science. He was elected to the Washington State Academy of Sciences and was on the Board of Directors for several years before serving as president of the Academy from 2018-2020. Dr. Thom has a PhD from the University of Washington School of Aquatic and Fishery Sciences.

Heather Burpee

Heather Burpee is a Research Associate Professor and the Director of Education and Outreach at the University of Washington's Integrated Design Lab. She is an expert in high-performance buildings that reduce energy and promote healthy indoor environments. Her research includes tracking health impacts and synergies between environmental quality, natural systems, sensory environments and energy efficiency. Some of her efforts in this area include creating roadmaps and protocols for performance-based design, tracking, and auditing for hospitals, higher education, and commercial buildings. Ms. Burpee consults regularly with design teams to implement high-performance buildings and she also develops curriculum and other educational opportunities for various groups on this topic. Ms. Burpee has a Master of Architecture degree from the University of Washington College of Built Environments.

Ken Currens

Dr. Ken Currens is the manager of the Conservation Planning Program for the Northwest Indian Fisheries Commission. He has expertise in population genetics, ecology, phylogeography, conservation strategy and planning, risk assessment, and endangered species. In his current role, Dr. Currens coordinates and develops annual and long-term research and conservation plans for Western Washington Indian Tribes and serves as the technical liaison for the tribes with the federal government, state agencies, and non-governmental organizations on conservation issues. He also contributes to endangered species and ecosystem recovery planning and manages a research program to provide support for recovery planning of fish species listed under the Endangered Species Act. Dr. Currens previously served as the Science Director for the Puget Sound Partnership. He has a PhD in population genetics, fishery science, and statistics from Oregon State University.

Heida Diefenderfer

Dr. Heida Diefenderfer is an Earth Scientist with the Energy and Environment Directorate of the Pacific Northwest National Laboratory, at PNNL's Marine and Coastal Research Lab in Sequim, WA. A restoration ecologist, Dr. Diefenderfer conducts long-term and large-scale ecological and geomorphological research across a variety of terrestrial and aquatic ecosystems with a focus on wetlands, forests, marshes, and submerged vegetation. This work spans several areas of applied research, including spatial planning, resilience, climate adaptation, endangered species recovery, and blue-carbon experimentation and field data development for Earth systems modeling. Dr. Diefenderfer's ongoing work includes research and adaptive management for the recovery of Endangered Species Act-listed fish as mitigation for energy infrastructure, and evidence-based assessment of large-scale ecosystem restoration. She also serves as chair of the Washington Natural Heritage Advisory Council. Dr. Diefenderfer received her PhD in Forest Resources and Ecosystem Analysis from the University of Washington and is a Faculty Fellow at the UW College of the Environment.

Tim Essington

Dr. Tim Essington is a Professor at the School of Aquatic and Fishery Sciences and former Director of the Center for Quantitative Sciences and the Interdisciplinary Quantitative Ecology & Resource Management Graduate Program at the University of Washington. His research uses quantitative approaches to understanding predator-prey and food web interactions among fish and other organisms in marine, estuarine, and freshwater habitats. He also investigates the conservation benefits of fisheries policy tools and how to apply risk-based approaches to decision making. Dr. Essington has served as an Editor for several scientific journals and as a member of multiple scientific advisory boards and panels, including for the Marine Stewardship Council, Puget Sound Partnership, Washington Marine Spatial Planning, the Ecosystem Science and Management Working Group with NOAA, and the National Center for Ecological Analysis. He was a Pew Marine Conservation Fellow in 2011, was awarded the Oscar Sette Award by the American Fisheries Society in 2017 for Outstanding Marine Fishery Biologist, and was appointed as an American Fisheries Society Fellow in 2021. He was awarded the UW College of the Environment Outstanding Research and Outstanding Teaching awards in 2018 and 2021, respectively. He held the Wakefield Endowed Professorship in Ocean and Fishery Sciences between 2008-2013 and again from 2021-2026. Dr. Essington has a PhD in Zoology from the University of Wisconsin-Madison.

Anand Jayakaran

Dr. Anand Jayakaran is a Professor with Washington State University based at the Puyallup Research and Extension Center. His role is to meet education and research needs in a region experiencing the impacts of rapid urbanization, a changing climate, and increasingly diverse communities. He develops strategies to manage water resources using Green Stormwater Infrastructure and ecological engineering principles. Ani's program aims to positively influence stormwater management decisions that impact traditionally underserved Black, and Indigenous communities, people of color, and lower-income groups. He holds bachelor's and master's degrees in Civil Engineering, a doctoral degree in Agricultural & Biological Engineering, and is a professionally licensed civil engineer in Washington.

Mary Ruckelshaus

Dr. Mary Ruckelshaus is the Managing Director of the Natural Capital Project and a consulting professor at Stanford University. Prior to her current position, she led the Ecosystem Services Program at NOAA's Northwest Fisheries Science Center and was an assistant professor of biological sciences at Florida State University. Her recent work focuses on developing ecological models to estimate the flow of ecosystem services and human wellbeing under variable management regimes. Dr. Ruckelshaus serves on the science council of The Nature Conservancy, the Board of Directors for the Wild Salmon Center, and on the Council of Advisers for Salish Sea Expeditions. She is also a member of the United Nations' High Level Panel on Building a Sustainable Ocean Economy and the U.S. Ocean Research Advisory Panel. Dr. Ruckelshaus is a past chair of the Science Advisory Board of the National Center for Ecological Analysis and Synthesis (NCEAS) and was previously Chief Scientist for the Puget Sound Partnership. Dr. Ruckelshaus has a PhD in Botany from the University of Washington.

Katharine Wellman

Dr. Katharine Wellman recently retired from Northern Economics, Inc., where she was a Senior Economist conducting applied research on a variety of topics related to the valuation of marine ecosystem goods and services and the economics of marine ecosystem restoration. Her work also considered the human dimension of ecosystem service recovery and associated indicators of human well-being. Dr. Wellman has served on the Puget Sound Partnership Science Panel and the Task Force on Southern Resident Killer Whale Recovery. She is currently a member of The SeaDoc Society Science Advisory Board and on the Board of Directors of the Schoodic Institute at Acadia National Park. She currently serves on the Board of the Northwest Maritime Center, and was previously the President of the Board of the Salish Sea Expedition. Dr. Wellman holds a PhD in Natural Resource Economics and a Masters of Marine Affairs from the University of Washington.

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Net Ecological Gain Definition, Goals, and Objectives

Prepared for the Washington State Department of Fish and Wildlife

April 2022

Net Ecological Gain Definition, Goals, and Objectives

Table of Contents

I. INTERPRETATION OF CHARGE

The Washington Department of Fish and Wildlife (WDFW) requested that the Washington State Academy of Sciences (WSAS) inform its work on the development of a net ecological gain (NEG) standard for public projects as part of the response to a proviso contained within Engrossed Substitute Senate Bill 5092 (2021). WSAS convened a committee of scientific and technical experts (referred to in this document as “the committee”) to conduct this scope of work. The full scope of work for the committee was to develop a definition, goals, objectives, and performance metrics for the net ecological gain standard, assess how sufficient existing standards have been in achieving endangered species recovery, and make recommendations about monitoring and indicators for no net loss and net ecological gain.

The committee interpreted the charge as producing a definition of net ecological gain relevant to Washington State, as well as providing examples of specific goals and objectives for how the definition would be applied to ecosystems or projects. The committee was informed that watersheds are of particular interest to WDFW, which has a goal of achieving resilient, self-perpetuating, viable ecosystems and biodiversity across the state. Similarly, the committee interpreted the charge as identifying performance metrics that are relevant across the state, although it is expected that these may vary according to ecological community types. The committee aimed to maintain the level of detail and rigor allowed by the science while meeting the task set out by WDFW by developing a report comprising two chapters.

This first report chapter synthesizes the committee's preliminary perspectives—developed since its first meeting on November 15, 2021—on a proposed definition for net ecological gain, considerations for defining net ecological gain, and goals and objectives for achieving net ecological gain. The subsequent chapter focuses on recommendations for metrics, monitoring, and indicators for net ecological gain standards and provides an assessment of no net loss.

II. DEFINITION OF NET ECOLOGICAL GAIN

Preamble

Earth’s natural systems have been profoundly affected by human activities, particularly over the past century when human population growth and industrialization (Figure 1) have transformed terrestrial and aquatic ecosystems. These transformations have often led to habitat loss and degradation for species that have cultural or economic roles recognized by humans. The balance between population and economic growth and management of ecosystem health is complex and dynamic. Specifically, as a key part of coupled human-natural systems, people are agents of change who affect the biophysical condition of ecosystems but also simultaneously (1) require functional ecosystems to provide life-supporting services that affect our well-being and (2) alter our behavior in response to ecosystem dynamics.

Net ecological gain (NEG) must be viewed in this larger context. In many cases, applications of NEG may occur in ecosystems that are already highly impacted and degraded by prior human activity. Thus, it may not always be feasible to return these ecosystems to states that resemble those of a century ago. Additionally, the effects of atmospheric greenhouse gases on climate, hydrologic patterns, and ocean chemistry will continue to grow, even under the most optimistic scenarios (Pörtner et al., 2022), meaning that ecosystems require the capacity to absorb or adapt to those effects without undergoing irreversible or deleterious transformation.

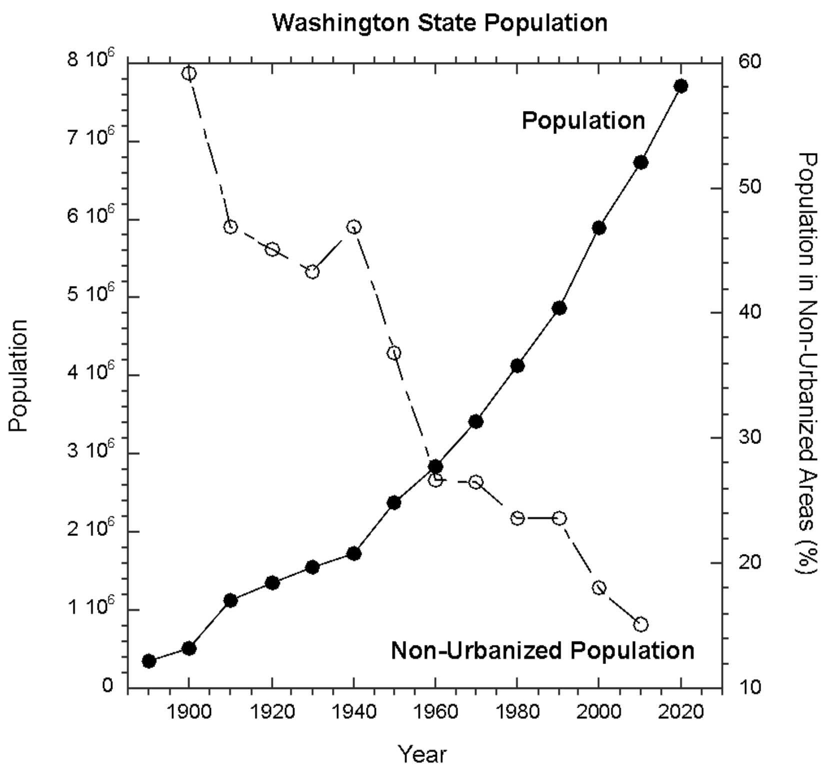

Figure 1. *Between 1890 and 2020, the population of Washington State grew from approximately 360,000 to 7.7 million people, of whom more than 84% (about 6.6 million) now live in urban areas (Iowa Community Indicators Program, 2022; U.S. Census Bureau, 2010). The population is expected to continue growing over the next decade. With continued urbanization, suburbanization, and sprawl come associated loss and degradation of natural habitats in those areas and the ecosystem services they provide. Net ecological gain is intended to buffer these changes.*

Conceptually, one can view NEG in the context illustrated in Figure 2. Although the health of many ecosystems is degraded compared to historic baselines, thoughtful infrastructure design and other development in terrestrial and aquatic systems can still lead to improvements in ecosystem status. Moreover, we judge these improvements based on a comparison to a theoretical future in which such developments and designs are not implemented.

While conceptually simple, deriving practical and specific guidelines for implementing net ecological gain is difficult in practice. This is because social-ecological systems are inherently complex and affected by a variety of human activities and sociopolitical drivers. These complexities have led to frequent reformulations within the scientific community regarding how terms like ecosystem health and ecosystem integrity are defined.

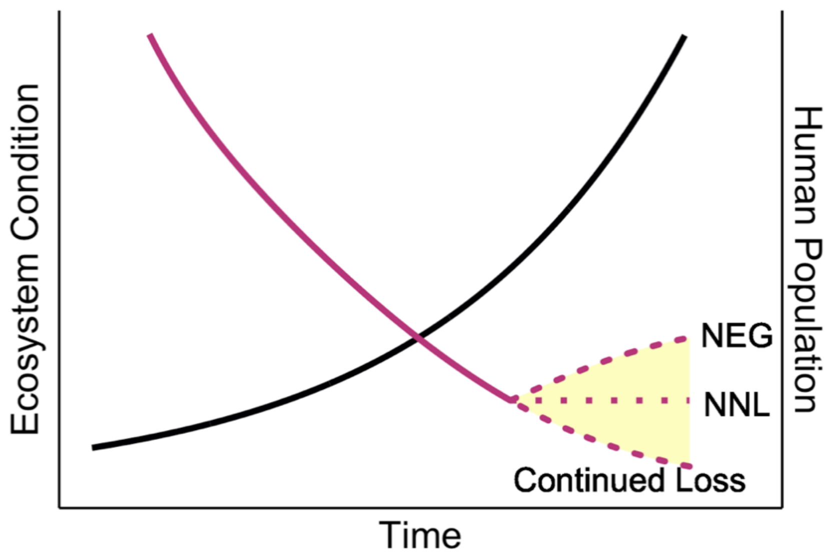

Figure 2. *Conceptual relationship between changes in population and ecosystem condition and the corresponding effects of implementing NEG or no net loss (NNL) vs. continued degradation of the ecosystem condition under current scenarios. Human population is depicted in black; ecosystem condition is in purple. This conceptual figure is based on population and ecosystem trends identified by the Washington Biodiversity Council (2007). Note that the human population is no longer increasing exponentially in the U.S. but shifting consumption choices may have similarly negative ecosystem impacts.*

Three key characteristics or elements of ecosystems must be recognized to frame definitions of net ecological gain:

- **Ecosystem**: The collection of fauna and flora and the key physical, biological, and chemical drivers that influence them in a specific location
- **Ecosystem Structure**: The biological, physical, and chemical constituents, how these constituents are organized and linked to one another, and the size of the ecosystem
- **Ecosystem Processes**: Feedbacks among ecosystem structure and composition occur through a series of processes, such as nutrient or water cycling, many of which benefit people through the production of goods and services.

The combined dynamic interaction of ecosystem components, structure, and processes creates the emergent properties of ecosystems that are relevant for ecosystem protection and restoration and that can maintain benefits to people. Some common emergent properties include:

- Biodiversity, defined as "the variability among living organisms from all sources including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part" (National Infrastructure Commission, 2021; Wilson, 1988)
- Resilience and adaptive capacity—the ability to cope with and adapt to changing conditions (e.g., climate change, sea level rise, wildfire, flooding, water quality)
- Productive habitat for culturally or economically valuable species
- Ecological regulation of air, soil, and water quality

Due to the variety of situations under which NEG could be considered or implemented in the future, any definition of net ecological gain that attempts to be applicable in all situations would risk being cumbersome, overly general, and not necessarily appropriate to guide decision-making. For that reason, the committee chose to define net ecological gain in terms that are specifically applicable to Washington State.

Definition

WSAS convened a committee of scientific experts to review the existing science and develop a definition of net ecological gain. The committee constructed this definition primarily from two existing definitions of NEG (Apex Goal Task Force, 2020; National Infrastructure Commission, 2021), also articulating additional components and considerations.

The proposed definition for NEG in the state of Washington is as follows:

> **Net ecological gain means that after development, there is an increase in biodiversity or resilience that improves the delivery of valued ecosystem functions in the affected ecosystem.**

Applying this definition of NEG will be contextual in nature and depend on the characteristics of the given social-ecological system. External considerations, such as the type of ecosystem (e.g., marine, nearshore, freshwater, prairie, shrub steppe—see Rocchio & Crawford, 2011), biogeographic region, and legacy conditions from human development and natural catastrophes shape both the biophysical and human conditions of the ecosystem. For any given intervention, the priority ecosystem objectives, attributes, and current and likely future stressors (e.g., climate impacts) will also vary. For example, ecosystem composition, structure, processes, and functions will vary depending on the type of ecosystem. These elements will, in turn, produce different kinds of goods and services that affect human well-being. There is also a wide variety of attributes that may be enhanced as part of NEG. Table 1 lists examples of such attributes, categorized by ecosystem element or property. Depending on values and the institutions where development is proposed, different individual and collective choices need to be considered for NEG to succeed. Likewise, explicit consideration of the spatial and temporal extent of post-construction restoration, maintenance, and monitoring will be necessary.

Several assumptions are also implicit within this proposed definition of NEG. First, some level of ecosystem degradation is coincident with meeting the demands created by humanity, such as the needs for sustenance and materials (Locke et al., 2021). However, ecosystem degradation ultimately results in reduced ecosystem services, thereby harming the people who rely on them. Ecosystem stewardship that aims to minimize degradation and increase key ecosystem attributes through recovery planning, conservation efforts, and restoration activities will facilitate the realization of NEG as defined in this report.

Table 1. *Examples of some key components or attributes of socio-ecological systems within Washington State that may be enhanced under NEG*

Ecosystem element or property	**Attributes that may be enhanced**
Ecosystem structure	● area/spatial extent ● spatial structure (e.g., continuity, connectivity) ● temporal structure ● habitat heterogeneity and complexity ● composition (e.g., native species abundance and distribution)
Biodiversity	● the number and relative abundance of viable species ● population status and trends for native flora, fauna, and fungi relative to historical conditions ● genetic diversity (including varieties) ● diversity of communities and ecosystems ● conservation and/or prevention of local extinction of native species
Ecosystem processes	● hydrology and water cycles ● nutrient cycling ● fluxes of mineral and organic materials ● primary and secondary productivity ● decomposition ● habitat formation ● species interactions ● species movements ● disturbance regimes
Ecosystem functions and services	● recreation ● flood and erosion regulation ● water provision and regulation ● distributed stormwater and runoff management, especially via green stormwater infrastructure ● elimination, reduction, or mitigation of environmental stressors, such as toxins, pollutants, or non-native species, including pollution filtration processes that reduce pollutants to downstream water bodies ● food and fiber production and sovereignty ● pollination ● soil health ● regulation of infectious agents and pests ● climate regulation through carbon storage and sequestration ● cultural and spiritual interactions and benefits ● treaty rights ● added green space or urban greening that provides physical and mental health benefits, especially for under-resourced communities and other vulnerable groups

	● promotion of equity and protection of human well-being through livelihoods, economic returns, community diversity, and sense of place ● other ecosystem processes that provide goods and services that contribute to economies, satisfaction of human needs, and health, either directly or indirectly
Ecosystem resilience	● ability of the ecosystem, including urban ecosystems, to absorb disturbances and reorganize to maintain critical functions ● ability of the ecosystem, including urban ecosystems, to withstand shocks and stresses and recover from them so that the system does not surpass irreversible thresholds

Net Ecological Gain and the Mitigation Hierarchy

The goal of net ecological gain falls within a hierarchy of action steps—known internationally as the mitigation hierarchy—that is intended to limit the impacts of development on biodiversity and ecosystem functions relative to a predetermined reference condition (Business and Biodiversity Offsets Programme, 2018; Maron et al., 2018). Understanding the theoretical and practical challenges learned from use of the mitigation hierarchy over the last 15 years is critical for developing a net ecological gain standard for Washington State.

Sequentially, the action steps of the mitigation hierarchy are applied to evaluate a proposed activity or intervention and relocate or redesign the intervention so that it can: 1) avoid, 2) minimize, 3) remediate, and/or 4) offset negative impacts on ecosystems and the net benefits they provide (Figure 3; Arlidge et al., 2018; Wende et al., 2018). Although there is often more interest from developers in focusing on the latter steps, the conservation benefits from the first steps are expected to be greater than those associated with the subsequent steps because uncertainty of success increases as the steps progress (Arlidge et al., 2018).

The first of the four steps of the mitigation hierarchy—avoid—focuses on assessing impacts prior to project design and development and selecting an alternative site for the development with fewer potential impacts (Phalan et al., 2018). Impacts to biological, ecological, or social elements that are deemed irreplaceable or that will require long restoration times (e.g., to endangered endemic species, iconic wilderness, unique archaeological sites, fragile coral systems) by definition cannot be offset to provide net gain because gains somewhere else are not comparable in type or amount (Arlidge et al., 2018; however, see discussion on comparability in Pope et al., 2021). The second step—minimize—involves using the most environmentally friendly design or construction practices available. The third step—remediate—emphasizes replacing or remedying the loss of biodiversity and ecosystem functions at the same location of the development or project. Finally, the fourth step—offset—involves improvement in biodiversity and ecosystem functions in another location that creates positive impacts that are equal to or greater than the residual impacts not addressed by the first three steps. Without offsets, net gain is generally impossible because not all impacts can be addressed by the first three steps. Offsets are accomplished either by protecting against an anticipated loss at another location through the removal of threats or by enhancing and restoring an already degraded location (Maron et al., 2012). Offsets are the most uncertain and controversial step because they require the assumption that impacts at a site can be accurately measured and appropriately balanced by actions elsewhere (Maron et al., 2016).

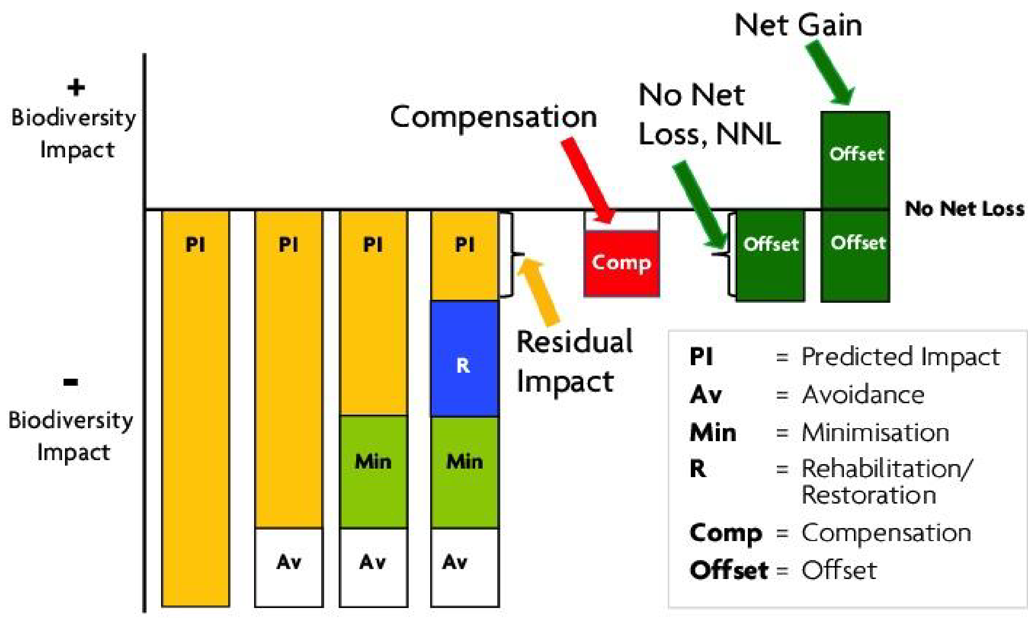

Figure 3. *Steps of the mitigation hierarchy for biodiversity impacts leading to net gain (Business and Biodiversity Offsets Programme, 2018, adapted from Rio Tinto and Govt. of Australia)*

The theoretical and practical challenges to successfully implementing the mitigation hierarchy have been well described elsewhere (e.g., Arlidge et al., 2018; Bull et al., 2014; Moilanen & Kotiaho, 2018; Tallis et al., 2015). Many of these challenges are associated with failure to resolve conceptual issues, inappropriate implementation of the hierarchy, inadequate monitoring, inequitable distribution of impact and offset, and lack of compliance. Two key issues deserve emphasis in a discussion of the mitigation hierarchy and its relevance to net ecological gain. One is the choice of reference scenarios for evaluating success because the concept of net gain is meaningless unless it is specified relative to alternative possible scenarios. Developing and agreeing on these scenarios is challenging, however, due to uncertainties associated with making projections and opportunities for gaming outcomes (Ruhl & Salzman, 2011). The other key issue is the importance of setting targets and monitoring outcomes. In this case, choosing appropriate metrics to ensure net gain is achieved is a critical and context-specific step. Metrics need to be 1) sensitive and predictably responsive to anticipated development impacts, 2) informative at different spatial scales, 3) feasible to monitor, and 4) cost effective. These topics will be addressed in more detail in the subsequent chapter by the committee.

III. CONSIDERATIONS FOR IMPLEMENTING NET ECOLOGICAL GAIN

The implementation of the proposed NEG definition requires an expanded operational definition to specify the attributes of the system that will be improved. The committee recommends considering the following factors to promote clarity and successful implementation of NEG.

Level of Specificity

The definition must be specific enough to readily address unique individual ecosystems, yet broad enough to be operationalizable for a wide range of diverse ecosystems and contexts across the state. Implementation of the definition must also encompass the built environment and address various aspects of human health and well-being, including economic and cultural consequences, physical and mental health, environmental justice, and intergenerational equity (Díaz et al., 2020).

Geographical Scale

The committee recommends a focus on NEG at the project level but urges that potential changes in the ecosystem attributes and services outlined in Table 1 also be considered within the context of the broader system (e.g., the watershed within which a site occurs and the body of water into which it discharges), which is likely subject to larger-scale processes affecting long-term NEG outcomes (Griffiths et al., 2019). Impacts to a particular site can affect other locations. Thus, implementation of a net ecological gain standard must include an integrated assessment of how individual sites fit into overarching ecosystems and landscapes, including how impacts of different projects could potentially interact with one another (Diefenderfer et al., 2021; National Academies of Science, Engineering, and Medicine, 2022).

Time Scale and Baseline Measurements

Effects of development or other interventions on a site may occur immediately or manifest well after the conclusion of a project. For this reason, monitoring by taking consistent measurements over time, including beyond the timespan of the project, is necessary to ensure that long-term gains result from implementation of the NEG standard. Implementing the NEG framework therefore requires identification of and accounting for potential prolonged human intervention and external resources to ensure key ecosystem processes are maintained. Further, the consideration of cumulative effects across time, including anticipated future effects–whether beneficial or detrimental–is crucial for ensuring successful NEG (Diefenderfer et al., 2021).

Based on findings from past practice (National Research Council, 2001) and the understanding of ecosystem response times (Carpenter & Turner, 2001), mitigation timeframes that are restricted to the duration of the activity will typically fail to advance ecosystem resilience. Rather, NEG requires that indicators be measured regularly against a baseline measurement from a specific point in time (Maron et al., 2021), ideally against the aforementioned reference condition. However, ecosystems are dynamic, so even some baseline measurements will have already been influenced by the widespread and historical impacts of human activity.

Notably, based on extensive documentation of impacts to date, researchers anticipate that climate change and the projected growth and consumption patterns of the human population will continue to accelerate impacts to ecosystems. These factors must be accounted for, and goals must be adjusted accordingly in instances where the aim is to restore a system (Centers for Disease Control and Prevention, 2021; Locke et al., 2021).

IV. GOALS AND OBJECTIVES FOR NET ECOLOGICAL GAIN

The committee articulated the following general goals for net ecological gain, each with corresponding objective(s) for desired outcomes. These intended outcomes would achieve improvements to the natural environment and fortify ecosystem resilience.

Sustain and Recover Biodiversity

Biodiversity is a key measure of an ecosystem's overall condition. To promote net ecological gain for biodiversity through the lens of enhancing ecosystem integrity, (1) the species diversity and genetic diversity of the biological community must be preserved or enhanced, (2) vulnerable species must be protected, and (3) viable populations must be maintained (Díaz et al., 2020; Stange et al., 2021). Washington contains an extensive array of ecosystems (Washington State Department of Natural Resources, 2022). Previous work has established methods to measure the ecological integrity of these ecosystems (Rocchio & Crawford, 2011; Rocchio et al., 2020a, 2020b). Some of these methods can also be applied to measure the progress of NEG during and after projects to ensure the protection and/or recovery of native species associated with impacted ecosystems.

Objective: Protect, conserve, restore, and enhance ecosystems to sustain biodiversity. Safeguarding biodiversity requires acknowledgement of the strong interconnections of life at all hierarchical levels of an ecosystem. It also calls for the articulation of required net outcomes and related methods of measurement pertaining to species populations, habitat ranges, and functions that are key to adaptation and persistence (Maron et al., 2021).

Protect and Enhance Natural Capital, Ecosystem Services, and Human Well-Being

Society relies on the natural environment for a variety of benefits essential to human survival, such as the provision of food, breathable air, and clean water. Species, habitats, and other ecosystem attributes constitute natural capital assets (Díaz et al., 2020). The flow of benefits from ecosystem structures and processes can be quantified by accounting for beneficiaries; some examples of this process may include identifying the number and demographic characteristics of people affected or calculating monetary values (e.g., avoided damages, livelihood support, food prices). Collectively, these ecosystem assets and flows are referred to as ecosystem services (National Infrastructure Commission, 2021).

Given the multifaceted relationship between humans and their natural surroundings, the well-being of humanity is intimately tied to ecosystem health. Thus, the concept of NEG extends beyond purely ecological implications to also include socioeconomic and human health considerations (Breslow et al., 2017; Griffiths et al., 2019). Economies from the global to local scale depend upon a wide variety of renewable and non-renewable resources that stem from natural capital (Locke et al., 2021). Additionally, two critical aspects of human well-being relate directly to ecological management: the ability to benefit from natural resources through both use and non-use values and the capability to thrive in one's surroundings (Breslow et al., 2017). For example, human physical health is affected by provision of air and water quality amid development projects, and mental health is affected by the amount of green space experienced. Both physical and mental health are key components of one's capacity to thrive in one's surroundings (Centers for Disease Control and Prevention, 2021).

Griffiths et al. (2019) proposed a "no worse-off principle" regarding the human health aspect of no net loss. According to this principle, the well-being of those affected by development projects must be prioritized as a component of NEG, with the outcome being equal to or better than their level of well-being prior to the project (Griffiths et al., 2019). Typically, underserved or impoverished groups are most affected by ecological loss, with wealthier members of the same community disproportionately benefiting through mitigation actions. It is important that those impacted by a project perceive that their well-being matches or exceeds what it was prior to the project. Further, special attention must be given to ensuring that vulnerable communities who may be disproportionately impacted are treated equitably and that effects on future generations are considered to promote intergenerational equity (Griffiths et al., 2019).

Objective: Maintain natural capital assets, which include components of the ecosystem composition such as habitat and species, so that they retain their ability to provide current or improved levels of ecosystem services and the resulting flows of benefits to people into the future.

Objective: Apply the mitigation hierarchy (which could include social compensation, for example) to ensure that affected communities emerge from the project "no worse-off" than they were before. Environmental justice and intergenerational equity are key considerations in determining fairness in social impacts (Griffiths et al., 2019).

Strengthen Ecosystem Resilience

By definition, a landscape may be composed of more than one ecosystem type. Activities at the project or site level that are incongruent with the overarching landscape can destabilize natural landscape-scale processes; therefore, it is critical to strengthen the resilience of ecosystem composition, structure, and processes at the ecosystem level. For example, increased resilience to natural disasters and human impacts can occur through ecosystem-based management and integrated landscape-scale planning.

Anthropogenic greenhouse gas emissions are another factor affecting resilience, with notable outcomes including dramatic increases in air and water temperatures, increased frequency of wildfires and floods, acidification of state waters, and loss of glacier and snowpack water reserves (Shukla et al., 2022). Revegetation and restricted degradation of ecosystems aid in reducing carbon emissions and thus support the mitigation of climate change impacts (Locke et al., 2021). Intact and restored ecosystems also can confer significant climate adaptation benefits through provision of ecosystem services, as described above. Because it affects all aspects of ecological integrity, from performance measurements to ecosystem and landscape resilience, climate change is an essential consideration in implementing the NEG standard. Urban ecosystems also have related resilience components within their own contexts (e.g., McPhearson et al., 2015).

Objective: Contextualize NEG efforts to the project site and larger scales to consider effects and the actions that are needed to confer resilience through larger-scale processes.

Objective: Foster greater ecosystem resilience by anticipating uncertainty around climate change impacts and incorporating expected impacts on the ecosystem into the design of mitigation and adaptation actions, including protection and restoration.

Objective: Protect against negative ecological impacts that result from safeguards against natural processes that are considered hazardous, such as flooding, wildfires, and landslides. Rather than attempts to prevent these natural processes, these occurrences must be accommodated and managed.

Objective: Protect and restore ecosystem-forming and maintaining processes (e.g., hydrology, sediment dynamics) that are impaired as a result of development projects.

Monitor and Record Best Practices

To continually improve the implementation of NEG, lessons learned must be captured and publicly disseminated according to best practices, such as the FAIR principles: Findability, Accessibility, Interoperability, and Reuse of digital assets (Wilkinson et al., 2016). This aspect of ecological management will significantly advance the ability of scientists and communities to contribute to increasing the success of future actions related to NEG. Such documentation requires a strong public commitment to structured approaches to compile and track project outcomes and findings, as well as a commitment to ongoing process improvement through continual implementation of best practices (Biber, 2011; Conservation Measures Partnership, 2020).

Objective: Compile and track the baseline measurements, subsequent periodic measurements, and observations or implications for future actions that emerge from these measurements.

Summary of Goals and Objectives

Table 2. *Summary of goals and corresponding objectives for net ecological gain*

Goal	**Objectives**
Sustain and Recover Biodiversity	● Protect, recover, and sustain native species biodiversity to enhance ecological integrity
Protect and Enhance Natural Capital, Ecosystem Services, and Human Well-Being	● Maintain and improve natural capital assets (e.g., habitats, species) so that they retain their ability to provide current or improved levels of ecosystem services and the resulting flows of benefits to people into the future ● Apply the mitigation hierarchy to ensure that affected communities emerge from the project “no worse-off” than they were before
Strengthen Ecosystem Resilience	● Contextualize NEG efforts to the project site and larger scales to consider effects and the actions that are needed to confer resilience through larger-scale processes ● Foster greater ecosystem resilience by anticipating uncertainty around climate change impacts and incorporating expected impacts on the ecosystem into the design of mitigation and adaptation actions ● Protect against negative ecological impacts that result from safeguards against natural processes that are considered hazardous, such as flooding, wildfires, and landslides ● Protect and restore ecosystem-forming and maintaining processes that are impaired due to development projects

Monitor and Record Best Practices for NEG	• Compile and track the baseline measurements, subsequent periodic measurements, and observations or implications for future actions that emerge from these measurements in a manner that is publicly accessible and usable for the long term

V. CONCLUSION

Net ecological gain is an approach aimed at reversing the human-associated degradation and loss of natural ecosystems and the species and services of those ecosystems. It recognizes that substantial human disturbance of ecosystems has occurred and will continue, while providing an approach that takes advantage of redesign and redevelopment to improve ecological functions, services, biodiversity, and resilience. Along with improving environmental conditions, realized NEG can improve human health and well-being. NEG is a simple concept but presents scientific, engineering, and human-based challenges. Having clear goals and objectives will guide implementation of an NEG standard. There are project examples of NEG in Washington State and internationally that demonstrate what can be achieved by creating strong operational definitions and following clearly outlined goals. The following chapter from the committee will focus on recommendations for metrics, monitoring, and indicators for a net ecological gain standard and provide an assessment of no net loss.

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WASHINGTON STATE
Academy of Sciences
Science in the Service of Washington State

Assessment of No Net Loss and Recommendations for Net Ecological Gain Metrics, Indicators, and Monitoring

Prepared for the Washington State Department of Fish and Wildlife

June 2022

Assessment of No Net Loss and Recommendations for Net Ecological Gain Metrics, Indicators, and Monitoring

Table of Contents

I. INTERPRETATION OF CHARGE

The Washington Department of Fish and Wildlife (WDFW) requested that the Washington State Academy of Sciences (WSAS) inform its work on the development of a net ecological gain (NEG) standard for public projects as part of the response to a proviso contained within Engrossed Substitute Senate Bill 5092 (2021). WSAS convened a committee of scientific and technical experts (referred to in this document as “the committee”) to conduct this scope of work. The full scope of work for the committee was to develop a definition, goals, objectives, and performance metrics for the net ecological gain standard; assess the sufficiency of existing standards in achieving endangered species recovery; and make recommendations about monitoring and indicators for no net loss and net ecological gain.

The committee’s first chapter on the NEG definition, goals, and objectives was previously shared with WDFW (Washington State Academy of Sciences, 2022). The committee interpreted their charge for this subsequent chapter, as outlined in the scope of work with WDFW, as (1) assessing whether and why existing standards of ecological protectiveness, such as no net loss (NNL) standards, have been sufficient or insufficient to protect ecological health and achieve endangered species recovery and (2) providing recommendations for:

- Performance metrics for the NEG standard
- Indicators to assess NNL and NEG
- Establishment of a monitoring system
- Incorporation of climate science predictions into NNL and NEG standards

This report chapter synthesizes the committee's perspectives on the effectiveness of existing ecological protection standards and focuses on recommendations regarding NEG metrics, monitoring, and indicators. The primary intended audiences for this document are Washington State agencies, tribes, and legislators.

To operationalize the concepts reviewed in this chapter, several additional steps are necessary, including educating agency staff and the public on NEG, developing inter-agency partnerships, building a workforce trained in interdisciplinary and transdisciplinary approaches to addressing socio-ecological challenges relevant to NEG, and helping to provide the scientific basis for any necessary legislation. In the concluding section of this chapter, the committee presents suggestions for some follow-on activities that may facilitate these next steps toward successful implementation of NEG in Washington State.

II. ASSESSMENT OF NO NET LOSS

The concept of no net loss (NNL) seeks to minimize impacts of human infrastructure on the environment, typically by applying some form of the mitigation hierarchy to sequentially avoid, minimize, remediate, and offset biodiversity impacts from new development (Bennett et al., 2017; also see the committee’s first chapter on the NEG definition, goals, and objectives, Washington State

Academy of Sciences, 2022). NNL was first introduced through the 1970 National Environmental Policy Act. Upon issuance of the Clean Water Act in 1972, the Army Corps of Engineers applied NNL to manage dredge materials and mitigate the disposal of contaminants into water. The George H. W. Bush Administration further promulgated the concept, implementing a no net loss standard for wetlands in the early 1990s.

Yet, many natural ecosystems continue to be converted to residential and commercial development under existing standards. When considering whether existing ecological standards, including NNL, have been sufficient in safeguarding ecological health and achieving endangered species recovery, **the committee's consensus view is that NNL has not been an effective approach for ecosystem or habitat management and protection nor for the maintenance of ecosystem services**. Within the larger scientific community, shortcomings of the NNL approach were articulated as long as 30 years ago. For example, two National Academies reports (National Research Council, 1992, 2001) on compensatory mitigation for wetland loss through development were highly critical of NNL. Other global studies have found little to no documented evidence of NNL success and high regional variability in such success (e.g., Bull & Strange, 2018; zu Ermgassen et al., 2019).

The failure of NNL is directly relevant to Washington State ecosystems and the health and well-being of its residents. In Washington, there are 33 known extirpated plants and 6 known extirpated animals—one freshwater bivalve, two species of butterfly, one beetle, and two bird species (Washington Department of Natural Resources, 2022). An entire extirpated ecosystem has been identified by the Washington Natural Heritage Program to date: the noble fir-redwood sorrel forest of the Willapa Hills. There are another 179 endangered ecosystems in the state, including forest types associated with Oregon white oak woodlands, red alder-bigleaf maple-Douglas fir rainforests, Douglas fir-Western hemlock rainforests, silver fir-Western hemlock rainforests, Western hemlock-Sitka spruce rainforests, Douglas fir-madrone woodland, paper birch and quaking aspen swamp forests, 20 riparian forest types, and four maritime swamp forest types. The Western juniper ecosystem is also endangered, as are numerous grassland, shrubland, bog, fen, marsh, vernal pool, and wet meadow ecosystem types.

Additionally, an assessment process for the intensive climate change vulnerability index (Dawson et al., 2011; Young et al., 2012), which is currently being implemented in Washington, has already identified many plant species that are highly or extremely vulnerable (Fertig, 2020, 2022). There are widespread threats to game species habitats as well. Some of these are a result of negative impacts of wind and solar energy development on mule deer in Eastern Washington. Band-tailed pigeon harvest opportunities have also been reduced despite a hunting closure that was implemented from 1991 to 2001 (Washington Department of Fish and Wildlife, 2021).

Clearly, there have been net losses of species and habitats in Washington. The committee is reasonably confident that without policy changes, these types of losses will continue and will contribute to the disappearance of distinct habitats and ecosystem types from Washington's terrestrial and aquatic landscapes.

Application of NNL has been unsuccessful in most instances for a variety of reasons. First, there are challenges associated with establishing appropriate baseline conditions. For sites that have experienced significant loss of habitat, biodiversity, or ecological functions, using the current condition as a baseline falls short of promoting adequate management and protection. For such sites, NEG is often a better approach because it necessitates an improvement in ecosystem biodiversity or resilience without requiring that the site revert to pristine conditions.

A second challenge of NNL lies in uneven distribution of impact and mitigation. Often, compensatory mitigation occurs offsite and fails to provide in-kind compensation for the loss. For example, a forest may be established offsite to compensate for wetland habitat loss, which does not truly offset the impacts of this loss. Poor implementation of NNL has been another common obstacle. For example, many wetland restorations have been inadequate. Limited funding and insufficient institutional structure for implementation often result in inadequate monitoring and enforcement before, during, and after a project. In addition, accurate assessment of the success of a standard's implementation can be difficult because this process requires the identification of appropriate targets, indicators, and metrics, as well as the determination of the appropriate spatial and temporal scales for monitoring. Finally, community buy-in for NNL has grown more difficult due to disproportionate impacts to low-income communities, as well as a pattern of compensatory actions under NNL failing to benefit the people most heavily impacted by a project.

Examining the reasons NNL has failed is imperative to designing and implementing a successful NEG standard. Many of the same challenges will persist under NEG without intentional action to improve the current approach to implementing ecological protection standards and overcome challenges related to funding and infrastructure limitations, incorporation of climate change science, monitoring, assessment, and community buy-in.

Beyond No Net Loss to Net Ecological Gain

In the committee's first chapter to WDFW (Washington State Academy of Sciences, 2022), the committee provided a definition, goals, and objectives for NEG in Washington State. The committee's proposed definition for NEG is:

> **Net ecological gain means that after development, there is an increase in biodiversity or resilience that improves the delivery of valued ecosystem functions in the affected ecosystem.**

NEG aims to achieve improvements to ecosystem health in comparison to a theoretical future in which the developments or projects did not occur, rather than using current conditions as a baseline. This approach seeks to go beyond simply offsetting loss to stopping and even reversing it.

The state of Washington has been considering NEG as an approach to preserve and restore ecological systems. The case studies provided in this chapter aim to demonstrate how the committee's broad definition, goals, objectives, and performance metrics for net ecological gain can be applied to various public projects in Washington State. The committee acknowledges that the case studies do not encompass all possible ecosystems and development situations in Washington State; they instead serve as examples to put these abstract concepts into perspective.

Future successful implementation of NEG in Washington will necessarily include the processes of defining targets, indicators, and metrics; building community support for the approach; establishing monitoring, assessment, and accountability systems; factoring in impacts of climate change; and assessing outcomes. These processes can be informed by existing ecologically relevant conceptual frameworks across various fields of study, as discussed throughout this chapter.

III. IMPLEMENTING AND ASSESSING A NET ECOLOGICAL GAIN STANDARD

Structured Decision Making and Ecosystem Planning

To progress toward the NEG goals and objectives outlined in committee's first chapter on the NEG definition, goals, and objectives, the committee recommends employing a conceptual framework that can effectively measure ecological function, structure, and processes. The field of ecological assessment includes several accepted frameworks for determining an ecosystem's condition by comparing its composition, structure, and function to baseline measurements. For instance, steps for measuring ecological integrity include identifying ecological attributes; determining metrics to measure degradation against baseline levels; assessing the attributes using remote sensing, rapid ground-based, and intensive ground-based metrics; and presenting the resulting measurements in a matrix that illustrates the interconnectedness of the attributes, metrics, and findings (Karr et al., 2021; Rocchio & Crawford, 2011; Rohwer & Marris, 2021; Wurtzebach & Schultz, 2016).

A well-accepted framework that is applicable to implementation of NEG is 'Structured Decision Making & Ecosystem Planning' (Gregory et al., 2012; Levin et al., 2018), which has been successfully applied to questions of fish and avian ecosystem management and restoration (Buenau et al., 2014; Neckles et al., 2015). This generic planning framework can be repurposed and adapted to a variety of scenarios.

Box 1. Fundamental Recommendations to Enhance the Probability of Successful NEG include:

- Understand controlling factors and linkages in the ecosystem
- Understand the role and mode of the actions of stressors and disturbances
- Apply science-based understanding to project design and development
- Apply simple yet effective technological solutions where appropriate
- Apply appropriate restoration and monitoring strategies
- Admit uncertainties and overcompensate in the design of projects for unavoidable damages

(modified from Thom et al., 2005b)

In the context of NEG and how it fits into a broader ecosystem planning process, this framework includes activities that aim to accomplish the following:

1. Describe the current state of the ecosystem (e.g., through state indicators and by creating an inventory of threats) and use conceptual models (e.g., Bayesian belief networks, qualitative models, Driver-Pressure-State-Impact-Response framework) to represent the way the ecosystem elements are thought to interact with each other, how they will respond to threats, and the potential pathways of human benefits
2. Articulate a set of desired futures, potentially including but not limited to a vision, strategic objectives, risk analysis, prioritization, and operational objectives
3. Create a plan to address top-priority threats and operational objectives, including:
    - Setting performance measures (which may or may not be the same as the previously described state indicators or threat indicators)
    - Identifying potential management strategies
    - Evaluating the range of outcomes for each objective
4. Implement the plan (in the context of NEG, this involves creating a built environment that seeks to achieve NEG) and establish time-bound measures of success and resources to monitor outcomes

Indicators developed using a structured decision making framework serve a variety of purposes and are selected based specifically on these purposes. Performance indicators need to be SMART: Specific, Measurable, Attainable, Relevant, and Time-bound.

Structured decision making is meant to provide a logic model that captures the pieces that need to be considered when evaluating NEG. **Structured decision making is a systematic and transparent process to evaluate a potential project and its impacts.** The process can be applied at different scales with varying intensity, but importantly, it must be as objective and transparent as possible, with conclusions drawn from available scientific evidence.

From a process standpoint, structured decision making also includes facilitating stakeholder identification of and consensus on the main threats and prioritizing multiple objectives. Involvement of diverse stakeholders and the affected community as early as practically possible helps generate buy-in and establish a forum for identifying goals, objectives, approaches, and solutions.

Ideally, the structured decision making process should be stakeholder-based and incorporate multiple objectives and values to determine how to best achieve NEG. Generally, the sooner stakeholders are brought into the process, the more successful the outcome will be (Gregory et al., 2012). There are various ways to do this, such as using a structured decision-making model that focuses on the science and engages stakeholders separately or by building stakeholder engagement into the process throughout (e.g., Environmental Protection Agency, 2022). Different approaches may also be required for different groups of stakeholders. Although such a process can be time-intensive, this engagement is critical for achieving long-term NEG (see the section on Human Well-Being, Stakeholder Engagement, and Community Buy-In below).

Overall, applying recognized and widely used frameworks such as structured decision making will help to maximize the efficiency, transparency, and replicability of NEG implementation.

Box 2. Case Study: Clinton Ferry Terminal Rebuild

The Clinton Ferry Terminal was redeveloped to address traffic concerns and needed repairs. The initial proposal was projected to remove approximately 3,000 square meters of eelgrass and create wide, shaded areas near the shore that would inhibit juvenile salmon migration. Terminal design engineers and scientists worked together to redesign the dock. The redesign included a narrower but longer dock, fewer pilings, reorientation of ferry slips to minimize bottom disturbances and turbidity, and addition of glass blocks in the walkway to allow light to pass. The net effect of this redesign was a reduction in projected loss of eelgrass to about 300 square meters.

Prior to the outset of the project, eelgrass shoots from the site were harvested and grown in culture, where they multiplied. Prior to completing the terminal rebuild, the cultured eelgrass was transplanted into previously disturbed areas, which resulted in an approximate 4:1 increase in eelgrass near the terminal over baseline conditions. While the eelgrass beneath the dock did not appear to respond to the additional light enabled by the glass blocks, it did show resilience and overall expansion over a 10-year period. The placement of the glass blocks also appeared to aid with the movement of salmon around the dock. Salmon primarily passed under the dock when there was minimal shadow. Overall, due to the redesign, the project resulted in a net gain in eelgrass and generally improved conditions for young salmon (Thom et al., 2005a, 2005b, 2012). Natural resource agencies met annually for 10 years with scientists and Washington State Ferry staff to review the monitoring results.

This project was rooted in a conceptual framework for measuring the goals and outcomes, which was in place prior to project initiation, thereby allowing review and mitigation of projected impacts in advance of the project's start. The Federal Highway Administration recognized this project with the 1997 National Environmental Excellence Award.

Tenets of the NEG definition articulated in the committee's first chapter on the NEG definition, goals, and objectives can be seen within this case study. For example, measurable net improvement to the ecosystem's structure and resilience can be seen in the expansion and resilience of eelgrass. Parallels can also be drawn between the goals and metrics presented in this chapter and the implementation of the Clinton Ferry Terminal rebuild (see below). Some of the project metrics that reflect the concepts presented in this document and the committee's first chapter (Washington State Academy of Sciences, 2022) include measurements of strengthened ecosystem resilience through the persistence of ecosystem structure and measurements of sustained biodiversity through improvements in populations of native species.

IV. ADDITIONAL CONSIDERATIONS FOR NEG IMPLEMENTATION

There are considerations specific to implementing NEG that have the potential to extend beyond a generic decision-making framework. Some of these considerations include the following.

- **Scale**. Potential impacts of any development project should be considered with careful attention to spatial, functional, and temporal scales because these considerations have the capacity to tip net outcomes from gain to loss.
    - Spatial scale may comprise an area as small as a building or property or may be most appropriately considered at the site, ecosystem or habitat, or landscape scale at which processes occur.
    - Functional scale pertains to the reach of impacts, including the location and demographics of the people affected.
    - Temporal scale refers to time-related considerations, such as the duration and anticipated peak of project outcomes. Evaluating temporal scale can be challenging because measurements typically occur after the conclusion of the project.
- **Distribution of impact**. It is important to consider the scale at which measurements are made versus the scale at which impacts accumulate. For example, a case study by the National Academies of Science, Engineering and Medicine (2022) details the relatively minor improvements in farmland management in the Mississippi River Basin relative to the size of the recurring hypoxic zone in the Gulf of Mexico. Conducting projections of what future conditions would be without the project is one method of adjusting project outcome measurements to potential changes in background environmental conditions that could occur for other reasons.
- **Distributional effects of restoration actions.** In addition to considering the distribution of impact, it is also critical to assess outcomes within the context of how a specific site contributes to critical ecosystem processes of the overall region in which it is situated. Individual sites vary in terms of their functional importance, their components or attributes, and the extent to which they contribute to human well-being (see Table 1 in the committee's first chapter on the NEG definition, goals, and objectives, Washington State Academy of Sciences, 2022). The determination of whether to move forward with a project, as well as the NEG considerations for that site, should take into account whether a site has high functional importance relative to the surrounding landscape.
- **Multiple objectives**. Often, impact assessments only examine a single objective, while NEG is a whole-system approach that takes place within the broad context of the complex, dynamic relationships between population and economic growth and the management of ecosystem health. Consideration of multiple objectives is important for situating NEG efforts within the larger context. As an example, the Puget Sound Partnership uses a structured decision analytic model developed by EPA (Yeardley et al., 2011) that enables the inclusion of multiple objectives and evolving scenarios. The flexibility of this model supports specific inquiry regarding outcomes. NEG efforts for impacts to the Columbia estuary followed a similar approach

(Diefenderfer et al., 2016), which is currently being adapted to the Whidbey Basin of Puget Sound (Whidbey Cumulative Effects Group, 2022).

- **Evaluation of uncertainties.** It is crucial to assess which pathways to NEG will be robust and able to accommodate uncertainties in the long-term. There are often critical uncertainties associated with development and ecological restoration projects relative to achieving the stated goals for the project outcomes. In addition, climate change poses a significant level of uncertainty for all ecosystems. Designing and employing an adaptive management process (e.g., Levin et al., 2018) is therefore important for NEG projects.

The committee's proposed definition of NEG emphasizes that the preferred approach is to first avoid or limit ecological losses that occur through development, thereby curtailing degradation that would require restoration efforts with less certain outcomes. Consistent with the hierarchy of mitigation, it is also assumed that development resulting in adverse effects is not allowable for ecosystems that are especially fragile or that play a central role in biodiversity or in the functioning of ecosystems and landscapes and the benefits they provide to humans (Díaz et al., 2020; Locke et al., 2021; Maron et al., 2021). **For critical ecosystems such as these, there are limits that will preclude achieving NEG from development**. Some of the critical ecosystems in Washington include those which have been systematically identified and classified statewide by the Washington Natural Heritage Program through implementation of the Natural Area Preserves Act (RCW 79.70.070) (Washington Natural Heritage Program, 2022). When projects move forward regardless of the environmental impacts to critical ecosystems, determining how to attain NEG can pose significant or even insurmountable challenges.

The concept of NEG is meaningless unless the proposed outcome is specified relative to alternative possible scenarios. Considering alternative scenarios is important for describing the anticipated outcomes if a particular project or action is not carried out. For example, impact-specific policies for no net loss and net ecological gain generally use counterfactual scenarios that describe what would be expected to happen in the absence of development and present associated mitigation actions as the basis for scenarios (Bull et al., 2014; Maron et al., 2018). Developing and agreeing on appropriate counterfactual scenarios can be challenging due to prediction-making uncertainties that are further exacerbated by climate change effects and potential opportunities for gaming outcomes (Salzman & Ruhl, 2010). Moreover, where a project impacts different biota and ecological processes, expected rates of change may vary spatially and temporally. The process of developing these counterfactual scenarios is important for the understanding of relevant ecological processes and the application of the chosen reference scenario for setting targets for NEG (i.e., desired outcomes of NEG-based activities).

To effectively promote net gain by addressing all variable factors, impact-specific scenarios should also be developed that go beyond counterfactual scenarios. Impact-specific scenarios consider the additional and cumulative impacts of ecosystem pressures attributable to threats that are unrelated to proposed development.

Broad, overarching policies for no net loss or net gain of biodiversity across a jurisdiction (e.g., state-wide goals by 2040 to achieve no net loss of biodiversity or a net increase in riparian habitat) often imply alternative reference scenarios in which all potential sources of loss need to be considered. However, although counterfactual scenarios can describe an assessment of potential impacts that can be translated into a no net loss threshold, they do not identify targets for net gain. Quantitative targets and metrics must be defined and monitored to demonstrate success in offsetting negative impacts (Arlidge et al., 2018; Wende et al., 2018). This process of setting targets is similar to the objective-setting process defined in EPA's Decision Analysis for a Sustainable Environment, Economy & Society (DASEES; Yeardley et al., 2011).

For context, Washington State is an area identified by the Intergovernmental Panel on Climate Change (IPCC) as having high conservation importance based on the high number of freshwater and terrestrial species and high projected habitat losses, with a 20% loss of marine fish and benthic animal biomass expected even under the lower-risk scenario (IPCC, 2022). The IPCC's Working Group II had high confidence that the migration, distribution, and abundance of key fish resources have been impacted in the Northeast Pacific (Pörtner et al., in press). Climate change will further impact these ecosystem attributes in a variety of ways. Some of the implications of climate change include larger, longer-burning, more frequent, and more severe fires; increased stream temperatures; and glacial recession and reduced snowpack impacting summer streamflow (Frans et al., 2018; Halofsky et al., 2020; Koontz et al., 2018). Even without further land conversion to accommodate the expansion of residential populations and commercial enterprises, widespread climate change effects detrimental to Pacific Northwest ecosystems are expected to continue.

Targets and eventual outcomes must meet three conditions (Gardner et al., 2013). First, losses and gains of biodiversity and ecosystem functions must be *comparable* in type and magnitude. This condition is often challenged by policy makers who want more flexibility and by some conservation biologists who advocate for "trading up" by exchanging offset areas with like-for-like potential for other areas that they view as having higher conservation value (Moilanen & Kotiaho, 2018).

Second, the desired gains through offsets must be *in addition* to those that would have occurred if the development did not take place. Projections of gains should extend beyond the site scale and explicitly take into consideration the cumulative effects of impacts at the landscape scale (Figure 1; Diefenderfer et al., 2021; Hood et al., 2022; National Academies of Science, Engineering and Medicine, 2022). For example, different sites within a watershed may have varying innate functions, meaning that the expectations for each site should also vary. Sites must be accounted for within the context of what that site provides to the function of the overall landscape. A challenge for both NNL and NEG is deciding what constitutes sufficient gain. Multiplier and mitigation ratios based on expected loss are one approach for simplifying the process of setting targets; these ratios should be informed by available science.

Third, desired gains must be *lasting*, exceeding or at least equaling the duration of the residual impacts of the development in the face of climate change. When identifying quantitative outcomes for offset gains, the timing of when outcomes are achieved must also be considered. Unless offset targets are achieved before development, delays usually at least temporarily cause losses of biodiversity or ecosystem functions (Gann et al., 2018); further, targets not achieved before the project onset may fail to address ecological losses that occur at offset locations during the delay. The impacts of such time lags are often addressed through multiplier or mitigation ratios that expand the offset target in proportion to expected delays, although this approach does not guarantee a net gain (Pope et al., 2021).

Choosing metrics to ensure net gain is achieved is a critical and context-specific step. Metrics need to be 1) sensitive and predictably responsive to anticipated development impacts, 2) informative at different spatial scales, and 3) feasible to monitor at the appropriate timescales to assess short- and long-term project outcomes.

Prioritization of NEG also requires that there be an “exit ramp” in the project development process, with one option being that the proposed project does not move forward as planned. Ideally, an initial step in project planning should entail an assessment of whether a location can reasonably withstand the proposed project. If implementation of NEG is infeasible because of too much risk or uncertainty, the project should be reconsidered for an alternative site or canceled.

Cumulative Effects and a Need for Large-Scale Planning to Achieve NEG

In addition to the localized impacts of an individual project, the cumulative impacts to surrounding ecosystems must be considered in planning for NEG. Successful implementation of NEG requires a transdisciplinary approach that addresses diverse socio-ecological needs across multiple spatial scales. This process may require assessing project impacts within the context of other ongoing or future projects and the current condition of the surrounding landscape (Fig. 1).

To assess and predict the cumulative ecosystem impacts of development, overarching goals should be set at the landscape scale in partnership with interdisciplinary experts, including scientists at state agencies, communities, and interested stakeholders. Examples of landscape-scale prioritization approaches include the WDFW strategies for nearshore protection and restoration in Puget Sound (Cereghino et al., 2012), the proposed use of landscape ecology principles in habitat restoration across the Columbia River Estuary (Hood et al., 2022), and prioritization of shoreline habitats for restoration under the Shoreline Master Program in Jefferson County (Diefenderfer et al., 2009).

In some cases, scientifically established and vetted goals set by state agencies can serve as these overarching goals; however, **Washington State currently lacks a systematic, state-wide landscape approach for evaluating the ecological processes that connect and sustain each of its ecosystem types and their natural factors of scale**, such as watershed or estuary size, gradients, and hydrology (see the section on Establishing a Monitoring System for NEG below).

In addition to setting overarching goals, **approaches that prioritize NEG should consider the cumulative impacts of individual projects toward larger landscape-scale targets**. A major drawback of many mitigation frameworks is that they focus on a single component of an ecosystem, such as floodplains or salmon. Combining these frameworks into an integrated approach would aid in addressing cumulative effects. For example, an overarching framework that integrates salmon recovery strategies with watershed goals would enable the assessment of how individual activities fit into broad, science-based goals that were set at the landscape level. For urban watersheds, this framework might integrate needs related to runoff, salmon habitat, and the impact of flows along marine shorelines.

In some cases, NEG may succeed at the project scale but fall short of the broader targets. It is nevertheless important to continually consider NEG within the larger context of cumulative impacts and to refine and adapt the associated approaches to work toward NEG at the landscape scale.

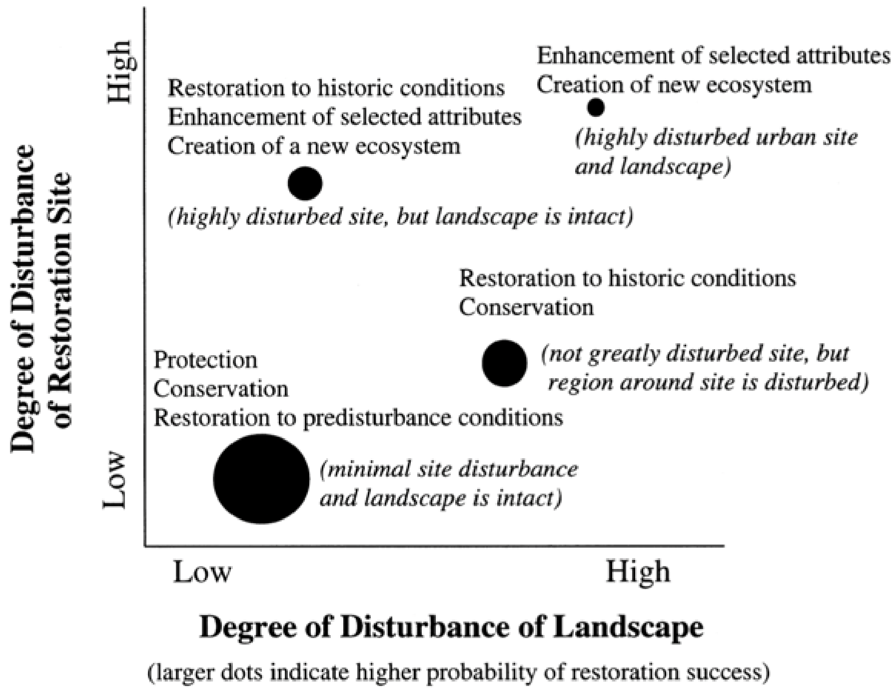

***Figure 1**. This graphic illustrates the generalized relationship between the level of disturbance or degradation of the site and the landscape within which the site is located. The most appropriate restoration strategies, including ecological protection and the enhancement of selected attributes, are listed for four theoretical conditions. The larger the dot, the greater the chance that the site could be restored (Thom et al., 2005b).*

Human Well-Being, Stakeholder Engagement, and Community Buy-In

As noted in the committee's first chapter on the NEG definition, goals, and objectives (Washington State Academy of Sciences, 2022), there is an interdependent relationship between human well-being and ecosystem health. Communities depend on ecosystem goods and services, such as clean water and air, to sustain human well-being, and thus are profoundly affected by impacts to the ecosystems around them (Environmental Protection Agency, 2022).

Inclusively engaging communities in decision making is integral to ensuring policies, programs, and decisions themselves reflect the diverse interests, values, beliefs, and perspectives regarding a given area or issue. The value of engaging communities early and at all stages of decision making is well documented (e.g., IPBES, 2015). Early, continued engagement can help ensure decisions are more transparent, democratic, and equitable both in process and outcome.

Research increasingly demonstrates the importance of incorporating local community and Indigenous knowledge within environmental decision making and planning. By intentionally and inclusively engaging communities, decision makers can become better informed or more able to fully understand the complexity of a given issue, its underlying causes or factors, and its potential impacts. This process helps to ensure longer-term stewardship and trust in governance around these issues. Activities associated with the new Healthy Environment for All (HEAL) Act (Washington State Legislature, 2021), which requires that agencies gather community input as part of environmental justice assessments, could help inform NEG efforts across Washington State.

The approach for obtaining community input varies depending upon the project scale and the composition and needs of the stakeholder group. However, a foundation of trust and community buy-in is critical to garner effective stakeholder engagement. Structured decision making is one way to involve stakeholders. A conceptual framework developed by the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) presents another approach for leveraging community input to co-create an integrative knowledge base. This framework relies on a multidisciplinary, participatory approach to synthesize diverse stakeholder knowledge and create greater comparability across assessments (Díaz et al., 2015). Other forms of participatory research that are becoming increasingly popular, such as the use of crowdsourced environmental data sensing and/or volunteer community scientists, also offer promising ways to engage communities and generate buy-in.

Box 3. Case Study: Floodplains by Design

Floodplains by Design (https://www.floodplainsbydesign.org/) is a public-private partnership led by the Department of Ecology, The Nature Conservancy, the Bonneville Environmental Foundation, and Puget Sound Partnership which aims to reduce flood risks and restore habitat along Washington's major river corridors by restoring former agricultural lands located in habitats supporting salmon and other biodiversity. For example, to develop a solution that was satisfactory for all stakeholders, the project team gathered input on a land management solution from local landowners, neighboring property owners, land use commissioners, scientists, and watershed managers in Skagit County. The collaborative solution resulted in natural capital (restored land and salmon habitat), economic capital, and social capital (good will established between governing bodies and local landowners and a sense of stewardship over the land). The Floodplains by Design approach has been applied to projects across Washington State since 2013. This approach offers an excellent example of the value of stakeholder involvement in NEG initiatives. **Stakeholder involvement can support positive outcomes for all involved parties and build community trust and buy-in.**

V. PERFORMANCE METRICS AND INDICATORS

To measure and document the effects of restorative and protective actions, it is critical to use appropriate and well-developed measures of change. The committee defines a metric as anything one measures, while an indicator is specific to a particular decision and is assessed as part of an evaluation cycle that measures progress toward a specified objective. Indicators are more general than metrics. In other words, all indicators are metrics, but not all metrics are indicators. For example, when assessing water quality, measurement of dissolved oxygen may be a metric, with an indicator for this assessment being the areal extent of water with quality that exceeds a predetermined oxygen level. Moreover, an indicator may comprise many metrics. Within the context of these definitions, many components of an ecosystem can be measured (metrics), but only a subset of those components are indicative of a particular ecosystem characteristic and directly useful for setting policy and making decisions (indicators). Some examples of recently published indicators include the use of growing-season sum exceedance value of hourly surface-water depth as a wetland inundation indicator within a proposed predictive framework for studies on estuarine–tidal river systems (Borde et al., 2020), as well as 7-day average daily maximum water depth as an indicator of marsh sediment accretion in a study on floodplain wetland morphology (Diefenderfer et al., 2021).

Process and Criteria for Setting NEG Indicators

This section describes approaches for developing criteria and indicators for net ecological gain. Rather than suggest specific indicators for net ecological gain across all habitat types and ecosystems represented in Washington, the committee aims to provide guidance on how to navigate the process of selecting indicators and tracking progress toward net ecological gain. The general process, criteria, and development of indicators discussed in this chapter build on the extensive work of the Business and Biodiversity Offset Programme (BBOP) and its technical documents (BBOP, 2012a, 2012b). Given that professionals throughout Washington are already working on ecological indicators for various plant and animal communities and ecosystems across the state, the committee also encourages inter-agency communication to develop appropriate indicators for Washington ecosystems based on existing data and information.

During the process of establishing indicators, it is important to consider (as described previously):

- Sites within their larger contexts, including their functions within the overall landscape and their contributions to cumulative impacts
- Geographical and temporal scale, because the scale at which a measurement is taken may differ from the scale at which the impacts accumulate
- An accepted and relevant conceptual framework
- Measurements that align with existing restoration strategies for the given region

To aid in identifying appropriate indicators, a baseline should be established prior to the beginning of a project. Creating a baseline can be challenging. Data from existing monitoring programs and ecosystem models can be helpful resources for compiling potential baseline or simulated data sets.

Indicators should be identified for both implementation and ecological outcomes. *Implementation indicators* measure the outputs of the planning and implementation processes for achieving net ecological gain. Implementation indicators are usually similar from case to case; a few examples of implementation indicators are summarized in Box 4 (also, see more in-depth examples in Appendix 1). In contrast, *ecological indicators*, which assess ecological outcomes, depend on the location (e.g., ecoregion and type of habitat), ecological and geographical scale (e.g., project size, dominant ecological processes, and landscape context), and anticipated direct and indirect impacts of the project. Ecological indicators often differ across projects and systems.

Box 4. Example of principles (P), criteria (C), and implementation indicators (I) as part of the orientation and planning steps of a net ecological gain process

These examples are excerpted and adapted from the Business and Biodiversity Offsets Programme (BBOP 2012a, BBOP 2012b) to illustrate concepts. The full process includes tribal and stakeholder participation components, which, for brevity, are not outlined here.

P: Adherence to the mitigation hierarchy: A biodiversity offset is a commitment to compensate for significant residual adverse impacts on biodiversity identified after appropriate avoidance, minimization, and onsite rehabilitation measures have been taken according to the mitigation hierarchy.

> C: The developer identifies, implements, and documents appropriate measures to avoid and minimize the direct, indirect, and cumulative negative impacts of the development project and to undertake onsite rehabilitation/restoration.
>
> I: An assessment of the development project's impacts on biodiversity (including direct, indirect, and cumulative impacts, as appropriate) is conducted with stakeholder participation

P: Net Ecological Gain: A biodiversity offset should be designed and implemented to achieve in situ, measurable conservation outcomes that can reasonably be expected to result in net gain of biodiversity and resilience.

> C: The net gain goal for the development project is explicitly stated, and the offset design and conservation outcomes required to achieve this goal are clearly described.
>
> I: All residual biodiversity losses due to the project are quantified relative to the 'pre-project' condition of affected biodiversity, which is identified, characterized, and documented.
>
> C: An explicit calculation of loss and gain is undertaken as the basis for the offset design and demonstrates the manner in which a net gain of biodiversity can be achieved by the offset.
>
> I: A set of key biodiversity components at the species, habitat, and ecosystem levels, including landscape features and components related to use and cultural values, is identified. The rationale for selecting these key biodiversity components to represent all biodiversity affected by the project is explained and documented.

P: Limits to what can be offset: There are situations in which residual impacts cannot be fully compensated for by a biodiversity offset because of the irreplaceability or vulnerability of the biodiversity affected.

> C: The degree of risk that the project's residual impacts on biodiversity may not be capable of being offset ('non-offsetable') is assessed and measures are taken to minimize this risk.
>
> I: An assessment is undertaken to predict the level of risk that the project's residual impacts on biodiversity will or will not be capable of being offset, with special attention afforded to any highly irreplaceable and vulnerable biodiversity components.

Example: Indicators of Salmon Ecosystems

The following example describes the Puget Sound Recovery Implementation Technical Team's (PS RITT) application of the Open Standards for the Practice of Conservation framework to identify ecological indicators (PS RITT, 2015). The committee chose to highlight PS RITT's work because it is the result of a multi-decade process and is considered the "gold standard" for developing and selecting criteria for biophysical indicators. Notably, the salmon ecosystem for which these indicators were developed is one of the best studied ecosystems in Washington State. Not all successful projects that achieve NEG will necessarily have the capacity to follow such a comprehensive process.

The basic approach used by PS RITT to develop their extensive list of indicators was to first identify linkages among the major components of the salmon ecosystem and then characterize the key ecological attributes (KEAs), pressures, and indicators. Ecosystem components are the attributes we care about conserving and include biodiversity, species, habitat types, ecological processes, and particular ecosystems that encompass the full breadth of conservation objectives for a specific project. KEAs are the characteristics of an ecosystem component that, if present, would support a viable component but, if missing or altered, would lead to loss or degradation of the component over time. Pressures are the proximate human activities or processes that have caused, are causing, or may cause the destruction, degradation, or impairment of KEAs and ecosystem components.

Within this example, PS RITT sorted 14 major ecosystem components of Chinook salmon ecosystems into three different categories: freshwater habitats, estuarine and marine habitats, and biological communities (i.e., species and food webs). These categories and the corresponding ecosystem components are shown in Table 1.

Table 1. *Ecological components by category in PS RITT's identification of indicators, adapted from Puget Sound Recovery Implementation Technical Team (PS RITT, 2015)*

Category	**Components**
Freshwater habitats	• Uplands • channels >50 m bankfull width • Channels <50 m bankfull width • Side channels • Non-channel lakes and wetlands
Estuarine and marine habitats	• Large estuaries • Coastal landforms • Bluff-backed beaches • Pocket estuaries and embayments • Rocky pocket estuaries • Rocky beaches • Offshore marine systems
Biological communities	• Species and food webs

Key ecological processes associated with each of these components were then used to identify KEAs. For freshwater salmon habitats, for example, seven key ecological processes highlighted 15 KEAs (PS RITT, 2015; Table 2).

Table 2. *Key ecological attributes identified by ecological process in PS RITT's identification of indicators, adapted from Puget Sound Recovery Implementation Technical Team (from Table 8, PS RITT, 2015)*

Ecological Process	**KEAs**
Sediment processes	• Sediment delivery • Sediment transport and storage
Hydrological processes	• High flow hydrological regime • Low flow hydrological regime
Organic matter processes	• Organic matter inputs • Organic matter retention and processing
Riparian processes	• Spatial extent and continuity • Riparian community structure • Riparian function
Nutrient supply	• Nutrient concentration • Water quality • Nutrient flux and cycling
Floodplain-channel interactions	• Floodplain connectivity • Floodplain structure and function
Habitat connectivity	• Habitat connectivity

Each KEA was mapped to an associated ecosystem component. Next, KEA indicators and pressure indicators (Table 3) were identified based on review of the scientific literature for each KEA. This demonstrates how different types of indicators can be developed for a key ecosystem process. The same approach was used for marine/estuarine and species and food web components (PS RITT, 2015).

These tables provide a relevant example developed by PS RITT (2015) for salmon ecosystems. The process they used to identify and develop indicators could be applied to other types of habitats and biological communities, as well, such as shrubsteppe, prairie, or grassland ecosystems.

Table 3. *KEA and pressure indicators for hydrology across relevant spatial scales, as an example of how different types of indicators can be developed for a key ecosystem process. (adapted from Table 10, PS RITT, 2015).*

Scale	KEA	KEA Indicators	Pressure Indicators
Watershed	• High-flow hydrology regime • Low-flow hydrology regime	• Area/basin discharge, threshold discharge, point discharge, groundwater recharge/discharge • Land cover, including percentages of impervious surface area and vegetative cover • Hydrographic patterns unique to each watershed will determine specific measures and the seasonal patterns most affecting Chinook (e.g., 7-day low-flow and peak-flow frequency, magnitude, and duration) • Groundwater elevation/flows	• Regulated instream flow hydrograph • Volume of in-basin storage • Withdrawals and consumption • Volume of out-of-basin transfer • Volume and location of stormwater discharge and related alteration of natural hydrologic processes (e.g., infiltration, surface water and groundwater flow patterns)
Reach	• High-flow hydrology regime • Low-flow hydrology regime	Seasonal hydrological patterns: • Water depth and velocity • Area and type of habitat units, including seasonal variation • Residual pool depth • Stage/discharge/habitat relationships (e.g., low flow resulting in isolated habitats, high velocities resulting in redd scouring)	• Scour depth in incubation habitats • Area of redd stranding due to natural or regulated flows • Area and connectivity of floodplain channels leading to stranding of juveniles during low-flow time periods • Rapid decreases in flow stage (e.g., ramping of regulated flows) that isolate pools in floodplain channels and wetlands

Choosing Indicators

Effective indicators are those that not only reflect that state of socio-ecological systems, but also are meaningful to people and inform decision making and planning cycles. James et al. (2012) provided an example of useful selection criteria and a possible method for ranking indicators. In this example, the authors divided criteria for choosing indicators into three categories: scientific credibility and relevance, data issues, and communication and sustainability (Table 4). Criteria were weighted by importance based on the project's goals and a review of the scientific literature. Each criterion for every possible indicator was then scored. Next, each indicator's score was calculated by totaling the products of each criterion evaluation by individual criterion weights.

To highlight ecological indicators for resilience, for example, ecological indicators such as those used by PS RITT (2015) can be weighted based on the review of resilience indicators in scientific literature (e.g., Grantham et al., 2019; Timpane-Padgham et al., 2017) and by how well they act as surrogates for resilience.

Table 4. *Criteria for choosing and ranking indicators, adapted from James et al. (2012).*

Category	**Criteria**
Scientific Credibility	• Theoretically sound, based on peer-reviewed findings, and capable of acting as a surrogate for a key ecosystem attribute • Relevant to management concerns, goals, and strategies • Responds predictably and is sufficiently sensitive to changes in a specific key ecosystem attribute • Responds predictably and sufficiently sensitive to a specific management action or pressure • Capable of being linked to defined reference points and/or progress targets to judge progress
Data Issues	• Directly measurable • Supported by historical data or information • Operationally simple so that sampling, measuring, processing, and analyzing the indicator is technically feasible • Quantitative measurements if possible • Spatial coverage available in all areas of interest • Time series available • Spatial and temporal variation understood • High signal-to-noise ratio to ensure that natural variability in indicator values does not prevent detection of significant changes
Communication & Sustainability	• Simple to interpret, easy to communicate, and supportive of public understanding that is consistent with technical definitions • Perceived as reliable and meaningful by a history of reporting • Cost-effective • Able to signal changes in key ecosystem attributes before they occur and, ideally, with sufficient lead time to allow for a management response • Comparable to those used in other geographic locations to contextualize ecosystem state and changes relative to other locations

VI. ESTABLISHING A MONITORING SYSTEM FOR NEG

NEG is most likely to succeed when accompanied by appropriate monitoring, assessment, and accountability systems. Individual projects that aim to achieve NEG require both targeted and long-term monitoring of relevant ecological processes at the regional or landscape scale. Monitoring at multiple scales is necessary because landscape-scale ecological conditions and dynamics are important benchmark metrics against which to measure the cumulative effects of individual projects. However, an important tenet of adaptive management is to use existing streams of monitoring data whenever possible, only adding further monitoring as needed to address critical uncertainties that pose risks to the achievement of project outcomes or to stakeholder interests (Ebberts et al., 2018). Although maintaining or establishing new monitoring programs can be challenging due to infrastructure and funding needs (Biber, 2011; Lindenmayer, 2020; Lovett et al., 2007), **monitoring is a critical component of NEG implementation that must be budgeted for and incorporated into planning at the regional and project scales.**

Knowledge of the relevant ecological system and its stressors, as well as awareness of the broader context, are foundational for developing comprehensive monitoring systems. As mentioned above in the section on Additional Considerations, a key component of implementing NEG is being able to understand and account for multiple interacting pressures on a system. Monitoring for multiple goals, including overarching landscape-scale goals, is therefore very important. Moreover, detecting and identifying pressures on a system requires long-term data collection, especially for detecting responses by the biological community. In some cases it may be possible to focus on a system's specific stressors and whether those stressors have been alleviated; however, this approach requires substantial prior knowledge of the system, its stressors, and what the effects of the development will be, and this level of knowledge is rarely available.

Other key considerations include timescale and geographic scale. Ideally, monitoring should entail comparison of metrics over time and should be calibrated to the timescale of affected processes, especially those that may extend past the project timeline. For example, monitoring of sediment accumulations in a breached levy would require time for the sediment to amass before measurements can be taken for comparison. In this example, targets at the project scale might pertain to limiting runoff, while targets at the landscape scale might pertain to achieving a cleaner overall outflow despite cumulative effects. In addition to accommodating temporal and geographic considerations, priorities and indicators for monitoring should be aligned across agencies.

Considerations for Urbanized Systems

Urban systems confer similar considerations as larger natural ecological systems. Establishing baseline measures or benchmarking existing conditions helps teams to understand the context of the project, set actionable goals, and establish how projects fit into a larger context of improving current or past states. Quantitative metrics to measure progress toward goals aid in decision making throughout the design process and after implementation. Projects often cross jurisdictional and disciplinary boundaries, sometimes requiring challenging collaborations among separate yet interrelated agencies and disciplines. Through integrated design and decision making, stakeholders can help define project goals and decision-making frameworks and contribute to establishing measurement and monitoring approaches. This integrated approach enables better documentation and understanding of successes or shortcomings within the projects and the impacts to the site, larger neighborhood, and beyond.

As with best practices in adaptive monitoring, there is value in using existing monitoring and metrics systems in urban systems (e.g., building-level municipal systems for monitoring water and energy). Use of public data sources enables assessment of how much water or energy is being used, where it is used, and whether that usage matches the design intent. Although this type of data collection and monitoring is often already in place to quantify usage within a site context, such data could be used more extensively across larger spatial scales for project-based evaluations.

Similar to the other fundamental considerations for monitoring outlined above, urban systems require effective interagency collaboration to reach better benchmarking goals and carry out sufficient monitoring. Prioritizing the monitoring of cumulative effects across multiple objectives is also critical as development projects are planned and executed. In addition, there is a need for clear communication with design teams about current or past states so that these teams can set appropriate goals relevant to design, operation, and use and better understand how their work contributes to larger NEG goals. For example, in the Aurora Swales project, described in Box 5, communicating the composition of stormwater runoff prior to and after project implementation aids the project team in assessing the impact of the work, helps the agencies with jurisdiction confirm the effectiveness of the project, and supports decision making for implementing similar solutions in other scenarios.

Box 5. Case Study: Aurora Bridge Swales

Background: Urban populations are growing and so are the number of cars on roadways and the amount of toxins entering the environment. Within the past 6 years, researchers in the Pacific Northwest have identified thousands of chemicals present in urban stormwater runoff, including toxins specifically responsible for the drastic decline of salmon populations in Puget Sound.

As an indicator species, salmon serve as a signal to the overall health of the marine environment. A dramatic decline in Pacific Northwest salmon populations spurred researchers to study the effects of stormwater runoff on the health of aquatic environments. The findings conclusively linked roadway runoff with salmon deaths (Chow et al., 2019), but surprisingly, the expected culprits—heavy metals and petroleum—were not responsible for salmon declines. While the specific source of the issue was unclear at the time, research findings did reveal that soil could be used to effectively filter the toxins (Spromberg et al., 2016), thereby reducing the negative effects of runoff on the salmon.

At the same time as the preliminary research was published, the project team of a new commercial office development project in the Fremont neighborhood of Seattle, WA, was assembling. Inspired by the recent research about stormwater effects on salmon mortality, the group wanted to see how they could apply the findings to their new building. The proposed building site was directly adjacent to and below the Aurora Bridge, a historic structure in Seattle under which all five of the region's salmon species swim to reach the network of rivers and streams for spawning.

Solution: The initial idea was simple: leverage the project's adjacency to the bridge to divert a downspout from the bridge and clean the water using a vegetated area before the water reached the salmon.

The solution was to locate a swale on a steep roadway instead of creating the settling pools used in more conventional green infrastructure. Embracing the steep grade of the roadway, the swales step and overflow through Corten steel weirs with every 2 feet of grade change. The use of steel is echoed in all phases, with custom details expressing the water story throughout. Native plants provide a robust forest floor below the canopy simulated by the bridge structure and columns. Flowering plants were also chosen to attract and support multiple species of local pollinators.

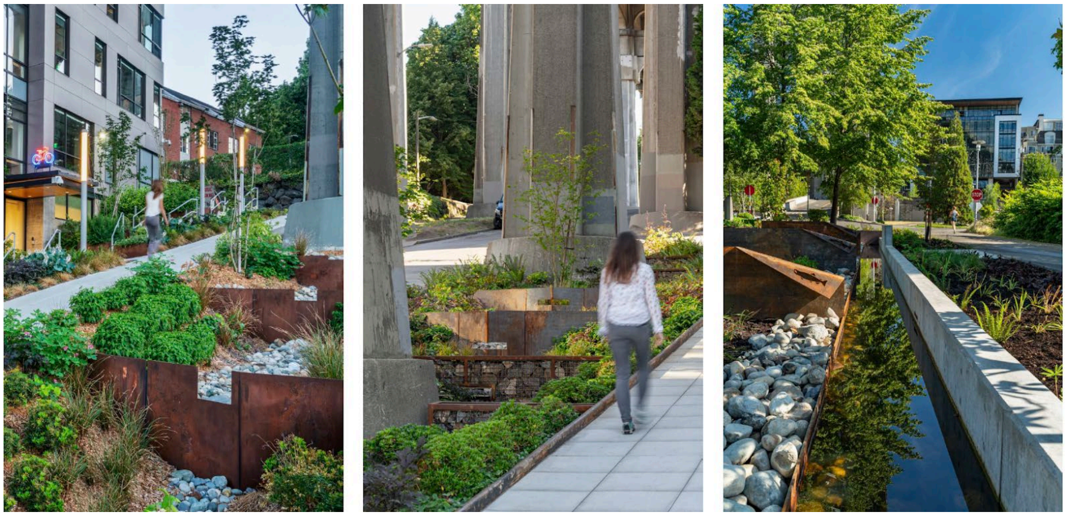

Figure 2. *The Aurora Bridge Swales phases I, II, and III is a first-of-its kind project that incorporates terraces of native plants and soils on three sites along the public right-of-way (Weber Thompson, 2022). These features function as a natural filter, and the project serves as a powerful example of the ability of private development to deploy a large-scale environmental response that can approach 100% effectiveness in reversing pollution's impacts through a replicable model.* ***This multi-faceted solution achieves NEG by beautifying the urban environment, improving biodiversity, mitigating heat-island impacts, and improving water quality while raising public awareness through community outreach and interactive educational elements.*** *Image credit: Meghan Montgomery, Built Work Photography.*

Challenges: Several barriers complicated the implementation of this vision. Among the most significant were the involvement of multiple municipal agencies and the lack of precedence for a private development to propose improvements that reach beyond the property boundary of the site. Specifically, the stormwater that falls on the Aurora Bridge changes jurisdiction many times before its outfall into Lake Union. Initially, rain falls onto the Washington State-owned bridge, where it flows into downspouts that are owned by the state but maintained by the Seattle Department of Transportation (SDOT). The downspouts end about 1 foot above the street below, where jurisdiction shifts solely to SDOT. From there, the stormwater enters a catch basin leading to a storm drain managed by Seattle Public Utilities, a subdivision of SDOT. When the storm drain crosses into a shoreline buffer within 200 feet of the water's edge of Lake Union, a set of Department of Ecology requirements and permits take effect, which include a below-grade outfall at the edge of the lake.

The simplicity of temporarily diverting stormwater was a critical factor in gaining support from the many review agencies. The approach avoided disputes over water rights or issues that might disenfranchise downstream users considering the water quality improvement.

Implementation: The second phase of the swales' construction occurred when the same design and development team proposed another office building on the opposite side of the bridge. With a clearer path for permitting and an established precedent, the project elected to divert two downspouts and take on the larger project goal of eliminating the use of potable water for non-potable uses within the building. The project installed a 20,000-gallon cistern to collect roof runoff and used the swale to slow and filter cistern overflow, which occurs for approximately 4 months out of the year.

A nearby property was also identified where five additional downspouts could be diverted into a grassy area. The third phase increased the volume of filtered bridge water to 2 million gallons, effectively treating the north half of the bridge deck above. **The goodwill and relationships built during the first and second phases helped to secure donations from other Fremont businesses for the third phase, as well as a matching grant from the state government.** As the third phase neared completion, researchers also successfully identified the chemical responsible for salmon deaths as 6PPD-quinone, a derivative of a preservative found in car tires (McIntyre et al., 2021; Tian et al., 2021).

Outcome: Tests of the water entering and leaving the swales confirmed measurable filtration of a large range of contaminants. The Aurora Bridge Swales project has won multiple awards for its successful design—most recently, the Honor Award in the General Design, Private Ownership category at the 2022 Washington Chapter American Society of Landscape Architects Awards (Weber Thompson, 2022).

Replicability: This project has high potential for replicability. Most urban bridges align with a roadway below; in these cases, green infrastructure is especially effective when the overflow at the end of the swale connects back to the existing storm pipe infrastructure that previously carried the unfiltered water to the lake or waterbody. **Reliance on green infrastructure can save municipalities from spending money to mechanically filter water at expensive treatment facilities.** Seattle Public Utilities has begun programs to incentivize similar improvements for private developments. A case study of the swales has also been included in a United Nations Guide for Sustainable Practices as a model to encourage professional designers to include green infrastructure as standard practice (Mossin et al., 2020).

Public communication and engagement: Public awareness of the transdisciplinary and innovative approach to this project is reinforced through many forms of public signage. Brass numbers embedded in the sidewalk illuminate the amount of water each swale cell mitigates. In addition, interactive brass plaques illustrate the many benefits of the strategies employed. Laser cutouts of the silhouettes of the five salmon species alert pedestrians to the greater story of how, **through smart development and design, we can help restore the aquatic environment.**

Figure 3. *The swales are built adjacent to the Aurora Bridge, a historic structure in Seattle where all five of the region's salmon species swim to reach the network of rivers and streams for spawning each year. Image credit: Weber Thompson.*

Box 6. Case Study: Seattle Waterfront

The current design of the Seattle waterfront is an excellent example of **how engineers and scientists used an interdisciplinary approach** to enhance the corridor that young salmon utilize along the waterfront as they out-migrate from the Duwamish River (Accola et al., 2022). This design was accomplished during the redevelopment of the Seattle waterfront for commercial and transportation operations.

The seawall and other structures of the highly developed Seattle waterfront suffered damage during an earthquake in 2001. A comprehensive effort to rebuild the waterfront included innovative measures to improve conditions for juvenile salmon migrating seaward from the adjacent Duwamish River. Scientists from the University of Washington and state agencies developed a plan to improve the migratory corridor used by salmon. This approach included texturizing the seawall, as well as enhancing light by incorporating glass blocks in the pedestrian walkway that borders the shoreline. The glass blocks allowed light to reach areas along the new seawall that supported algae growth. Algae form habitat for prey utilized by juvenile salmon. The light also enhanced the young salmon's ability to maintain their out-migration pattern. Research has demonstrated that the juveniles have benefited from these science-backed innovations (Accola et al., 2022). The combination of seawall enhancements and light transmittance through the walkway is considered a clear example of net ecological gain within the context of a highly active and developed shoreline redevelopment project.

Although the Seattle waterfront project includes elements from the Clinton Ferry Terminal Rebuild example, the Seattle project took advantage of a natural disaster to enhance a selected attribute (e.g., salmon feeding, rearing, and migration) in support of net ecological gain. The city of Seattle took the opportunity to highlight the positive benefits of the project and educate residents about salmon and how the community can use science to improve the environment.

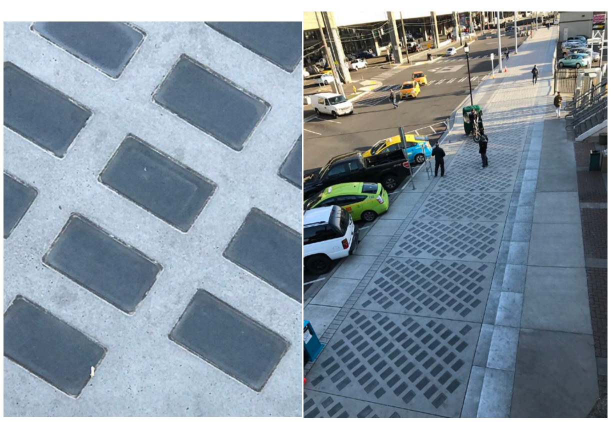

Figure 4. *View of glass blocks in Seattle waterfront walkway. These blocks allow light to stimulate growth of benthic algae that harbor prey for juvenile salmon. The blocks also provide a lighted corridor for migration of the juveniles as they exit Elliott Bay.*

VII. MONITORING IN WASHINGTON STATE

Several successful monitoring programs are found throughout the state. There are also newly developed tools and approaches for facilitating efficient monitoring across larger geographic areas (NASEM, 2022). However, not all of these resources are designed to assess indicators at the fine spatial or temporal scales that may be required at the project scale. Thus, **for individual projects, when there are critical uncertainties that would affect a system or community, there should be resources allocated for assessing variables and monitoring outcomes that go beyond data collection from previously existing regional monitoring programs**. There should also be contingency plans to repair and restore critical ecosystem elements if unexpected issues arise. This process is especially important for built infrastructure, which poses unique challenges to monitoring because development projects cannot typically be redone once they are completed.

At the landscape scale, there may also be potential for existing monitoring programs in the state to be strengthened and integrated with one another. Increased interagency collaboration and improved coordination of monitoring efforts across public and private entities could help expand spatial and temporal coverage and provide more comprehensive data on ecological trends across the state. This coordination and adequate funds to enable it are increasingly important as ecosystems and the species within them respond to climate change and land use change simultaneously.

Ecosystem types are classified by the Washington Natural Heritage Program (Washington State Department of Natural Resources, 2022), with data maintained through the international NatureServe network (http://www.natureserve.com) and summarized on an approximately 5-year cycle in State Natural Heritage Plans. Department of Natural Resources scientists have prioritized these ecosystems by conservation status ranks across each ecosystem's state (S) range and entire or global (G) range (Washington Natural Heritage Program, 2022).

A helpful step toward ecosystem process-based understanding would be the creation of a resource available to practitioners and stakeholders that is structured by the state's ecosystem types and includes the various monitoring programs that are or were implemented within each ecosystem's boundaries. The monitoring programs listed would include, for example, those for water quality and quantity, sediment transport, land cover type, geological evolution, and biota, with links to monitoring data and published reports, journal articles, and student theses and dissertations.

One demonstrated way of approaching the challenge of monitoring is to define Essential (or Potential) Conservation Areas. Several other states, including Colorado and Virginia, designate such areas as part of their natural heritage methodology. These areas are established by defining ecological boundaries around the occurrence of certain ecological elements that require long-term protection. Box 7 presents an example of how Colorado approaches this challenge.

Box 7. Potential Conservation Area (PCA):

"PCAs represent Colorado Natural Heritage's Program's best estimates of the primary areas supporting the long-term survival of targeted element occurrences and typically include adjacent suitable habitat and buffers from disturbance. PCA refers to the ability of a conservation area to maintain healthy, viable targets over the long term (100+ years), including the ability to respond to natural or human-caused environmental change. PCAs do not necessarily preclude human activities, but their ability to function naturally may be greatly influenced by them. PCAs at all scales may require ecological management or restoration to maintain their functionality. PCAs are assigned biodiversity significance ranks ranging from 1 (Outstanding Significance) to 5 (General Interest). Ranks are based on the rarity and quality of the element occurrences in the site.

Additionally, PCAs:

- Are often based on desk-top scientific references and need ground-truthing
- Focus on biological and physical factors and do not account for land ownership and political concerns
- Support land-use planning and conservation strategies but do not have legal meaning or in any way represent an attempt to regulate or limit the use of private property
- Do not automatically exclude specific activities, rather it is hypothesized that some activities will cause degradation to the elements or the processes on which they depend, while others will not."

(Colorado Natural Heritage Program, https://cnhp.colostate.edu/ourdata/help/)

VIII. NEXT STEPS FOR ADVANCING NEG IN WASHINGTON STATE

Within this report, the committee aimed to provide guidance on implementing NEG but recognizes that other critical steps must be taken prior to operationalizing this concept. Enabling NEG is a complicated process and a fairly new concept for which implementation practices will likely be learned and refined over time. Moreover, the successful implementation of NEG will vary by project scope and scale, with no single correct approach or solution.

The committee recommends the following initial steps to lay the groundwork for implementing and attaining NEG.

- Engage with the public throughout the project to increase trust, buy-in, and input around the NEG concept.
- Ensure adequate monitoring of ecosystems and habitats throughout the state to provide baselines and identify key indicators for NEG in future projects.
- Enable and incentivize cross-agency and cross-disciplinary communication and collaboration on NEG-related issues throughout the state.
- Create resources that provide information on all current monitoring systems to facilitate collaboration and access to relevant information.

- Invest in research, monitoring, and planning regarding climate change resilience to ensure ecosystem resilience and infrastructure sufficiency for addressing the impacts of future climate stressors.
- Provide funding and educational opportunities to develop a workforce trained in collaborative, interdisciplinary approaches to solving socio-ecological challenges in Washington State.

Overall, NEG provides an opportunity to take a transdisciplinary approach to promoting the health and well-being of Washington residents and the ecosystems they rely on. The precise approaches to NEG will vary by project and will depend upon available scientific evidence, engineering capabilities, and community needs. To help determine the appropriate approach for each situation, **the committee recommends the creation of a joint, interagency NEG council or committee comprising contributors from each state agency.** The Natural Areas Preserve Act of 1972—and the subsequently formed Natural Heritage Advisory Council and Natural Resources Conservation Areas—provide a possible template for cross-agency efforts to identify areas in need of protection and approaches for promoting NEG when such areas may be impacted. The committee urges that regional experts; natural, physical, and social scientists; engineers; and community leaders and partners be involved in assembling this council.

IX. CONCLUSION

In this chapter, the Committee addressed the present understanding of no net loss relative to net ecological gain and provided background information and recommendations on the process of developing metrics and indicators for net ecological gain.

Local, national, and global studies have shown that the NNL approach has been widely used but has been generally unsuccessful for several reasons. Reasons include the continued loss of habitat quality and area, inadequate implementation, offsite (as opposed to onsite) actions, and lack of enforcement. In contrast, NEG aims to achieve documented improvement in ecosystem health from the baseline ecosystem condition following redevelopment.

Successful implementation of NEG requires systematic assessment of (1) baseline conditions at a location and how the site contributes to ecological processes regionally and (2) what approaches can best be applied to maximize the probability of quantifiable gain following a redevelopment of the site. The first step should rely on available science, while the second requires input from natural and social scientists, engineers, and stakeholders to define the desired state, appropriate indicators, and steps that can be taken to achieve the desired state. The committee recognizes the complexity of these tasks and recommends employing the systematic process of structured decision making. The committee also advises applying a transdisciplinary approach that addresses social-ecological needs across multiple spatial scales.

Because of the wide array of physical and ecological conditions, as well as the diversity of potential development projects, the application of NEG is contextual. This diversity emphasizes the need to establish a process that is applicable across a range of conditions and situations. Project impacts must also be assessed within the context of ongoing or future projects, the current condition of the surrounding landscape, and the human well-being aspects of the location, as well as projected climate change impacts.

Throughout the process of planning and quantifying NEG, there is a need for objective, science-based metrics and indicators. Within this chapter, the committee has provided a set of standard methods and guidance to develop metrics, set indicators, and establish a performance monitoring system. The committee has also included examples of recognized NEG projects in Washington State. Finally, the committee has recommended steps, including strong public involvement, to move forward in enabling and implementing NEG.

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Appendix A.

Example of principles (P), criteria (C), and implementation indicators (I) to consider during the orientation and planning steps of a net ecological gain process. Table is divided into the four major stages of the process, and for each stage, the relevant Principles, Criteria, and Indicators are described in summary form. Although stages are organized sequentially, planning is usually iterative as some activities may call for refining earlier work. Excerpted and adapted from the Business and Biodiversity Offsets Programme (BBOP; 2012a, 2012b) to illustrate concepts.

Stage and Activity	Principles (P), Criteria (C) & Indicators
Review project scope & activities	P1: *Adherence to the mitigation hierarchy: A biodiversity offset is a commitment to compensate for significant residual adverse impacts on biodiversity identified after appropriate avoidance, minimization and on-site rehabilitation measures have been taken according to the mitigation hierarchy.*
	C: The developer shall identify, implement, and document appropriate measures to avoid and minimize the direct, indirect and cumulative negative impacts of the development project and to undertake on-site rehabilitation/restoration.
	I: An assessment of the development project's impacts on biodiversity (including direct, indirect and cumulative impacts, as appropriate) is conducted with stakeholder participation
Review the legal framework and/or policy context for a biodiversity offset	P4: *Net Ecological Gain: A biodiversity offset should be designed and implemented to achieve in situ, measurable conservation outcomes that can reasonably be expected to result in net gain of biodiversity and resilience.*
	C: The net gain goal for the development project shall be explicitly stated, and the offset design and conservation outcomes required to achieve this goal clearly described.
	I: All residual biodiversity losses due to the project are quantified relative to the 'pre-project' condition of affected biodiversity, which is identified, characterized, and documented.
	C: An explicit calculation of loss and gain shall be undertaken as the basis for the offset design and shall demonstrate the manner in which a net gain of biodiversity can be achieved by the offset.
	I: A set of key biodiversity components at species, habitats, and ecosystem levels, including landscape features and components related to use and cultural values, is identified. The rationale for selecting these key biodiversity components to represent all the biodiversity affected by the project is explained and documented.
	P2: *Limits to what can be offset: There are situations where residual impacts cannot be fully compensated for by a biodiversity offset because of the irreplaceability or vulnerability of the biodiversity affected.*
	C: The risk that the project's residual impacts on biodiversity may not be capable of being offset ('non-offsetable') shall be assessed and measures taken to minimize this risk.

	I: An assessment is undertaken to predict the level of risk that the project's residual impacts on biodiversity will be or not be capable of being offset, with special attention afforded to any highly irreplaceable and vulnerable biodiversity components.
Initiate a tribal participation process	*P6: Tribal participation: Tribes who depend on the land and its biodiversity to sustain their treaty rights will be included in the decision-making about biodiversity offsets, including their evaluation, selection, design, implementation, and monitoring.*
	C: Consultation and participation of tribes shall be integrated into the decision-making process for offset design and implementation and documented in the Biodiversity Offset Management Plan.
	I: For projects and/or offsets with adverse impacts on tribes, their free, prior and informed consent (FPIC) will be obtained and documented.
Initiate a stakeholder participation process	P6: *Stakeholder participation: In areas affected by the development project and by the biodiversity offset, the effective participation of stakeholders should be ensured in decision-making about biodiversity offsets, including their evaluation, selection, design, implementation, and monitoring.*
	C: Consultation and participation of relevant stakeholders shall be integrated into the decision-making process for offset design and implementation and documented in the Biodiversity Offset Management Plan.
	I: Documentation of consultation and participation of stakeholders.
Apply mitigation hierarchy. Review significance of impact at regional and landscape level	P1: *Adherence to the mitigation hierarchy:*
	C: The developer shall identify, implement and document appropriate measures to avoid and minimise the direct, indirect and cumulative negative impacts of the development project and to undertake on-site rehabilitation/restoration.
	I: Measures to avoid and minimise biodiversity loss and to rehabilitate/restore biodiversity affected by the project are defined and documented, and these measures implemented, monitored and managed for the duration of the project's impacts.
	C: The biodiversity offset shall only address the residual impacts of the development project, namely those impacts left after all the appropriate avoidance, minimisation and rehabilitation/restoration actions have been identified.
	I: Any residual losses of biodiversity that may exist following avoidance, minimisation and rehabilitation/restoration are identified and described in the Biodiversity Offset Management Plan.
	P2: *Limits to what can be offset*
	C: The risk that the project's residual impacts on biodiversity may not be capable of being offset ('non-offsetable') shall be assessed and measures taken to minimise this risk.

	I: The risk assessment demonstrates how the project's residual impacts can and will be offset through specific measures and commitments, taking into account the level of risk and uncertainties regarding the delivery of the offset.
Determine the need for an offset based on residual adverse effects	*P6: Tribal participation*
	C: Consultation and participation of relevant tribes shall be integrated into the decision-making process for offset design and implementation, and documented in the Biodiversity Offset Management Plan.
	I: Relevant tribes are identified and informed of the desire to design and implement a biodiversity offset for the project.
	I: Records are maintained that document the results of informed consultation and participation of relevant tribes related to the design and implementation of the biodiversity offset.
	P6: *Stakeholder participation*
	C: Consultation and participation of relevant stakeholders shall be integrated into the decision-making process for offset design and implementation, and documented in the Biodiversity Offset Management Plan.
	I: Relevant stakeholders are identified and informed of the plan to design and implement a biodiversity offset for the project.
	I: Records are maintained that document the results of informed consultation and participation of relevant stakeholders related to the design and implementation of the biodiversity offset.
	P9: Transparency: The design and implementation of a biodiversity offset, and communication of its results to the public, should be undertaken in a transparent and timely manner.
	C: The developer responsible for designing and implementing the biodiversity offset shall ensure that clear, up to date, and easily accessible information is provided to stakeholders and the public on the offset design and implementation, including outcomes to date.
	I: An independent mechanism (such as a steering committee, review panel, or system for peer review) is established to oversee the offset design and implementation process and report regularly to the public on their assessment of progress.
	I: Information on baseline findings, impact assessment as well as offset design and implementation is reported to stakeholders and the public in appropriate media during offset design and implementation