**Report from the Biodiversity Study Team: Recommendation for a CEOS Biodiversity Virtual Constellation**

**Draft for discussion at the CEOS SIT Technical Workshop**

**Submitted by the CEOS Biodiversity Study Team**

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This document provides the BST’s response to the four-part Task

it was assigned at the CEOS 2024 Plenary and makes a recommendation regarding an enduring CEOS engagement with biodiversity

**Introduction: Why was the CEOS Biodiversity Study Team (BST) formed and what was it tasked to do?**

Global biodiversity is declining rapidly, posing a direct threat to society and human well-being. This is the common conclusion of multiple, major international reports. These reports[[2]](#footnote-2) consolidate data from many sources and explore the decline in biodiversity from several perspectives, but their key conclusions are the same, including an emphasis on the dependency that society has on biodiversity and how the services it provides underpin economic security. Space-based EO is in a unique position to provide regular monitoring of key biodiversity variables that decision makers and the public can use to understand biodiversity status and what, where, and why biodiversity is changing—essential for an appropriate societal response.

**Selected Report Conclusions**

* IPBES Global Assessment (2019): One million species at risk of extinction, many within decades, threatening the ecosystems that support food, water, health, and livelihoods
* WWF’s Living Planet Report (2024): vertebrate populations have declined 73% between 1970 and 2020.
* FAO’s Global Forest Resources Assessment 2020: the world lost a net **178 million hectares** of forest from 1990 to 2020
* Dasgupta Review (2021): Over half of global economic output depends on natural systems, yet nature’s resources are being consumed faster than they can regenerate.

Biodiversity was recognized as a thematic gap in CEOS in 2012, resulting in the creation of the CEOS Biodiversity Activity. The activity was supported by only a few CEOS Agencies for a decade until approximately 2022, when a biodiversity discussion group formed to examine how space-based Earth observation (EO) and the work of CEOS could support biodiversity on a higher level. This renewed focus on biodiversity was due largely to the visibility provided by the above-mentioned reports as well as the work of the UN Convention on Biological Diversity that was developing its next 10-year plan. At the same time, it was becoming clear that significant advances in technology were enabling improved biodiversity monitoring from space. These discussions within CEOS pointed to the need for a more formal mechanism, resulting in the creation of the CEOS Ecosystem Extent Task Team (EETT) at the 2022 CEOS Plenary. The EETT was tasked with writing a white paper describing how existing and future EO missions can support the development of Ecosystem Extent products and to create demonstrators to show this. Within the broad realm of biodiversity, the focus on ecosystem extent was selected because of the key role played by EO and its nearly universal importance to the biodiversity community.

Exploration of the role of EO for biodiversity monitoring, and the potential role of CEOS, gained momentum when the Canadian Space Agency (CSA) became 2024 CEOS Chair and selected biodiversity as one of its themes for the year. Throughout the one-year CEOS Chair term, discussions were held with CEOS Agencies, Working Groups, and Virtual Constellations, as well as external stakeholders, including the Convention on Biological Diversity (CBD). Biodiversity featured prominently on the agendas of the three major meetings CEOS held in 2024. Information from these discussions led to the formation of the CEOS Biodiversity Study Team, which was tasked with assessing how CEOS could and should engage with biodiversity in future years and to recommend the mechanism by which to do so.

The BST Terms of Reference identified four tasks:

1. Conduct a stakeholder assessment;
2. Consult across CEOS entities and agencies to leverage existing activities relevant to biodiversity and implement lessons learned and recommendations;
3. Assess the options for sustainable support for biodiversity in CEOS;
4. In collaboration with the CEOS executive officer, develop supporting documentation for the recommended option.

**Approach: How did the Biodiversity Study Team execute its tasks?**

The BST’s first step was to invite CEOS Agencies, WGs, VCs, and external stakeholders to name representatives to join as BST members. Once membership was established (App. 1), co-leads were selected by consensus in accordance with common CEOS selection procedures at the first BST meeting which was held on 10 January 2025. An approach was then developed that divided the work into three Phases that followed the key items in the BST’s Terms of Reference (ToR).

**Phase 1: Stakeholder Assessment (item 1 in the ToR)**

Phase 1 focused on understanding the needs of the biodiversity community. It started with identifying, through discussions held at several BST meetings, the key external organizations and stakeholders with whom CEOS should engage to ensure its efforts are well aligned with the global biodiversity agendas. (Table 1). A BST member was assigned to each organization to collect and consolidate their user needs based on prior knowledge, documentation, and discussions with the organization. A standard format was used for the collected needs to simplify consolidation across all users into a form that could be assessed by CEOS Agencies and entities in Phase 2. Ecosystem Extent was selected as a thematic focus rather than being tied to a single organization, as it is an inherently cross-cutting topic that serves the needs of numerous organizations. No BST member was able to commit to developing requirements for IOC/UNESCO, however, given the strong overlap in user needs across domains, thematic areas, and organizations, this did not affect the overall work and conclusions of the BST. In any case, marine-related needs will be addressed as part of the activities envisioned under the new CEOS structure being proposed.

The outcome of Phase 1 is captured in Appendix 2 as a spreadsheet that categorizes common user needs and lists them along with brief explanations.

**Table 1.** Key organizations contacted.

|  |  |
| --- | --- |
| [**Ecosystem Extent**](https://geobon.org/ebvs/what-are-ebvs/) | An Essential Biodiversity Variable that is not tied to a single organization, but a universally needed product across the biodiversity community that underpins numerous applications |
| [**GEO BON**](https://geobon.org/) | GEO Biodiversity Observation Network |
| [**IOC/UNESCO**](https://www.ioc.unesco.org/en) | Intergovernmental Oceanographic Commission of UNESCO |
| [**IPBES**](https://www.ipbes.net/) | Inter-governmental Platform on Biodiversity and Ecosystem Service (analogous to IPCC) |
| [**Ramsar Convention on Wetlands**](file:///C%3A%5CUsers%5Ccmcmaho1%5CAppData%5CLocal%5CMicrosoft%5CWindows%5CINetCache%5CContent.Outlook%5CCPT5309X%5Cramsar.org) | International treaty on Wetlands (signed in 1971 in Ramsar, Iran) |
| [**TNFD**](https://tnfd.global/) | Taskforce on Nature-related Financial Disclosures (other “nature finance” organizations were also considered) |
| [**UNCBD**](https://www.cbd.int/) | UN Convention on Biological Diversity |
| [**UNCCD**](https://www.unccd.int/) | UN Convention to Combat Desertification |
| [**UNSEEA**](https://seea.un.org/) | UN System of Environmental-Economic Accounting |

**Phase 2: Connections to CEOS (item 2 in the ToR)**

Phase 2 assessed the potential for CEOS to address the user needs identified in Phase 1. This phase began by sending the User Needs Spreadsheet to each CEOS Agency (Members and Associates), WG, and VC and asked them to identify which biodiversity need(s) they had potential to contribute to. As many CEOS Agencies do not have biodiversity expertise on staff and do not include dedicated biodiversity activities in their work programs, the response from members was somewhat limited. Many of the five CEOS Working Groups and eight Virtual Constellations have expertise and activities that are highly relevant to biodiversity monitoring and this was reflected in their responses to the User Needs Spreadsheet. Based on those responses, the BST followed up with some CEOS WGs (WGISS, WGDisasters, WGCapD) and VCs (WGCV, LSI-VC, COAST-VC, and SST-VC) to further explore potential synergies and contributions to CEOS biodiversity efforts.

**Identification and Assessment of Options**

The BST assessed five potential mechanisms for CEOS to enhance the role of space-based EO to monitor, study, and measure biodiversity in future years. Each of these options is described and assessed below, followed by a summary table that compares the benefits and challenges of each.

1. **Working Group**

Each of the five existing CEOS WGs function and carry out a mandate that fundamentally respond to the mission of CEOS. When they are well-resourced with constant support, expertise, and four-year leadership commitments, they bring stability to all of CEOS. This is the highest bar when considering which mechanism CEOS could establish, as explained in the *CEOS Working Group Process Paper,* but when one or more of these baseline criteria are lacking, the impact is felt across the entire organization. All five CEOS WGs benefit from a supply of subject matter experts employed by or on behalf of CEOS Agencies, underpinning what these WGs can accomplish individually and through cross-cutting support to the rest of the organization. WG mandates and reporting responsibilities are major, including the commitment to travel to attend CEOS meetings. To ensure stability in the work of CEOS and predictability in leadership succession, WGs also require four-year Agency-level written commitments to serve two-years as Vice Chair and two-years as Chair, and they are accountable to CEOS leadership, with direct accountability to the CEOS Chair. The fact that most CEOS Agencies do not have a biodiversity program or in-house biodiversity expertise, in practical terms this means that it will always be challenging to meet and maintain the requirements for a WG on biodiversity.

1. **Virtual Constellation**

The eight existing CEOS VCs met the criteria in the *CEOS Virtual Constellations Process Paper* at their inception as “a set of space and ground segment capabilities operating together in a coordinated manner, in effect a virtual system that overlaps in coverage in order to meet a combined and common set of Earth observation requirements”. Some VCs focus on a single variable whose measurements come from a variety of different sensors (Precipitation; Sea Surface Temperature; Ocean Colour Radiometry; Ocean Surface Topography; Ocean Surface Vector Wind), while others are more domain-based (Atmospheric Composition; Land Surface Imaging; Coastal Observations Applications, Services and Tools). VC membership composition can evolve and grow flexibly in relation to projects/deliverables that necessitate specific expertise. While they mainly consist of Agency experts and contractors, some VCs engage subject matter experts from universities and institutes who are sponsored by a CEOS Agency. VC reporting is done mainly through the SIT Chair and at CEOS meetings, involving relatively less travel than WGs. The assessment of the BST is that the VC model presents challenges that can be met and also offers a greater degree of flexibility, making it a practical and achievable CEOS mechanism for supporting biodiversity.

1. **Establish a New Subgroup under the Land Surface Imaging Virtual Constellation (LSI-VC)**

LSI-VC has two subgroups (Forests and Biomass, and GEOGLAM) and facilitates coordination among Agencies to enhance their contribution to land surface-based fundamental measurement products. Focus areas include data acquisition prioritization and coordination, including new missions; user requirements; data harmonization and reprocessing; calibration; CEOS Analysis Ready Data; and data processing, distribution and analysis in conjunction with the System Engineering Office and the Working Group on Information Systems and Services. New subgroups are approved by the CEOS SIT Chair based on LSI-VC recommendations. The assessment of the BST is that the work of this VC is supportive to biodiversity in the terrestrial domain, but clearly lacking in the marine realm. As such, despite its strengths, the LSI-VC structure cannot serve as a fully comprehensive mechanism for supporting biodiversity efforts within CEOS.

1. **Federated Approach**

This option would coordinate CEOS efforts on biodiversity by building on existing expertise and capabilities distributed across multiple CEOS entities. Rather than establishing a dedicated new CEOS structure, this model relies on a networked configuration of contributions from CEOS groups already engaged in relevant activities. In this model, biodiversity-related work would be embedded within the mandates of existing CEOS entities. However, current mandates lack coverage in some key biodiversity domains, and this model does not offer the strategic focus, sustained leadership, and operational setting needed to meet the strong demand for coordinated CEOS biodiversity monitoring. While possible, making this model sustainable would be challenging and it would not bring the concentration of expertise that a CEOS VC dedicated Biodiversity would offer.

1. **Ad Hoc Teams Approach**

The BST also looked at a scenario in which sufficient biodiversity expertise could not be guaranteed with enough certainty to establish a sustainable new mechanism. In this approach, CEOS could create one or more *Ad Hoc* Teams as needed to support biodiversity-related new initiatives that originate from within CEOS and/or as external requests. An *Ad Hoc* Team may be appropriate when an activity does not align with an existing CEOS entity (Reference: *CEOS Governance and Processes Document;* Page 7). Such teams have a finite duration and are focused on addressing a specific function approved by CEOS as a “New Initiative” or an “External Request”. This approach offers one or more Agencies interested in supporting a given effort the mechanism to do so, but without the permanence and level of CEOS resources needed for a WG or VC. While the Ad Hoc Team model could provide an entry point for CEOS engagement in biodiversity, the BST assessment is that it is not suitable as a foundation for sustained and long-term efforts within CEOS. For CEOS to engage credibly and effectively in biodiversity over the long term, a more structured mechanism is required.

**Resources**

An enduring CEOS engagement with biodiversity will require commitment by CEOS Agencies. There is significant interest in biodiversity as indicated in the diversity of the Biodiversity Study Team membership (App. 1), which is supported by the following Agencies:

* CNES
* CSA
* CSIRO (co-lead)
* EC
* ECCC
* ESA (co-lead)
* ISRO
* JAXA
* NASA (co-lead)
* NOAA
* UKSA
* USGS

It is fully expected that these Agencies will continue their engagement in this topic for CEOS and, in addition, that other members of the research and applied biodiversity communities will look to participate and support future CEOS biodiversity activities.

**Assessment and Recommendation**

Table 2 compares the benefits and challenges of the five options the BST assessed. It answers the specific task the BST was assigned in its ToR: “assess the options for sustainable support for biodiversity in CEOS”.

**Table 2.** Comparison of the five options considered.

| **Option** | **Benefits** | **Challenges** |
| --- | --- | --- |
| CEOS Working Group | * High institutional visibility and influence
* Strong ties to international conventions (e.g., CBD, Ramsar, UNCCD and UNFCCC)
* Sustained CEOS actions on biodiversity
* Long term commitment from CEOS agencies to support biodiversity actions
* Structured leadership model ensuring continuity and planning of biodiversity activities within CEOS
* Direct engagement with CEOS internal structure (WGs and VCs) and the CEOS Secretariat
 | * Heavy mandate of its own and across the entire CEOS organization
* Demanding governance and reporting: Requires regular reporting, contributions to CEOS meetings, and alignment with CEOS processes
* Heavy coordination burden: due to its cross-cutting nature, needs to interact with many CEOS entities, partners, and external stakeholders
* Greater travel burden
* Must secure 4-year agency commitments to ensure stability and predictability for leadership succession
* High resource requirement: requires sustained commitment from at least 4 to 5 CEOS Agencies for permanent support and rotating leadership
 |
| CEOS Virtual Constellation | * Flexible and scalable: VC membership can grow or shift as new expertise or priorities emerge
* Offers a concentration of expertise without the requirements of a WG
* Manageable reporting and leadership responsibilities, allowing easy engagement from CEOS agencies
* Well-suited for changes in membership composition based on the expertise needed for chosen activities
* Proven success model: VCs have demonstrated success in other thematic areas (e.g., land, ocean, atmosphere)
 | * Similar challenges to other options
* No challenges were identified that could not be addressed
* Requires clear leadership and coordination: while lighter than a WG, a VC still needs agencies' commitment to maintain momentum and effective coordination
* Dependence on CEOS agencies sponsorship of biodiversity expertise: sustained success requires agencies to provide biodiversity experts from within their agencies and/or externally
 |
| New Subgroup in LSI-VC | * Operates within an existing CEOS entity, avoiding the need to create a new entity
* Simplifies startup
* Synergies with existing LSI-VC work: facilitates collaboration with other CEOS terrestrial activities, particularly subgroup on Forests & Biomass
 | * Land domain focus: poorly suited for a comprehensive biodiversity approach that must also address marine and coastal ecosystems
* Lacks alignment with the CEOS VCs that focus on the marine realm
* Limited mandate for cross-cutting biodiversity needs (may be constrained by LSI-VC’s scope)
* Could dilute biodiversity visibility: biodiversity may be seen as a subset topic rather than a standalone priority of CEOS
 |
| Federated Approach  | * Avoids creating a new CEOS entity
* Could leverage existing CEOS entities (e.g., WGISS, WGCV, COAST, LSI-VC) and experts, avoiding governance overhead
* Offers Agencies the opportunity to sponsor biodiversity expertise not currently on their staff (e.g., from a university or institute)
 | * Lack of strategic focus: without a central home, biodiversity activities risk being fragmented and reactive
* Coordination complexity: requires significant coordination across CEOS entities, to align scattered efforts
* Weaker CEOS identity and visibility: Difficult to establish CEOS as a recognized biodiversity actor without a dedicated structure
* Biodiversity expertise in existing CEOS entities is limited
* Existing CEOS entities already have established priorities that would likely continue to take precedence over sustained biodiversity engagement
* Makes establishing end user relationships more challenging
 |
| *Ad Hoc* Teams formed to address a specific new initiative or external request | * Light structure: lower setup burden than WGs or VCs, minimal administrative overhead
* Good for targeted activities: well-suited for focused tasks such as supporting a specific biodiversity report, pilot project, or external request
* Responsive and time-bound: Can be quickly mobilized to respond to emerging needs and external requests
* Provides an entry point for CEOS agency involvement in biodiversity activities: Agencies can test involvement before committing to longer-term CEOS structures
* Defines a clear focus, outputs, and outcomes
 | * Not designed for sustained engagement within CEOS: Inappropriate for long-term CEOS coordination on biodiversity and external partnerships
* Narrow focus on a single topic/target task, making it hard to address biodiversity's multi-faceted and evolving challenges
* Finite duration: Ad Hoc Teams are temporary and dissolve upon completion of their assigned tasks, which limits biodiversity engagement continuity if not transitioned in a permanent CEOS structure
* Does not support long-term relationship with users: hard to build long lasting links with biodiversity policy frameworks, user communities, and science partners
 |

**Recommendation**: The Biodiversity Study Team recommends the establishment of a Biodiversity Virtual Constellation as the most effective and sustainable option for ensuring a long term and impactful CEOS engagement in support of Biodiversity.

A Biodiversity Virtual Constellation (B-VC) would offer the flexibility to tailor the VC with the expertise needed to address identified user needs and activities for which the ensemble of CEOS Agencies is ideally suited. A Virtual Constellation can accommodate a range of contributions, from sustained Agency leadership to smaller or targeted inputs, allowing broad participation across CEOS. The B-VC model also supports the possibility for agencies to sponsor external biodiversity experts for defined periods, useful for Agencies that may not have in-house biodiversity programmes. The B-VC is envisioned as a dynamic and evolving structure, capable of adjusting its composition and priorities over time. The accompanying Terms of Reference and Implementation Plan outline an initial set of priority actions that B-VC co-leads, in consultation with VC members and other CEOS entities, can refine or revise in response to emerging needs, scientific advances, or policy developments.

The *CEOS Virtual Constellation Process Paper* lists seven goals for Virtual Constellations. As discussed in Appendix 3, these goals are consistent with a CEOS response to the user needs identified in the BST’s Stakeholder Assessment and the recommendation for a CEOS Biodiversity Virtual Constellation.

**Summary and Conclusions**

The Biodiversity Study Team has complied with the mandate it was given at the 2024 CEOS Plenary. It performed a detailed stakeholder assessment in Phase 1. In Phase 2, it consulted with CEOS Working Groups, Virtual Constellations, and Agencies (Members and Associates) to assess existing resources, capabilities, and the potential for CEOS to address those needs. Using the results of those consultations as inputs, the BST identified five options whose practical advantages and disadvantages, as well as resilience to cyclical changes in resources and expertise provided by CEOS Agencies, were assessed. This assessment led to the recommendation for a CEOS Biodiversity Virtual Constellation and was used to prioritize the activities described in the B-VC Terms of Reference and Implementation Plan.

**Request to Principals**

* Acknowledge that the BST has fulfilled its assigned tasks
* Agree that a Full Proposal for a CEOS Biodiversity Virtual Constellation (B-VC) is an appropriate next step
* Extend the BST’s duration to provide time to develop and submit a Full Proposal for a B-VC in preparation for a decision at SIT-41 in April 2026

**Appendix 1**

**CEOS Biodiversity Study Team Membership**

**Co-Leads**

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* Shaun Levick (CSIRO)
* Marc Paganini (ESA)

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* Christine Bognar

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* Roger Sayre
* Kelly Bruno

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* Ryan Vandermeulen
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**Appendix 2**

**Stakeholder Assessment (BST Phase 1)**

The Stakeholder Assessment is available as a spreadsheet, located [here](https://docs.google.com/spreadsheets/d/1_jXWxatFOdHt_abg9TDDKE_I_2sSSHiP/edit?gid=189842937#gid=189842937).

**Appendix 3**

**Goals from the CEOS Virtual Constellation Process Paper**

This Appendix lists the seven goals outlined in the *CEOS Virtual Constellation Process Paper* and discusses them in light of the BST recommendation for a Biodiversity Virtual Constellation. All seven goals align with the BST’s recommendation. A Biodiversity Virtual Constellation would optimize filling gaps that exist between user needs and utilization of Earth Observation data that CEOS agencies provide.

* *Move space agencies’ coordination efforts from the generic to the specific – i.e., adopting a problem-focused approach to achieve significant results in terms of actual implementation and physical outputs (such as new products or contribution to Fundamental Climate Data Records) within a relatively short time;*

A problem-focused approach that responds to the specific needs of biodiversity users is essential. A Biodiversity Virtual Constellation could address the specific reasons that the inherent value of EO data is not fully utilized to address many of the needs identified in the Stakeholder Assessment. Many of these reasons are already identified in the Ecosystem Extent Task Team White Paper along with the EETT’s recommendations to address them. The EETT was scoped specifically to Ecosystem Extent. However, it also captured and shared similar information on the more general topic of biodiversity.

* *Improve considerably the extent to which the combined outputs of the various agency programs are relevant to specific applications, such as climate and other GEO SBAs, and respond to the requirements for space-based observations expressed in, e.g., Integrated Global Observing Strategy (IGOS) Theme reports and the Global Climate Observing System (GCOS) Implementation Plan;*

CEOS Agencies provide a variety of complementary observations that are essential to understanding and monitoring biodiversity. Combining observations from different types of sensors, such as optical, radar, and lidar, was a key recommendation in the EETT’s White paper and takes advantage of the synergy inherent in these observations’ complementarity, leading to a whole that is great than the sum of its parts. GEO BON’s concept for a Global Biodiversity Observing System (GBiOS) will require significant space-based observations and CEOS is the appropriate organization to facilitate their development and integration into GBiOS.

* *Facilitate the participation of smaller contributors;*

Although the biodiversity community includes a number of large organizations (e.g., Table 1), much of the scientific work is done by individual investigators (e.g., a university researcher), small teams (e.g., iDiv in Germany), or as small segments of larger organizations (e.g., EO expertise in several NGOs). Including these smaller contributors is essential because they are the most likely source of advanced algorithms such as those that combine data from different sensor types. These algorithms are essential if gaps in the data processing workflow are to be filled.

* *Recognize that existing assets could be used more effectively in support of the ongoing GEOSS 10-Year Implementation Plan;*

The *GEO Strategic Plan 2016-2025: Implementing GEOSS* is now in the process of being replaced by the *GEO Post-2025 Strategy Implementation Plan*. This new strategic document is currently under discussion and review, but the draft version does include substantial elements related to biodiversity and highlights the importance of having this as a key strategic item for GEO moving forwards. Further, of the six proposed focus areas for the new post-2025 GEO work Programme, “Ecosystems, biodiversity and carbon management” is one.

* *Realize the overall potential benefits at global scale that would result from reduced redundancy and improved continuity and overlap among missions;*

Continuity of data is essential for applications users, including those in the biodiversity community. Users are reluctant to invest in data or products that may not be available in the future.

* *Create the conditions, through the adoption of a series of requirements and guidelines which satisfy key GEOSS requirements, whereby all agencies – large and small – as well as other contributors, are able and indeed encouraged to make their contributions to the common objective of developing the space segment of GEOSS; and,*

This is directly relevant to GEO BON’s Global Biodiversity Observing System (GBiOS). It is currently in the concept development stage and contributions by CEOS will be essential.

* *Use an accreditation/recognition process, based on an agreed set of metrics, to ensure that proposed contributions to a Constellation will help to satisfy the relevant community needs.*

This goal helps ensure proper allocation of resources to maximize the return on investment, i.e., that invested resources have sufficient impact on biodiversity. This is an underlying principle to prioritize the activities of a Biodiversity Virtual Constellation.

1. Jet Propulsion Laboratory, California Institute of Technology [↑](#footnote-ref-1)
2. IPBES Global Assessment Report, 2019; WWF Living Planet Report, biannual since 1998; CBD Global Biodiversity Outlook GBO-5 2020, quinquennial since 2001; Dasgupta Review, 2021; FAO Global Forest Resources Assessment 2020, quinquennial since 1990; World Economic Forum Nature Risk Rising, 2020; World Economic Forum Global Risks 2024, annual; Global Wetland Outlook, periodic since 2018 [↑](#footnote-ref-2)