

1 **Chapter 3: Frameworks and**
2 **Approaches for Assessing Nature in**
3 **the US**

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DRAFT

1 Summary

2 The Nature Record National Assessment employs a suite of frameworks and approaches to
3 assess the status and trends of US lands, waters, biodiversity, and wildlife, as well as the
4 benefits they provide for the country’s economy, health, culture, security, and climate. This
5 methodology draws on the history, approaches, and applications of nature assessments in
6 the US and around the world and incorporates multiple dimensions of environmental
7 equity and justice. By reflecting on knowledge gaps and emerging issues, the Assessment
8 also identifies opportunities for bolstering US national-scale assessments in the future.

9 Different disciplines, communities, and cultures understand nature in different ways, and
10 the breadth of the Assessment reflects this. Three chapters report on the status, trends,
11 and future projections of terrestrial, marine, and inland water ecosystems (Chs. 6, 7, 8),
12 while another chapter explores the factors that drive changes in nature (Ch. 9). Three
13 cross-cutting chapters focus on equity in access to nature, the connections between
14 people and nature, and the impacts of climate change (Chs. 2, 5, 10). Four benefits
15 chapters consider human–environment relationships that resonate with diverse
16 communities and stakeholders (Chs. 11–14). Two chapters highlight bright spots and future
17 opportunities for nature assessment to inform decision-making (Chs. 4, 15). The
18 Assessment draws on a wide range of scientific underpinnings and aims to advance
19 understanding and decision-making by employing a holistic and evidence-based approach
20 informed by public engagement.

21 The frameworks and approaches adopted by this Assessment are based on previous
22 influential assessments across scales, taxa, and sectors. Effective approaches include
23 recruitment of authors at different career stages with diverse perspectives and expertise,
24 working with Indigenous and local knowledge holders, and conducting author training,
25 independent reviews, and public engagement. Accessibility, reusability, and transparency
26 lead to datasets that live on beyond any one assessment product. With sufficient
27 resources and time, future assessments could consider establishing shared scenarios,
28 developing consistent baselines, and creating a non-federally led consortium of
29 stakeholders to link national, local, and regional priorities. Other emerging issues are
30 artificial intelligence (AI) impacts and opportunities and the potential for co-developing
31 approaches to nature assessments that transcend political ideologies to reach broader
32 audiences.

33 Background

34 Assessments of the natural world have taken many forms and approaches and spanned
35 geographies and taxonomic scales. This Assessment takes stock of US lands, waters,
36 biodiversity, and wildlife and the benefits they provide for the country’s economy, health,
37 culture, security, and climate. As the first comprehensive assessment of nature across the
38 US, this report draws on the history and effective practices—as well as addresses
39 knowledge gaps—of previous nature assessments. By analyzing the breadth of available

1 methods for assessing nature—and their scientific underpinnings—this chapter situates
2 the Assessment in the context of a well-established body of previous work and lays the
3 groundwork for the approaches taken within this report.

4 Conceptualizations of nature change over time and are shaped by science and society (1).
5 Different cultures and worldviews may adopt different perspectives on the relationship
6 between people and nature, and these perspectives influence key concepts, conservation
7 strategies, and scientific underpinnings (2,3). The Assessment has proposed a definition of
8 nature that makes explicit key assumptions about nature and can be applied consistently
9 across the report (Soranno et al. in review). Nature is defined as “the complex web of all
10 forms of life (plants, animals, fungi, protists, and prokaryotes) together with the abiotic
11 [non-living] components and processes that sustain life. Nature includes humans and is
12 dynamic—encompassing ecological, evolutionary, physical, behavioral, social, economic,
13 and cultural interactions at multiple scales” (Soranno et al. in review).

14 This definition recognizes that humans are part of nature, as are human-altered systems
15 such as urban green spaces, managed forests, and agricultural fields. However, nature
16 does not include everything. Strictly human creations (e.g., built, virtual, or institutional
17 structures) that intentionally exclude living beings are not included in this definition of
18 nature (Soranno et al., in review). This definition is grounded in scientific systems thinking
19 and is intended to provide a foundation for defining nature in legal, cultural, and place-
20 based governance contexts.

21 Nature assessments have historically served a range of purposes (Box 3.1). Broadly, they
22 provide baseline and trend data that help people make decisions and create informed
23 strategies on many issues, including environmental management, restoration, and
24 protection. Nature assessments can also provide a foundation for understanding how the
25 extent and condition of natural systems affect human populations and, conversely, how
26 human activities affect natural systems. By highlighting knowledge gaps, assessments can
27 play an important role in guiding and prioritizing research needs. Nature assessments also
28 have the potential to increase public and stakeholder awareness about the status of
29 nature, the interdependence of humans and nature, and the ways in which humans can
30 help to ensure the long-term functioning of Earth’s ecological systems.

31 Here we provide an overview of the frameworks and approaches used throughout this
32 Assessment and put them in the context of previous assessments, future assessments,
33 and multiple dimensions of environmental justice. This chapter thus provides a high-level
34 synthesis of conceptual frameworks and paradigms underpinning the Assessment. A
35 description of the implemented frameworks and approaches supports transparency,
36 accessibility, and interpretation of results so as to better inform policy- and decision-
37 making.

38 **Box 3.1. Example Uses, Applications, and Decision Contexts for Nature Assessment**

39 Nature-focused assessments are done for different purposes:

- 1 • **Species conservation assessments** determine the status of individual species and
2 their risk of extinction. Example: US Fish and Wildlife Service assessments inform
3 endangered species listings: [https://www.fws.gov/project/species-status-](https://www.fws.gov/project/species-status-assessment)
4 [assessment](https://www.fws.gov/project/species-status-assessment) (4).
- 5 • **Site-level assessments of biodiversity and habitat** evaluate impacts of proposed
6 projects and can determine required compensatory mitigation. Example: Wetland
7 Assessment Method assesses the compliance of North Carolina wetlands to the
8 Clean Water Act: <https://www.deq.nc.gov/ncwam-manual> (5).
- 9 • **Organization-level (e.g., businesses, cities) assessments** explore impacts and
10 material dependencies on nature and biodiversity. Example: assessment developed
11 by the Taskforce on Nature-related Financial Disclosures are being piloted by many
12 companies: <https://tnfd.global/> (6).
- 13 • **Assessments of interventions and management actions** can be used to evaluate
14 and improve their effectiveness. Example: an assessment of global conservation
15 actions evaluating protected areas, sustainable management, habitat conservation,
16 restoration, and invasive species control (7).
- 17 • **National or regional ecosystem assessments** synthesize knowledge on
18 biodiversity and ecosystem services, tailoring the information to national or regional
19 priorities and specific policy questions. Example: the National Biodiversity and
20 Ecosystem Services Assessment for Cameroon (8). Some integrate the economic
21 impact of nature into national wealth accounting, including the costs of nature
22 degradation and the benefits of nature restoration into economic indicators (e.g.,
23 gross domestic product [GDP]), creating what is often called a green GDP. Examples
24 include the UK National Ecosystem Assessment (9) and Australia’s National
25 Ecosystem Accounts (10).
- 26 • **Global assessments** are intergovernmental, integrated efforts to understand recent
27 anthropogenic transformations of Earth’s living systems, the roots of these
28 transformations, and their implications for society. They can focus on a range of
29 topics from pollinators to alien species to biodiversity. Examples include the IPBES
30 (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem
31 Services) global assessment <https://www.ipbes.net/global-assessment> (11) and the
32 UN assessment of the world's oceans
33 <https://www.un.org/regularprocess/woa2launch> (12)

34 [END BOX 3.1 HERE]

35 Considering Multiple Dimensions of Equity and Justice in Nature 36 Assessments

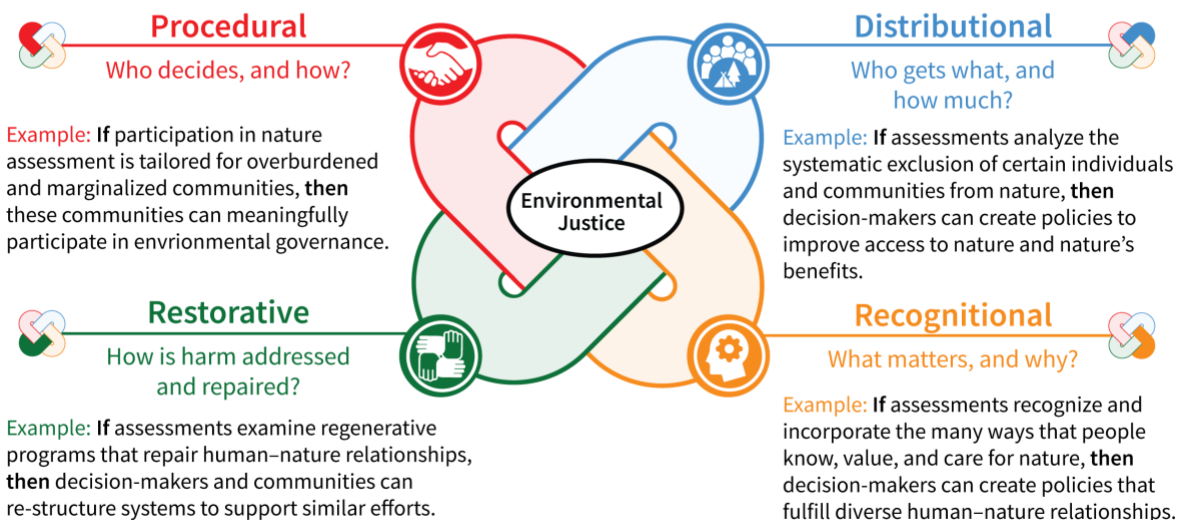
37 How nature is defined and assessed can either contribute to a more **just** and equitable
38 world or perpetuate and reproduce harm. Aligning nature assessments with principles of
39 **environmental justice** and **equity** can help improve the well-being of all people and

1 ecosystems and address the historical marginalization of particular peoples and
2 perspectives (13,14).

3 We highlight four interacting dimensions of environmental justice: distributional,
4 recognitional, procedural, and reparative (Figure 3.1). All dimensions relate to many
5 intersecting demographic categories (including race, ethnicity, gender, ability, class, and
6 citizenship), as well as the relationships between present and future generations and
7 between human and nonhuman life (13,15,16). These dimensions provide a conceptual
8 framework to center equity and environmental justice in nature assessment.

9 **Figure 3.1. Dimensions of Environmental Justice as They Relate to Nature Assessment**

Dimensions of Environmental Justice as They Relate to Nature Assessment



10

11 **Understanding the importance of equity involves considering multiple dimensions of**
12 **environmental justice.**

13 *Four interacting dimensions of environmental justice and equity include procedural (red),*
14 *distributional (blue), recognitional (orange), and restorative (green). By considering each of*
15 *these four dimensions in all aspects of the assessment process, a nature assessment can*
16 *more effectively inform governance and policies aimed at addressing equity issues.*

17 *Adapted from Marino et al. 2023 (17).*

18 **Distributional justice** in nature assessment asks Who has access to nature and how
19 much? For whom is nature modified? (Figure 3.1). Access to nature, nature's contributions
20 to people (14,18), and the ability to practice reciprocal relations between nature and
21 people (19,20) are inequitably distributed in the US (21–25). Environmental **risk** and **harm**
22 are disproportionately imposed on people of color, Indigenous peoples, lower-income
23 people, and other communities who experience—and resist—systemic oppression and

1 discrimination. Discounting the impacts of human activities on future generations and
2 nonhuman entities also contributes to distributional injustice (13,26,27).

3 A nature assessment that explores distributional justice assesses the distribution of nature
4 access and benefits. This involves evaluating observable **indicators** of relevant **metrics** at
5 appropriate spatial and temporal scales (e.g., tree canopy cover and the Nature Gap (28)).
6 To identify relevant metrics and scales, an assessment must be grounded in the historical
7 context, and the drivers, of ongoing environmental injustices.

8 **Recognitional justice** in nature assessment asks Whose worldviews, **knowledge**
9 **systems**, and values are reflected in the assessment of nature, and how? (Figure 3.1).
10 People and communities across the US have diverse ways of conceptualizing, coming to
11 know, and valuing nature (29,30). However, most mainstream science and policy reflect
12 extractive perspectives of nature and prioritize the value of nature as a commodity (KM 2 in
13 (31)). Recognizing diverse worldviews, knowledge systems, and values is necessary for
14 addressing complex challenges such as biodiversity loss. Doing so can lead to more
15 sustainable and equitable outcomes, increase the legitimacy of public policy, and enable
16 **self-determination** and **sovereignty** (23,32–38). Recognitional justice intersects with
17 other dimensions of justice by manifesting in fair and representative decision-making (30),
18 more equitable distribution of nature access and benefits (39), and **epistemic justice** for
19 diverse **knowledge holders** (40).

20 Key entry points for recognitional justice in nature assessment include the definition of
21 nature and the conceptualization of people–nature relationships ([IPBES Glossary](#) (41),
22 Soranno et al. in review). Assessment frameworks, metrics, and standards for evidence
23 also contribute to recognitional justice when they integrate diverse ways of knowing (see
24 "Weaving Diverse Ways of Knowing in Nature Assessment" below) and reflect the values of
25 those who will use and be impacted by the assessment (28).

26 **Procedural justice** in nature assessment asks Who decides how nature is defined and
27 assessed and how is that decision made? (Figure 3.1). Procedural justice “demands the
28 right to participate as equal partners at every level of decision-making, including needs
29 assessment, planning, implementation, enforcement and evaluation” (42); also recognized
30 in the 1992 Rio Declaration, Principle 10 (43). Both the degree and the quality of
31 participation matters (44–48). **Meaningful participation** (48,49) is necessary and
32 indispensable if an assessment is to achieve accuracy, legitimacy, and usefulness for
33 decision-making. It will affect the assessment’s accuracy, legitimacy, and usefulness for
34 decision-making. Just processes also consider how to account for the interests of future
35 generations and the nonhuman, or more-than-human, world (27).

36 The intentional composition of author teams and decision-making bodies is an opportunity
37 for procedural justice in nature assessment. A nature assessment that is led and co-
38 created by individuals with diverse expertise and backgrounds, particularly those who
39 reflect the population of end users of the assessment (e.g., see Ch. 1: Overview), adheres
40 to principles of procedural justice.

1 **Restorative justice** in nature assessment asks How can nature assessment strengthen
2 knowledge to prevent the reproduction, and contribute to the repair, of past harms? (Figure
3 3.1). Restorative justice strives for the **mutual repair** of damaged relationships among and
4 between humans and nature (40,50). Mutual repair begins by acknowledging histories of
5 social and ecological trauma (40,51) and is carried out on the terms of those harmed
6 (52,53). As a result, restorative justice will look different for different communities.
7 Restorative justice is a regenerative process that takes place over extended timelines and
8 calls for a broader societal shift toward reciprocal relationships and **relational values**
9 (50,52).

10 Case studies of restorative justice are integral to assessing the status and trends of
11 people–nature relationships. Cases of restorative justice also provide roadmaps to
12 policymakers who seek to produce lasting co-benefits for people and nature without
13 reproducing past harms. Assessing drivers and trends in the production of social and
14 ecological harm can also provide source material to facilitate acknowledgement and
15 accountability for restorative justice.

16 Historical and Current Practices of Assessing Nature

17 Nature assessments are typically initiated by significant environmental and societal events
18 and aim to strengthen conservation policies and management. Approaches to nature
19 assessment depend on scope, scale, and stakeholder needs. Some assessments
20 synthesize existing knowledge, while others develop original data. Effective practices from
21 prior assessments include recruiting diverse and representative authors, incorporating
22 stakeholder feedback, developing content based on a common conceptual framework,
23 prioritizing data accessibility, and integrating findings across ecosystem components and
24 functions.

25 This Assessment is informed by and builds on previous nature assessments conducted in
26 the US and around the world (Figure 3.2). A common goal of most assessments is to
27 provide evidence for decision-making (54–56). Other than that shared goal, assessment
28 scale, scope, process, and types vary widely (Figure 3.2). Some assessments, such as
29 fisheries stock assessments, collect their own data and are “purpose-built” and
30 constrained. Other assessments also collect novel datasets or compile existing data to
31 analyze the state of a given taxa, biodiversity of a particular region, or status and trends of
32 an ecosystem service. The Nature Record is the type of assessment that brings together
33 expert authors to provide an authoritative synthesis of the current state of knowledge in a
34 field or topic. Hereafter, discussion on assessment history and practices will focus on this
35 category of assessment, with the recognition that there are many ways to conduct
36 assessments of nature.

37 Synthetic expert-led nature assessments such as The Nature Record are powerful
38 documents that differ from literature reviews or meta-analyses because they leverage
39 expert knowledge to build findings. They draw on rigorous systematic approaches such as

1 weight-of-evidence, or in the case of The Nature Record, consensus evaluation of the
2 existing body of scientific evidence based on authors' expert judgment. As a result, they are
3 considered influential and authoritative, allowing for integration of knowledge from
4 disparate disciplines and levels of organization (57). Assessments involving biodiversity
5 and nature topics may be nature-focused (58) or nature-inclusive (59), and are either
6 targeted (60) or comprehensive (61) (Figure 3.2).

7 Precolonial Period to the Present

8 The history of nature assessment and its applications in the US, spanning from precolonial
9 times to the present, reflect shifts in society, culture, environmental governance, and
10 scientific and policy innovations. Nature has been assessed and managed by Tribes and
11 Indigenous Peoples through a diverse array of Indigenous knowledge systems from time
12 immemorial to the present. Long before the formal establishment of modern "nature
13 assessments" in the 20th century, Indigenous Peoples around the world, including in the
14 US, developed and practiced systems of social and ecological knowledge and stewardship
15 over millennia (62–64). These traditions—often referred to collectively as Indigenous
16 Knowledge (IK)—combine observation, practice, and responsibility to sustain reciprocal
17 human–environment relationships with ecosystems (61,65,66). While the timeline below
18 focuses on the legal and governance frameworks of most modern nature assessments—
19 rooted in conservation, environmental law, and policy beginning in the 1930s—Indigenous
20 and place-based knowledge traditions continue to evolve and remain foundational to
21 understanding nature and its transformations (66–68). Several recent assessments, such
22 as the Fifth National Climate Assessment (59) and (Whyte et al. in press) have prioritized
23 inclusion of Indigenous authors, knowledge, and perspectives. Despite this progress,
24 Indigenous Knowledge and authorship are still vastly underrepresented in nature
25 assessments and mostly absent from historical assessments due to marginalization as a
26 result of colonization (66,69,70).

27 1930s–1940s: The Bennett Era—the Dust Bowl and Soil Conservation

28 During the Great Depression, economic shocks, resource extraction, droughts, and land
29 degradation culminated in the Dust Bowl, particularly in the Great Plains region of the US
30 (71). This event triggered one of the first modern national-scale nature assessments since
31 the establishment of the United States. Dr. Hugh Hammond Bennett, known as the "father
32 of soil conservation," advanced an understanding of soil erosion's agricultural impacts. His
33 seminal publication, "Soil Erosion: A National Menace" (71,72), catalyzed the
34 establishment of federal soil erosion stations in 1929. Under President Roosevelt's New
35 Deal, significant legislation, including the Soil Conservation and Domestic Allotment Act of
36 1936 (73), created the Soil Conservation Service, later renamed the Natural Resources
37 Conservation Service (NRCS) in 1994, to manage soil and water conservation on private
38 lands.

1 1950s–1960s: The Carson Era—Foundation of Modern Nature Assessments

2 After World War II, growing concerns about resource depletion, chemical pollution, and
3 environmental destruction (74,75) laid the groundwork for modern nature assessments
4 (76,77). Rachel Carson’s book *Silent Spring* (78) was not an assessment per se, but it
5 catalyzed widespread public awareness of the ecological and health impacts of pesticides,
6 prompting subsequent environmental monitoring programs and policy reforms (e.g.,
7 establishment of the Environmental Defense Fund in 1967). Likewise, Garrett Hardin’s
8 essay “The Tragedy of the Commons” (79) influenced later assessments of collective
9 resource use and governance. In the marine environment, The Stratton Commission’s 1969
10 report “Our Nation and the Sea” highlighted the importance of marine science for
11 developing a sustainable and productive ocean economy, laying the groundwork for the
12 creation of NOAA and other foundational ocean governance. These intellectual
13 interventions, alongside policy innovations like the Wilderness Act (80), the Water Pollution
14 Control Act (81), and President Lyndon Johnson’s vision for “natural beauty” (82), set the
15 stage for systematic environmental assessments by shaping the political and institutional
16 context in which they emerged.

17 1970s–1980s: Era of Institutionalization of Nature Assessments

18 This era marked the systematic integration of nature assessments into policy. Events like
19 the Stockholm Conference (83), the creation of the World Climate Research Programme
20 (84), the ratification of the Montreal Protocol (85), and the establishment of the
21 Intergovernmental Panel on Climate Change (86) underscored global cooperation.
22 Influential reports such as “Limits to Growth” (87) highlighted the value of assessments in
23 identifying resource constraints and sustainable development solutions. In the US, major
24 environmental legislation during this period both drew from and institutionalized
25 assessments. The Environmental Protection Agency was created in part due to
26 assessments of pollution impacts, while the Clean Air Act (1970) (88), Clean Water Act
27 (1972) (89), and Endangered Species Act (1973) (90) codified protections based on
28 emerging assessment evidence. Crucially, some legislation also established mechanisms
29 for ongoing assessments: The National Environmental Policy Act (1970) (91) required
30 Environmental Impact Assessments for federal projects; the Forest and Rangeland
31 Renewable Resources Planning Act of 1974 required ongoing assessment of the Nation’s
32 forests and rangelands (60); and the Marine Mammal Protection Act (1972) (92) and the
33 Magnuson–Stevens Fishery Conservation and Management Act (1976) (93) mandated
34 stock assessments and monitoring of marine species and fisheries. In addition to
35 Magnuson–Stevens Act, the Coastal Zone Management Act (1972) and Marine Protection,
36 Research, and Sanctuaries Act (1972) institutionalized coastal and ocean assessment.
37 Conservation programs such as the Food Security Act (1985) further integrated
38 assessments into land-use management ((94).

1 1990s–2000s: Era of Linking Ecosystem Services to Human Well-Being

2 Global concerns about biodiversity loss and climate change spurred the Rio Conventions
3 (95–97) and assessments such as the Millennium Ecosystem Assessment (MEA; 2005)
4 (58). These efforts were highly influenced by the first report of the IPCC, which addressed
5 the impacts of climate change on nature (98). The MEA elevated the concept of ecosystem
6 services and established a strong link to their contribution to human well-being. This
7 period also marked an early broadening of the scientific underpinnings of nature
8 assessment beyond ecology. Incorporating economics, public health, and social science
9 was seen as integral to understanding human–nature relationships. A report funded by the
10 Heinz Center, “State of the Nation’s Ecosystems” (2002) ((99), may have been the first
11 broadly framed nature-focused assessment for the US. The Global Change Research Act of
12 1990 (100) established the US Global Change Research Program (USGCRP) and its
13 flagship National Climate Assessment (NCA) to coordinate and advance integrated
14 assessment of global environmental change (101). This led to several nature-inclusive
15 NCAs (e.g., (102)). While largely expert-driven, these assessments began to experiment
16 with stakeholder engagement and user-oriented framing, foreshadowing later co-
17 production approaches. The President’s Committee of Advisors on Science and
18 Technology report, “Teaming with Life” (1998), further reinforced systems-based and
19 interdisciplinary approaches to biodiversity and ecosystem assessment (103). With
20 increasing political attention on nature’s value for the economy, the US passed the Energy
21 Policy Act of 2005 (104) and strengthened NRCS to lead a multiagency Conservation
22 Effects Assessment Project (105), which quantified conservation benefits. Marine and
23 coastal assessments also advanced significantly in this period. The Pew Oceans
24 Commission (2003) and U.S. Commission on Ocean Policy (2004) led to the National
25 Ocean Policy (2010) and the NOAA Integrated Ecosystem Assessment (IEA) Program. The
26 NOAA IEA Program, initiated around 2006 and expanded from 2008 onward,
27 institutionalized a marine ecosystem services and resilience assessment framework (106).

28 2010s–2020s: Era of Equity, Resilience, Natural Capital, and Technological 29 Integration

30 This era reflects a decisive shift toward transdisciplinary and transboundary assessment
31 models, explicitly integrating social science, governance, and lived experience alongside
32 biophysical data. Recent assessments have prioritized biodiversity, nature and equity, and
33 technological assessment innovations. Examples include the Intergovernmental Science-
34 Policy Platform on Biodiversity and Ecosystem Services (IPBES) nature- and biodiversity-
35 focused assessments (61,107); other nature-inclusive assessments (108,109); and the
36 most recent NCA (102,110). Co-production of knowledge with policymakers, practitioners,
37 and communities became a defining design principle of major global assessments during
38 this period. Frameworks such as the System for Environmental Economic Accounting
39 (SEEA) for developing **natural capital accounting** (111,112) advanced biodiversity and
40 ecosystem assessment and valuation. Technological advancements in internet access
41 ensured connectedness of scientific communities and, together with tools such as

1 satellite monitoring (e.g., [Global Forest Watch](#) (113,114)), revolutionized the possibility of
2 global assessments of nature.

3 US initiatives during this era focused on advancing the integration of technology, justice,
4 and equity into natural capital assessments and environmental policy, such as the Tribal
5 Climate Resilience Program (115,116), the Justice40 Initiative (117), the establishment of
6 the White House Environmental Justice Advisory Council (118), the Sacred Sites
7 Memorandum of Understanding (119), the Executive Order on Strengthening the Nation's
8 Forests, Communities, and Local Economies (120), the Ocean Justice Strategy (121), the
9 National Strategy to Develop Statistics for Environmental-Economic Decisions (122),
10 investments through the Inflation Reduction Act and Bipartisan Infrastructure Law (123),
11 and strategies such as the US National Ocean Biodiversity Strategy (124). Recent
12 assessments have made strides to incorporate Indigenous Knowledge not only as an equity
13 consideration but also as a distinct and complementary way of knowing that informs
14 problem framing, the development of relevant indicators, and interpretation (59).
15 Intentional interfaces between Indigenous and Western science are increasingly shaping
16 assessment methodologies. More importantly, Indigenous Peoples and Tribes have led
17 their own groundbreaking assessments (68). Recent Federal Government efforts have also
18 promoted nature-based solutions, incorporated biodiversity and climate change into
19 national security strategy, and advocated for consideration of ecosystem services into
20 cost-benefit analyses (125–128).

21 [Nature Assessment Methods and Effective Practices](#)

22 Synthetic, expert-led nature assessments involve a variety of approaches depending on
23 scope, scale, sources of information, objectives, sectors, and leading organization. A
24 common thread among many such assessments is that they synthesize the current body of
25 material and then evaluate the likelihood and/or confidence of certain findings based on
26 the referenced materials and expert consensus (Table 3.1) (57,102,129–131). Synthetic
27 assessments often draw from a range of sources, including peer-reviewed literature,
28 Indigenous Knowledge, and gray literature (Figure 3.2, Table 3.1) (69,102,130). Other
29 assessments develop novel analyses and products (field data collection, database
30 compilation, modeling, natural capital valuation) and outline research findings (Figure 3.2)
31 (132–134).

32

1 **Table 3.1 Assessment Characteristics**

- 2 *This table lists selected assessments that exemplify specific assessment characteristics or*
 3 *methods, approaches, and effective practices, corresponding with the Figure 3.2 diagram.*

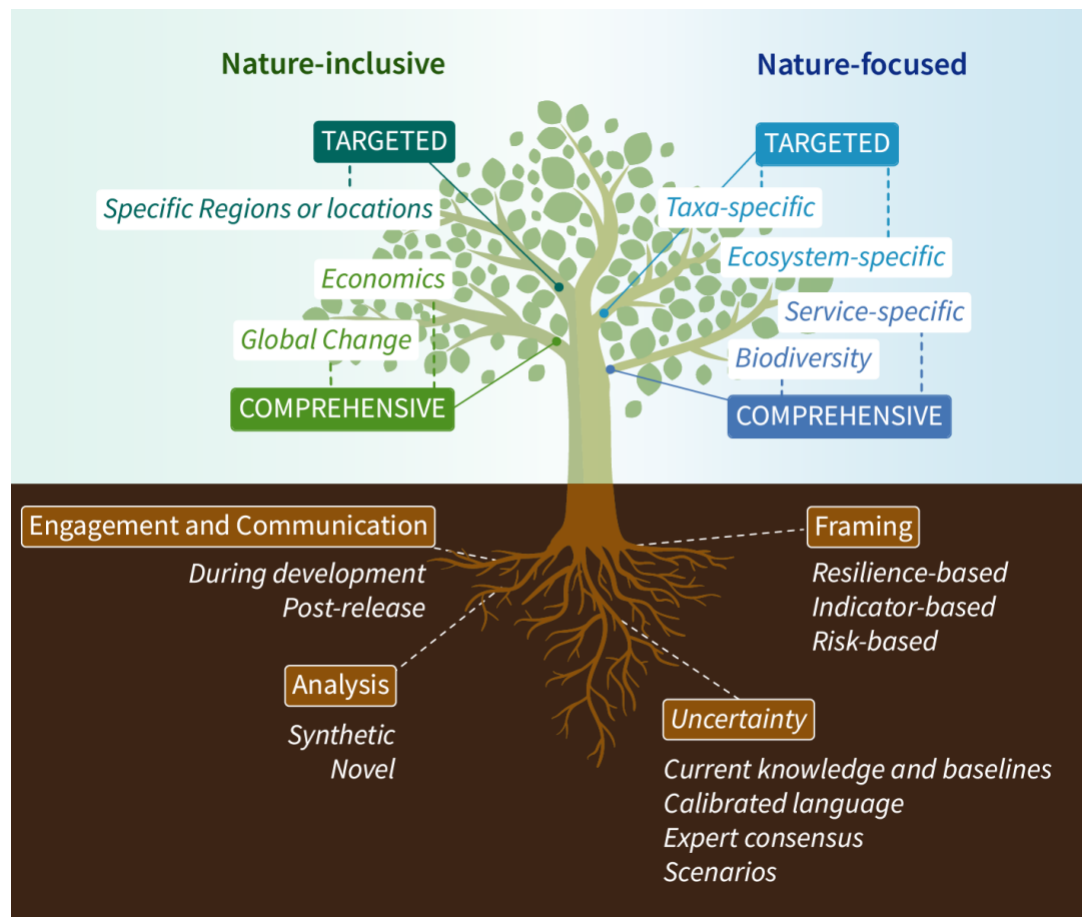
Assessment Characteristics			
Scope	Focus	Example Types	Example Assessments
Nature-inclusive	Comprehensive	Global change	National Climate Assessment, IPCC Climate Change Synthesis Report, California Climate Change Assessment
	Targeted	Economics, other sectors based on specific ecosystem services	The Changing Wealth of Nations, Inclusive Wealth Report
Nature-focused	Comprehensive	Biodiversity	IBES Global Assessment, The Nature Record Assessment, The Nature Record, Living Planet Report, Millenium Ecosystem Assessment, Biodiversity and Climate Change Assessment for North America
	Targeted	Taxa-specific, ecosystem-specific, ecosystem service-specific	2nd Global Amphibian Assessment, 2nd World Ocean Assessment, IPBES Assessment Report on Pollination, NABCI State of the Birds Report

4

Methods, Approaches, and Effective Practices in Previous Assessments			
Overarching Categories	Specific Approaches	Example Types	Example Assessments
Engagement and communication	During development	Round tables, interviews, public comment	National Climate Assessment, The Nature Record National Assessment
	Post-release	Summary for policymakers, story maps, education resources	IPBES Global Assessment, IPCC Climate Change Synthesis Report, Millenium Ecosystem Assessment, California National Climate Assessment
Analysis	Synthetic analysis	Indigenous Knowledge, scientific publication, gray literature, meta-analysis, literature review, knowledge compilation	National Climate Assessment, IPBES Global Assessment, IPCC Climate Change Synthesis Report, Status of Tribes and Climate Change Report Release, California National Climate Assessment, The Nature Record National Assessment
	Novel analysis	Field data collection, database compilation, modeling, natural capital valuation	The Changing Wealth of Nations, Living Planet Report, National Rivers and Streams Assessment, Future of America's Forest and Rangelands, West Hawai'i Integrated Ecosystem Assessment, Biodiversity in Focus Report
Uncertainty	Current knowledge (snapshot in time) and baselines	TBD	TBD

	Calibrated language	Confidence/likelihood	National Climate Assessment, IPCC Climate Change Synthesis Report, IPBES Global Assessment
	Expert consensus	TBD	2nd Global Amphibian Assessment
	Scenarios	Quantitative, qualitative, storylines, identification of baseline	National Climate Assessment, IPCC Climate Change Synthesis Report, IPBES Global Assessment, California Climate Change Assessment
Framing	Risk-based (What is valued that's at risk?)	Exposure and consequence	Biodiversity in Focus Report
	Indicator-based (measuring traits of each system component)	Status and trends	Living Planet Report
	Resilience-based (focusing on system-wide functional resilience)	TBD	TBD

1 **Figure 3.2. Approaches of Previous Assessments**



2

3 **Previous nature-related assessments utilize a range of methods, approaches, and**
 4 **effective practices.**

5 *The tree diagram depicts the range of characteristics (branches) and methods,*
 6 *approaches, and effective practices (roots) used in previous nature-related assessments.*
 7 *Past nature assessments can be characterized as having nature-inclusive versus nature-*
 8 *focused scope and comprehensive or targeted focus; several examples of different types of*
 9 *assessment scopes and foci are included in the diagram and listed in Table 3.1. The*
 10 *methods, approaches, and effective practices are organized into categories of engagement*
 11 *and communication, analysis, uncertainty, and framing. The corresponding Table 3.1*
 12 *includes example assessments for these various characteristics and approaches. Figure*
 13 *original to the Nature Record.*

14 Inclusion of biodiversity indicators or underlying conceptual frameworks can connect
 15 knowledge across assessments, foster collaboration across scales and geographical
 16 areas, and provide useful evidence for conservation policies (70,135,136). Assessments
 17 can be framed around approaches that are risk-based (identifying what is valued that is at
 18 risk), indicator-based (measuring traits of each system component), or resilience-based

1 (focusing on system-wide functional resilience (137,138)). Many assessments integrate
2 certain biodiversity indicators (e.g., [IUCN Red List of Threatened Species and of](#)
3 [Ecosystems](#) (139), [Living Planet Index](#) (140), [Biodiversity Intactness Index](#) (141)) using data
4 and knowledge from global experts (134,142). Other consistent underlying conceptual
5 frameworks (14,130) include “nature’s contributions to people” (14), or integrated
6 ecosystem assessments, which describe both research gaps and management
7 recommendations (132,143,144). To increase relevance to policymaking across scales
8 (e.g., [Convention on Biological Diversity, Kunming-Montreal Global Biodiversity Framework](#)
9 (145)), assessments may discuss policy goals, including describing multiple scenarios
10 based on different actions or future conditions and producing a summary for policymakers
11 (70,102,131,136,146–149).

12 Development practices implemented by this Assessment build on assessments such as
13 IPBES, NCA, and IPCC Synthesis Reports that have succeeded in generating what are
14 widely seen as trustworthy and useful products (150). These practices include recruiting
15 authors with diverse perspectives (151,152), building teams with a mix of early-career and
16 experienced experts (153), and working with Indigenous and local knowledge holders for
17 holistic place-based understanding (18,55). Assessment producers address disciplinary
18 “tunnel vision” through comprehensive author training, multidisciplinary teaming, and
19 implementation of independent reviews by experts (154,155). Public engagement deepens
20 the responsiveness of assessments to users; in order to broaden perspectives, writing
21 teams sometimes receive feedback from stakeholders and other interest groups through
22 public comment periods, outreach workshops and webinars, and working meetings
23 (102,154,156,157).

24 In this era of big data (extremely large and complex datasets), information from
25 assessments is most useful if it adheres to FAIR data principles: findable, accessible,
26 interoperable, and reusable (158). Research communities are now standardizing
27 information for cross-comparability using repositories such as the Global Biodiversity
28 Information Facility and the Ocean Biodiversity Information System (158,159). The
29 sustainability of long-term monitoring data in the US currently is entrusted to program-
30 specific or established data depositories, such as Dryad, the National Ecological
31 Observatory Network data portal, the Environmental Data Initiative, and the Ocean
32 Observatories Initiative data repository, which support biodiversity data. These data
33 management practices lead to datasets that live on beyond any one assessment product.

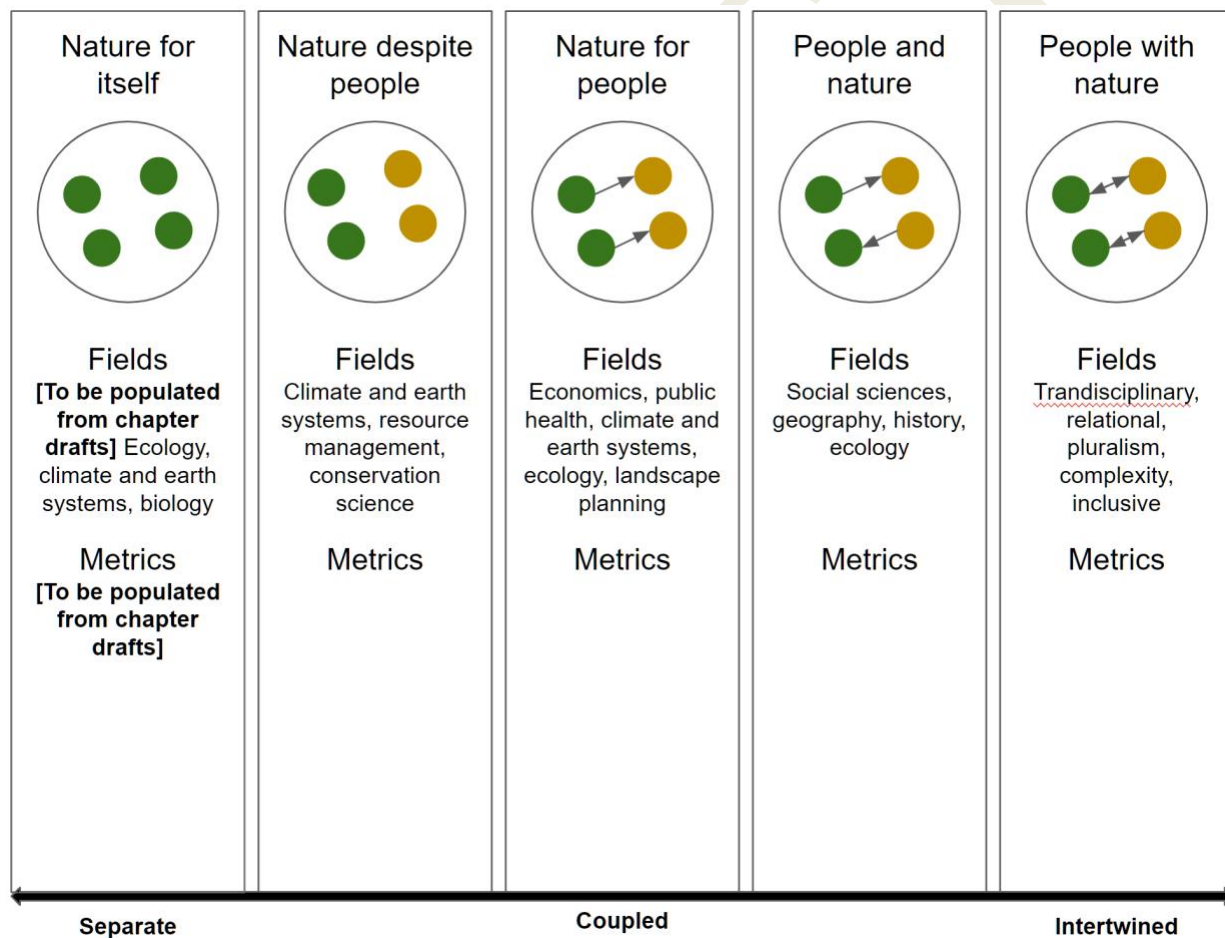
34 A goal of many assessments is to extend a basic accounting of ecosystem components
35 into a more holistic understanding of ecosystem functions and services to support
36 management decisions amid impacts (138,144). For place-based assessments, holistic
37 understanding means examining biological systems spanning from genetics to
38 ecosystems, and social systems from the behavior of individuals to societal governance at
39 multiple scales (70,160). Future assessments will continue to reflect a dynamic and
40 contextual approach to understanding the human–nature relationships, resulting in new
41 data, methods, and insights into the status and trends of social–ecological systems.

1 Frameworks and Approaches for The Nature Record National
2 Assessment

3 Setting the Stage: Conceptualizing People–Nature Relationships

4 The Assessment exemplifies how various disciplines, communities, cultures, and regions
5 define, assess, and value nature. Different conceptions of the human–nature relationship
6 have emerged and become more or less dominant over time (1), as have the worldviews
7 and scientific underpinnings that shape how researchers assess the status and trends of
8 nature (Figure 3.3).

9 **Figure 3.3. The Nature Record National Assessment Approaches to Assessing Social–**
10 **Ecological Systems**



11 Relationships between people and nature vary widely based on perspectives and
12 worldviews and are catalogued in diverse ways.
13

14 *Approaches to assessing nature involve differing perspectives on the separation of people*
15 *and nature and associated key ideas and scientific underpinnings. Draft figure adapted*
16 *from Reyers and Bennett 2025 (3).*

1 The Assessment chapters draw on different conceptualizations of the human–nature
2 relationship, basing their assessment on associated literatures and disciplines depending
3 on the chapter focus. For example, a “nature for people” perspective recognizes the value
4 of ecosystem services and draws heavily on the integration of ecology and economics to
5 quantify nature’s contributions to human well-being (161). By contrast, a “people with
6 nature” perspective emphasizes concepts of environmental justice and co-evolution,
7 requiring transdisciplinary and pluralistic scholarship on the human–nature relationship
8 and recognizing contributions of both Western and Indigenous worldviews (162,163).

9 Acknowledging that much of the Assessment relies primarily on Western science
10 concepts, metrics, and methods (and indeed so does Figure 3.3 just by separating “people”
11 and “nature” into two concepts), a special collection in the journal *Earth Stewardship* will
12 complement the Assessment by focusing on Indigenous Knowledge. Future nature
13 assessments may continue to reflect a dynamic and contextual approach to understanding
14 human–nature relationships, resulting in new methods and insights into the status and
15 trends of social–ecological systems.

16 [Approaches to Assessing the Status and Trends of Nature](#)

17 [Geographic Scope and Ecosystems](#)

18 The Assessment considers nature within all 50 states, marine areas (exclusive economic
19 zones), and US territories, as well as Federally (and non-federally) Recognized Tribes that
20 share these geographies. The scope of the Assessment includes marine and inland
21 (surface and ground) waters, all terrestrial systems, rural and urban systems, mineral
22 resources, and the biotic and abiotic elements that make up the structure and affect the
23 function of ecosystems and their corresponding **social–ecological relationships**. Some
24 chapters focus on national or subnational trends, for example, when describing the role of
25 nature in climate mitigation or resilience to natural hazards. Other chapters rely on detailed
26 case studies of human communities and their surrounding environments in particular
27 geographies to illustrate the factors that underpin nonmaterial or relational values for
28 nature. The variety of geographic scales and ecosystems reflects the scope and scale of a
29 national assessment that aims to include a wide range of topics, some of which can be
30 assessed nationally or locally, such as cultural values, which are specific to place-based
31 social contexts.

32 [Drivers of Nature](#)

33 Social–ecological systems have undergone profound environmental changes as a result of
34 human and nonhuman activity (164). This Assessment documents drivers and pressures
35 that impact both people and nature. Its chapters describe a range of drivers that affect the
36 status and trends of nature and associated benefits. Biophysical changes—such as
37 climate change, the spread of invasive species, air and water pollution, habitat loss, and
38 land-use change—are considered in multiple chapters. Drivers of change are also
39 influenced by social, economic, and cultural factors—such as wealth inequality,

1 discrimination, and disparities in access to recreation or other natural amenities—that
2 shape the environmental impact and the distribution of nature’s benefits. The Assessment
3 also considers drivers of change that result in benefits to people and nature, including
4 investments in species-level and ecosystem-level protections, technological advances
5 that facilitate monitoring, land restoration, stewardship of cultural resources, and
6 investments in nature-based education.

7 Benefits Assessed

8 The Assessment recognizes the multitude of ways in which natural systems support valued
9 goods and services. In particular, Chapter 13: Health and Well-Being explores how access
10 to healthy ecosystems supports physical, mental, and community health. Chapter 14: Risk
11 and Security documents how nature reduces risks and supports resilience in the face of
12 disasters. Chapter 12: Economy unpacks how nature underpins the US economy and the
13 importance of accounting for its value. Chapter 11: Culture focuses on cultural, spiritual,
14 and social benefits of nature.

15 Several chapters note that market benefits of nature include enhanced property values and
16 timber and agricultural products, as well as nonmarket benefits that include subsistence
17 lifestyles and spiritual, cultural, and recreational values. Relational and nonmaterial values
18 are central to chapters considering cultural and natural heritage and “bright spots” in
19 social–ecological systems. The distribution of well-being arising from ecosystem goods
20 and services across space and among different demographic groups is critical to an
21 understanding of nature’s benefits. Not all benefits can be described in monetary terms,
22 and the Assessment draws on evidence from both qualitative and quantitative approaches
23 to measure the multiple benefits of nature and its impacts on human health and well-
24 being.

25 Metrics and Methods

26 Chapters in the Assessment employ metrics and methods typical of their respective
27 disciplines to evaluate the many dimensions of nature. For example, Chapter 12: Economy
28 uses market and nonmarket valuation methods to assess the value and distribution of
29 nature’s benefits, while Chapter 11: Culture draws on qualitative and interpretive
30 approaches to understand relational and nonmaterial values. Many chapters focus on
31 access to nature—such as proximity to parks, exposure to natural spaces, or barriers to
32 engagement—since access is the foundation for receiving and equitably sharing many of
33 nature’s benefits.

34 Building on The Nature Record National Assessment in Future US 35 Nature Assessments

36 Future US nature assessments can build on the frameworks and approaches used in this
37 Assessment. Given time and resource constraints, the current Assessment draws on

1 literature review and expert consensus to generate the first nationwide assessment of
2 nature for the US. Going forward, opportunities for data collection and management,
3 analysis of established scenarios against consistent baselines, expanded application of
4 diverse ways of knowing, and engagement could help to strengthen the science and uptake
5 of future assessments.

6 Data and Information Gaps and Opportunities

7 Data on trends in land and sea management, land-use change, and other human drivers of
8 change remain fragmented (165–167). A lack of information makes it difficult to build a
9 comprehensive picture of changes in ecosystem condition or track how different
10 management practices affect long-term ecosystem health, resilience, and services over
11 time (168). Much of the available information is collected through remote sensing by
12 federal agencies, by state natural resource departments, and by private landowners or
13 companies, yet reporting standards and data coverage vary widely. A review of major land
14 management activities found poor data availability for forest harvest, grazing and mowing,
15 artificial wetland drainage, tillage, and fire management (169,170). Data are also limited for
16 coastal and marine management activities such as deep sea mining, offshore energy,
17 aquaculture, oil spills, and more (171). Data limitations make it difficult to develop an
18 accurate baseline from which to track future changes or predict the impact of alternative
19 management practices.

20 There is insufficient information on how human activities are affecting species migration
21 and migratory pathways (172,173), and indeed these impacts were out of scope for this
22 Assessment but deserve attention in future assessments. Drivers of impacts on migratory
23 species are similar to those for resident species but also include modifications of natural
24 systems such as dams and transportation corridors and direct harvest of migratory species
25 (172). Future assessments might not only evaluate drivers of change for current
26 configurations of communities but also allow for future changes, such as populations
27 newly established owing to unaided or assisted migration (174).

28 Long-term monitoring efforts that use standard collection protocols provide an
29 observational basis for the national status of biodiversity and ecosystems, which form the
30 baseline for trends assessment, validation of new types of data collection (e.g., image,
31 audio, and eDNA—genetic material shed from living organisms that can be used for
32 identification), and scenario modeling. In the US, monitoring programs such as the
33 National Ecological Observatory Network, the Long-Term Ecological Research network, the
34 Ocean Observatory Initiative, state Natural Heritage Programs, and Forest Inventory and
35 Analysis create foundational data (175). In order to evaluate the societal impacts of
36 biodiversity and ecosystem change through the lens of ecosystem services, additional
37 types of data are needed. These data include direct benefits (e.g., amount of timber
38 harvested, fish caught, acres of crops irrigated, people recreating) as well as contextual
39 information about the portion of this value attributable to nature versus built or human
40 capital and goods. With sufficient data, the dependence of companies on nature and its

1 services can be traced through balance sheets identifying labor and capital use, as well as
2 costs and benefits to consumers (176). Nonmarket valuation for goods relies on a host of
3 methods that have widely varying and intensive data needs that extend well beyond those
4 needed for market goods (177–179). Overall, the data on nature’s economic impacts in the
5 US are relatively scattered and difficult to compile, and critical gaps remain.

6 Improving future nature assessment in the US would require universal adoption of
7 interoperable and FAIR approaches and models to ensure comparability, transparency, and
8 reuse of data across sectors and scales (180). Future US nature assessments would be
9 strengthened by a community of practice and a federated network to coordinate data and
10 fill critical gaps, building on global initiatives such as the System of Environmental
11 Economic Accounting’s Ecosystem Accounting, IPBES, and the Group on Earth
12 Observations Biodiversity Observation Network.

13 Baselines, Scenarios, and Modeling

14 The Nature Record has not yet established an agreed-upon baseline and set of scenarios,
15 but with sufficient resources, the initiative could consider doing so for future assessments.
16 The IPCC assessments, one of the most authoritative examples of an assessment process,
17 established a consistent set of historical baseline information and socioeconomic
18 pathways and emissions scenarios, as well as coordinated modeling efforts that support
19 the climate assessment. Lessons learned from more than 30 years of climate assessment
20 indicate the value of and demand for context-specific data and models (129). However,
21 setting a baseline and identifying scenarios for a nature assessment can be challenging.

22 A frame of reference is critical for measuring the status and trends of biodiversity,
23 ecosystems, and social–ecological systems, whether this is a baseline (i.e., known
24 biodiversity at a fixed point in history) or a counterfactual (i.e., a scenario of what would
25 have occurred without human impact). Baselines are needed to evaluate alternative
26 management scenarios or evaluate different ideas about the future, set targets, and
27 measure changes in biodiversity and social–ecological systems over time (181). The choice
28 of baseline, such as the 1970s, preindustrial, or precolonial, could profoundly change
29 understanding of biodiversity loss, biodiversity targets, plans for reintroduction, and the
30 level of resources required to achieve conservation objectives (182). The IPBES uses a
31 baseline of preindustrial conditions to approximate nature before “significant” human
32 impact. While there were periods of deforestation and disturbance to natural systems for
33 centuries, the Industrial Revolution accelerated these changes globally. The choice of
34 preindustrial conditions as a baseline has been useful for IPBES and could be useful for
35 future US nature assessments because it connects analysis of the drivers of nature to
36 trends in nature and societal benefits and to management interventions. It is also the
37 standard baseline used in climate change assessments.

38 If future US nature assessments move forward with a preindustrial baseline for biodiversity,
39 there will be challenges in implementing it. Our documented knowledge of historical
40 baselines is limited by a lack of direct observational data on species abundance and

1 human activities before 1970. Most biodiversity monitoring schemes were initiated in the
2 20th century, well after anthropogenic pressures had already reached at least half of their
3 current magnitude (181,183). Thus, the data and scientific perceptions reflect ecosystems
4 that have been deeply transformed by human actions. Creative approaches for gathering
5 historical information on species (e.g., fur harvest data (184) and historical restaurant
6 menus showing shifts in seafood offerings (185)) can provide valuable perspective on the
7 size, scale, extent, and time period for species declines, helping to address shifting-
8 baseline syndrome, a phenomenon where each new generation accepts a progressively
9 degraded state of the environment as the new normal. Also, when evaluating specific
10 species and habitats against a baseline, local extinctions and degradation of some
11 ecosystems before the baseline date may result in a biased perception of species' habitat
12 preferences, such as misidentifying marginal species habitats as core ones. Incorporating
13 long-term (centuries-old) occurrence records with recent records may provide better
14 information on species–environment relationships (181). Given data limitations and
15 variability in the timing and rate of species and habitat loss, maintaining flexibility to
16 incorporate other types of historical data and information in evaluating nature loss seems
17 valuable.

18 For scenarios, the IPBES nature assessments build on the IPCC model with a nature
19 futures framework (NFF) and standard scenarios. The NFF classifies diverse relationships
20 with nature into three core value perspectives (Nature for Nature, Nature for Society, and
21 Nature as Culture) (186). Implementing IPBES global scenarios of biodiversity and
22 ecosystem services presents five major challenges in producing policy-relevant results:
23 scenarios need to “1) better account for the role of nature in future human development
24 storylines; 2) improve the representation of drivers in the scenarios by increasing the
25 resolution (temporal, spatial and thematic) of land-use as key driver of biodiversity change
26 and including additional relevant drivers; 3) explicitly integrate species- and trait-level
27 biodiversity in ecosystem services models; 4) expand the coverage of the multiple
28 dimensions of biodiversity and ecosystem services; and finally, 5) incorporate time-series
29 or one-off historical data in the calibration and validation of biodiversity and ecosystem
30 services models” (187). Future US nature assessments could learn from the IPBES and
31 IPCC models and develop a set of agreed-upon scenarios for the US that could align with
32 the global scenarios. Researchers could in turn use these scenarios to make comparable
33 predictions about the future of biodiversity and ecosystem service provision.

34 Another area for advancing future nature assessments involves greater use of integrated
35 assessment models that incorporate biodiversity and ecosystem services. The integrated
36 modeling approach could be an important tool for improving understanding of
37 interconnected social–economic–ecological systems and for analyzing how policy
38 alternatives can shift future trajectories toward more sustainable development. However,
39 several advancements are needed before such a tool can be fully implemented, including
40 “1) downscaling impacts of direct and indirect drivers on ecosystems; 2) incorporating
41 feedbacks in ecosystems; 3) linking ecological impacts to human well-being; 4)

1 disaggregating outcomes for distributional equity considerations; and 5) incorporating
2 dynamic feedbacks of ecosystem services on the social economic system” (188).

3 Engagement and Communication

4 The Nature Record draws on extensive engagement conducted through workshops,
5 webinars, and public comments in the Federal Register, many of which were carried out for
6 this Assessment (189–192). The Nature Record conducted more than 100 public
7 engagement events to scope components of interest to different communities and
8 stakeholders and benefited from two rounds of feedback invited through the Federal
9 Registry for the National Nature Assessment (The Nature Record’s predecessor project).
10 The Nature Record also established an advisory board to ensure that the Assessment is
11 useful for decision-making, included nonacademic experts in author teams to increase the
12 utility of the Assessment, and developed consensus-based conclusions drawn by author
13 teams. These kinds of engagement and communication activities provide information
14 about an assessment to the public, reveal stakeholder and community questions and
15 goals, and elicit feedback on assessment decisions and content. Creative approaches,
16 including art contests and community and professional poetry contributions, among other
17 approaches, strengthen public engagement in the assessment development process (157)
18 and further raise awareness of human–environment relationships across the US.

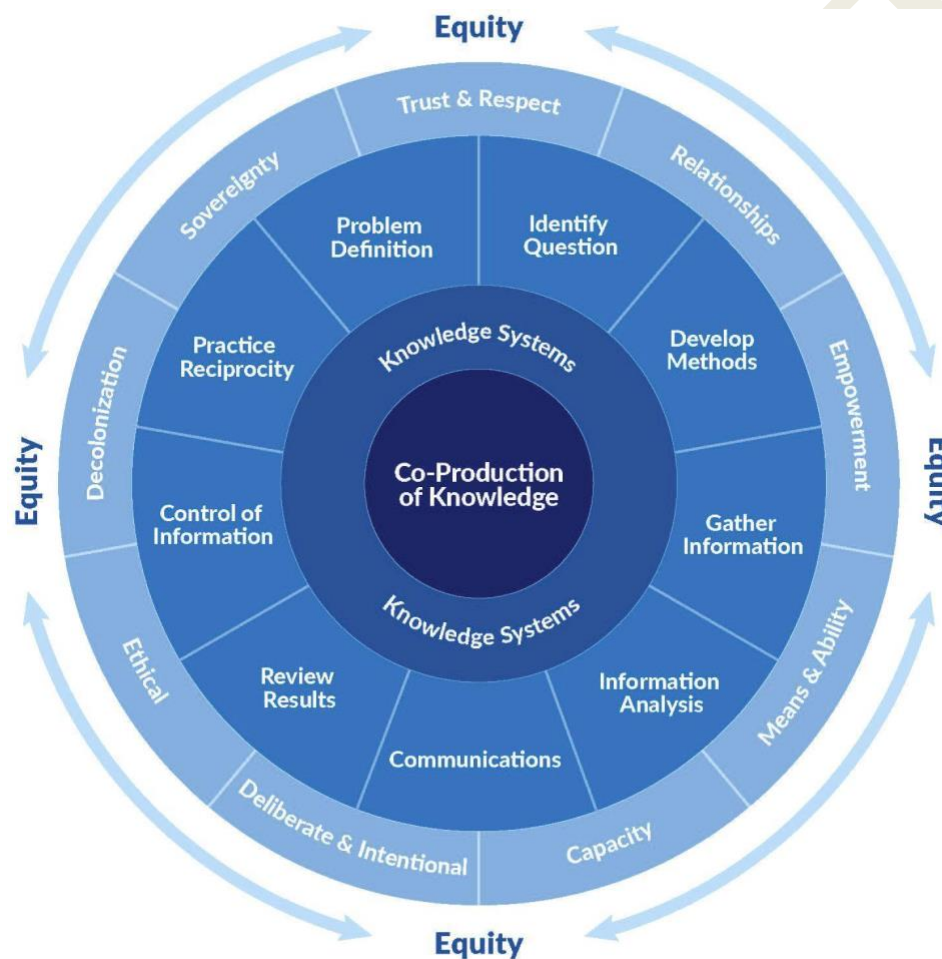
19 While there are limits to how the Federal Government can engage in collaboration and co-
20 production with those outside the government, federal assessments can still strengthen
21 relevance and usability through structured engagement and feedback processes.
22 Researchers involved with the National Climate Assessments have proposed the creation
23 of a non-federally led network or consortium to bring together stakeholders (including local
24 governments, Tribal Nations, private sector, researchers, NGOs, and youth) to provide
25 recommendations on future assessments, which could help bring in local and regional
26 priorities (193). Some relevant networks already exist in the US. For example, each state is
27 required to develop a State Wildlife Action Plan in order to receive federal funding for
28 wildlife management efforts (194). Many of these plans are linked regionally through
29 partnerships such as the Landscape Conservation Cooperatives Network, regional Fish
30 and Wildlife agencies, and the US Fish and Wildlife Service’s Science Applications
31 program, all of which have established methods for co-production, scenario planning, and
32 integration across jurisdictions. States also track species occurrences and critical habitats
33 through state natural heritage programs, which are part of the NatureServe Network that
34 aggregates this data nationally (195).

35 These state-led data collection and planning processes could be more tightly linked to
36 future nature assessments to deepen the relevance of the national assessment and
37 increase alignment with user needs (196). One example that could be replicated in the US
38 is the Nature Futures Framework discussed earlier (197), which emerged from a series of
39 participatory co-production (46) workshops conducted as part of the IPBES assessment. In
40 a similar way, local working groups could co-create scenarios for future nature

1 assessments that reflect alternative options for conservation, economic development, and
2 land use in a region.

3 Another opportunity to align assessment with local priorities lies in existing methods and
4 requirements for Tribal Consultation within Federal agencies (198). Given time and
5 resource constraints for this Assessment, co-production was not feasible across all 574
6 Federally Recognized Tribes in the US (Figure 3.4). The following section describes
7 concepts, frameworks, and approaches that are important for engaging with Indigenous
8 Communities to broaden nature assessment with diverse ways of knowing (199).

9 **Figure 3.4. A Framework for Co-Production of Knowledge**



10

11 **Learning from multiple knowledge systems is an iterative process that involves**
12 **actions and conceptual tools to build equity.**

13 *While the term “co-production” may be a traditionally Western science term, the*
14 *underlying actions and processes of reciprocity, relationships, communication, and other*
15 *elements of co-production align with Indigenous knowledges and practices (199). This*
16 *figure is from a paper on co-production of knowledge in Arctic systems. The first author,*

1 *Ellam yua, is the Yup'ik name for the “spirit or person of the universe.” By including the*
2 *spirit’s name in the paper’s authorship, the authors “affirm the greater powers at work in*
3 *these efforts” (199). The paper defines co-production as the “process of bringing together*
4 *two different knowledge systems, in true partnership and equity, to enhance, learn, and*
5 *create new understandings on a specific topic” (199). The center ring in the figure is the*
6 *goal. The second ring from the center represents the union of Indigenous Knowledge*
7 *systems and science. The third ring shows the actions taken in a cyclical, iterative research*
8 *process. These actions interconnect with the fourth ring to establish equity. The fourth ring*
9 *depicts the conceptual tools that all persons involved in the co-production process need to*
10 *implement and pay continuous attention to. Equity is the cornerstone of the co-production*
11 *of knowledge approach and thus encircles the framework. The authors of the paper*
12 *specifically apply the framework to Arctic Indigenous Knowledge Systems and science, but*
13 *they indicate its application to diverse knowledge systems and topics. Reprinted from Yua*
14 *et al. 2022 (199).*

15 Weaving Diverse Ways of Knowing in Nature Assessment

16 Nature assessments reflect underlying assumptions about what nature is, what counts as
17 reliable knowledge, and what responsibilities flow from knowledge. Thus, nature
18 assessment is not only a technical integration challenge but also an exercise in interfacing
19 knowledge systems and worldviews—creating respectful, transparent pathways for
20 engaging Indigenous Knowledge systems alongside Western scientific approaches without
21 reducing one to the terms, standards, or categories of the other.

22 One approach involves weaving together Indigenous Knowledge systems and Western
23 science in nature assessment to address complex social–ecological challenges. To move
24 beyond the practice of incorporating (or assimilating) other knowledge systems into
25 Western science, future national nature assessments could look to approaches such as
26 Two-Eyed Seeing, which fosters equitable dual knowledges as reciprocal, coexisting, and
27 complementary (200,201). While Two-Eyed Seeing shares similarities with other
28 Indigenous frameworks from around the world, it emphasizes that knowledge transforms
29 the holder, who in turns bears a responsibility to act on that knowledge (202). Interfacing
30 knowledge systems also requires attention to governance, consent, and appropriate use.
31 This includes clarifying how knowledge will be requested, interpreted, credited, and
32 protected; respecting Tribal sovereignty and community protocols; and recognizing that
33 some knowledge is not meant for public dissemination or extraction into external products.

34 Nature assessments can expand the use of Indigenous Knowledge (IK) by considering the
35 cumulative body of knowledge, practices, and beliefs passed down through generations by
36 Indigenous and local communities (203). Studies using IK provide a deep, place-based
37 understanding of ecosystems, accumulated over generations through lived experience
38 (204). This complements the broader, often data-driven approach of Western science,
39 creating a more comprehensive understanding of ecological systems, relationships, and
40 dynamics (205).

1 Approaches that reflect local, community-based knowledge can also provide important
2 insight for nature assessment that is missed by reliance on exclusively academic
3 research—for example, through farming records of first frost or qualitative phenological
4 descriptions of insect–plant relationships (206). IK and local expert knowledge also fill in
5 data gaps, often by providing a source of long-term observations that Western science
6 approaches may only observe indirectly. For example, in marine ecosystems, Indigenous
7 and local knowledge of herring behavior aligns with scientific findings that young herring
8 rely on older fish to guide their migration routes, illustrating how IK and local knowledge
9 can reveal critical ecological relationships and inform sustainable fisheries management
10 (207).

11 Learning from diverse knowledge systems strengthens the robustness, inclusivity, and
12 usefulness of nature assessments, leading to decisions that support ecological integrity
13 and equitable outcomes for communities. When scientific and Indigenous perspectives
14 are interwoven, the resulting decisions are more likely to be sustainable, particularly in
15 policy development, conservation planning, and resource management (208). Indigenous
16 Knowledge systems that emphasize relationship, context, respect and care, responsibility,
17 and community bolster resilience and inform adaptation to change (209,210), while
18 Western science enhances responses to environmental uncertainties and change (211).
19 For example, Indigenous art and knowledge systems understand, reflect, and
20 communicate the interconnectedness of nature and nature assessment in ways that
21 Western science and communication products would be limited (Figure 3.5).

1 **Figure 3.5. Woven Around the Basket, Weaving Interconnections**



2

3 **Indigenous art and knowledge systems communicate the interconnectedness of**
4 **nature and the breadth of topics in this Assessment.**

5 *This graphic illustrates the interconnected way in which many Indigenous Peoples*
6 *experience the world and includes symbols inspired by stories and teachings of the diverse*
7 *Peoples of North America. The illustration's overall shape is inspired by the Lakota Star*
8 *Quilt, representing the circle of life. Various topics discussed in the Assessment are*
9 *depicted as illustrations within the blue and green lines to demonstrate that while the*
10 *Assessment is divided into independent chapters, the topics are part of an interdependent*
11 *whole: (starting at the top and moving counterclockwise) the star represents the Bright*
12 *Spots chapter, the corn (Dine inspired) represents the Economy and Equity chapters;*
13 *beaded art, the Culture chapter; red thunderbolts (Kiowa inspired), the Risk and Security*
14 *chapter; the black mountain (Kiowa inspired), the Climate Change chapter; the deer*
15 *(Ledger art inspired), the Terrestrial Ecosystems chapter; and the feather (Kiowa inspired),*
16 *the Health and Well-Being chapter. In the center, hands holding a basket represent the*
17 *Opportunities chapter; the basket also resembles a turtle, as some creation stories include*
18 *a turtle, which can be thought of as either the continent of North America or as the entire*
19 *Earth, depending on the storyteller. The light to dark blue lines in the image represent the*

1 *Inland Waters and Marine Ecosystems* chapters, while the light to dark green lines
2 represent the *Drivers and Connection* chapters. The illustration also includes elements of
3 the medicine wheel to represent nature's cycles, interconnectedness, and holistic health:
4 the top white diamond symbolizes north, stars, and intellect; the left black diamond is
5 west, physical health, weaving and beading; the bottom red diamond is south, spiritual
6 health, soul, and mountain (Kiowa inspired); and the right yellow diamond is east, growth,
7 and flower (Yaqui inspired). Figure original to *The Nature Record* by Artist and Knowledge
8 Holder, Lucilla Taryole, *Kiowa and Muscogee Creek* (Mvskoke). This figure was inspired by
9 the *Indigenous Holistic Worldview Illustration in The Status of Tribes and Climate Change*
10 *Report 2021* (68).

11 At the same time, acknowledging that science both shapes and is shaped by the systems it
12 studies is essential for developing effective approaches for drawing on multiple knowledge
13 systems in assessments (212). Doing so requires evidence-based methods that integrate
14 data and values-based methods that engage with underlying assumptions and navigate
15 ethical-political realities. For example, participatory research often treats reality as co-
16 created through relationships, whereas experimental or survey-based approaches tend to
17 assume reality exists independently of observation, leading to potential tensions around
18 research design and credit. Approaches to resolving such conflicts for nature assessment
19 include explicitly examining questions of ontology (the reality of nature), epistemology
20 (how reliable knowledge about nature is created), axiology (the ethical issues addressed),
21 and the societal implications of research (37,212).

22 Emerging Issues

23 Technological advancements are accelerating and expanding data collection through
24 satellite remote sensing, eDNA, acoustic monitoring, camera traps, networked sensors,
25 and smartphone-based public science. At the same time, advances in AI and digital
26 platforms are accelerating analysis and integration of these new data (213,214). These
27 advances can greatly increase and enhance information used in nature assessments. For
28 example, major increases in species occurrence data have emerged over the last decade
29 through apps like iNaturalist and BirdNET, which now use AI image and audio data
30 processing. These data are improving mapping of species distribution and range and
31 monitoring of invasive species. New methods also enable identification of species from
32 space (215,216) and can use higher-resolution image data to identify individuals, enabling
33 measurement of the population size, which is a better indication of the health of a species
34 than simply species occurrence (217). Advancements in identifying and tracking individual
35 animals resulted from the recent development of globally unique animal IDs and a digital
36 home for storing metadata and other information (218–220). Researchers are also using AI
37 with image and other data processing to help identify new species (221).

38 In addition to expanding data on species, AI can be used to build system models to
39 generate credible counterfactuals (baselines) and scenarios for evaluation of conservation
40 policy options, as can digital twin modeling, which is the process of creating a virtual

1 replica to simulate, analyze, and optimize its performance (222–224). Deep learning
2 models can be used to look at existing land-use trends to predict future land-use change.
3 AI can also be used to accelerate and automate data and literature review and analysis,
4 which, if designed for a national nature assessment, could result in a living literature review
5 approach with continual updating of core elements of the assessment (225,226). Finally, AI
6 can help to incorporate research published in multiple languages and gray literature (227).
7 To take advantage of the myriad opportunities in an ethical and responsible manner, future
8 national-scale efforts could develop principles for ethical and responsible AI applications
9 in nature assessment and also explore the reciprocal impacts of AI on nature via energy,
10 land, and water use (228). As the first nation-scale report on nature in the US, the
11 Assessment has the potential to inform conservation, natural resource, and development
12 decisions at a variety of scales (Box 3.1) and to lay the groundwork for future nature
13 assessments. Addressing the complex environmental and societal challenges laid out in
14 this Assessment requires that a broad range of public and private actors interface at global
15 to local levels. Multilevel governance that encourages knowledge sharing and promotes
16 collaboration can help to facilitate learning and adaptation in complex social–ecological
17 systems (229). The way in which The Nature Record navigated changes in the Federal
18 Government to evolve from a government-led to a private-led influential scientific
19 assessment suggests an opportunity for future assessments to explore polycentric
20 governance as a way of coping with change. Co-management of future national nature
21 assessments among diverse actors would help to distribute rights and responsibilities,
22 foster competition and collaboration, and encourage learning and experimentation (230).
23 Approaches to nature assessment that are in themselves resilient to societal change may
24 be better equipped to inform long-term management of complex social–ecological
25 systems and to realize nature’s benefits at multiple scales (231).

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