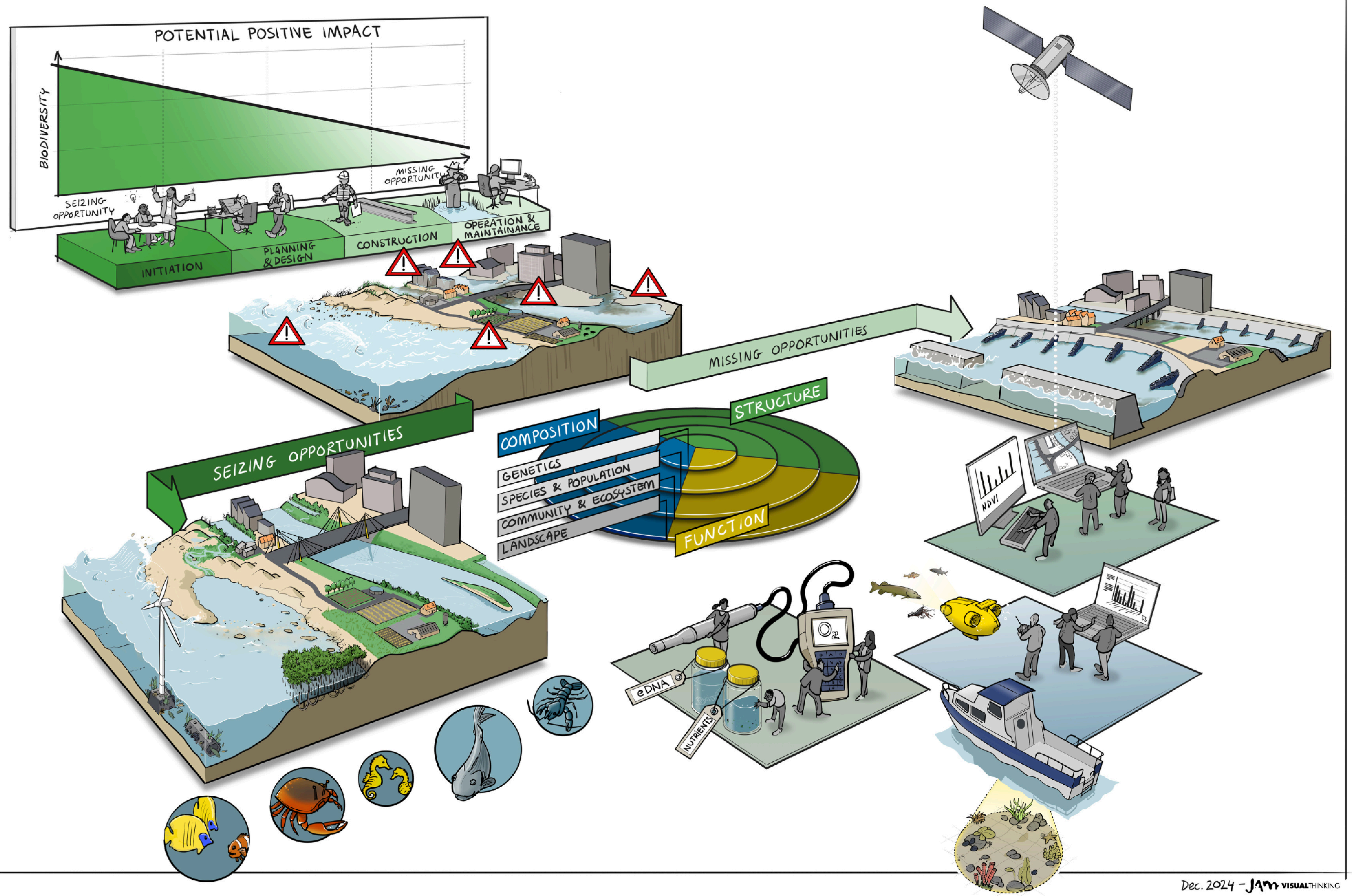
DESIGNING FOR BIODIVERSITY IN RIVERS, DELTAS, AND COASTS



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Introduction

Over the past 50 years, the direct and indirect drivers of biodiversity loss—such as changes in land and water use, overexploitation of biological resources, climate change, pollution, and invasive species—have intensified. Infrastructure development contributes to several of these pressures by shaping how land and water are used, altering natural flows, and fragmenting habitats. Yet, when thoughtfully designed, it also offers opportunities to reduce harm and actively support biodiversity.

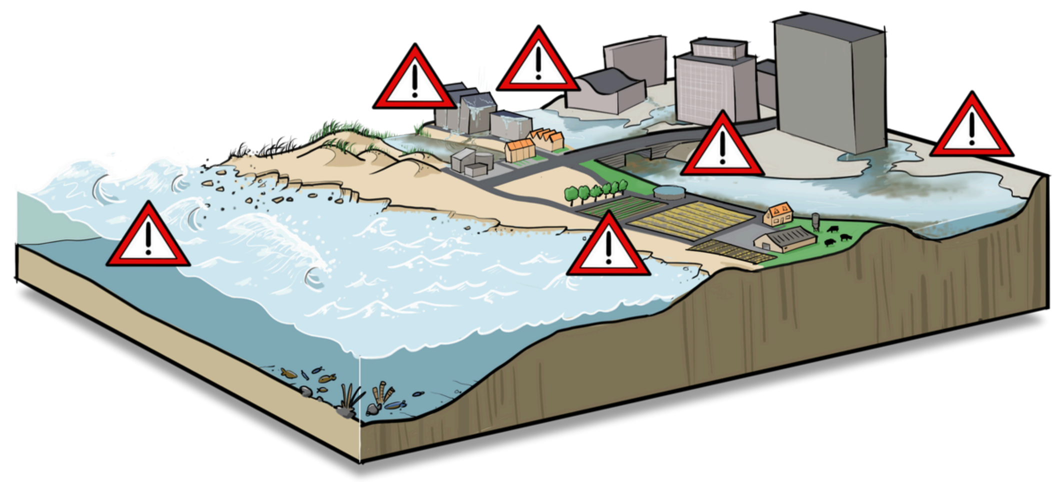


Figure 1: Climate hazards in delta cities include sea level rise, more frequent storms, fluvial and pluvial flooding, subsidence, and pollution—all of which can be addressed through green or gray solutions

This infographic, developed by EcoShape, provides practical guidance for integrating biodiversity considerations into infrastructure projects. It supports the adoption and implementation of green infrastructure approaches and offers companies tools to apply them effectively.

The Importance of Early Biodiversity Integration

Integrating biodiversity early in infrastructure projects increases the potential for positive impact and minimizes missed opportunities. The earlier biodiversity considerations are included, the greater the benefits for both nature and development. In the initiation phase, there is flexibility to avoid negative impacts by setting biodiversity goals, allocating budgets, selecting less damaging sites, and engaging stakeholders. During the planning and design phase, decisions on site layout and construction methods can help minimize impacts, though avoidance becomes more difficult as baseline studies and permitting processes advance. By the construction phase, most decisions are fixed, limiting options to compensate for impacts, such as habitat restoration. In the operation and maintenance phase, only minor opportunities remain, such as site management or ecological monitoring. Early alignment with biodiversity policies, the mitigation hierarchy (avoid, minimize, compensate), and relevant frameworks can support compliance, reduce risks, and facilitate access to funding.

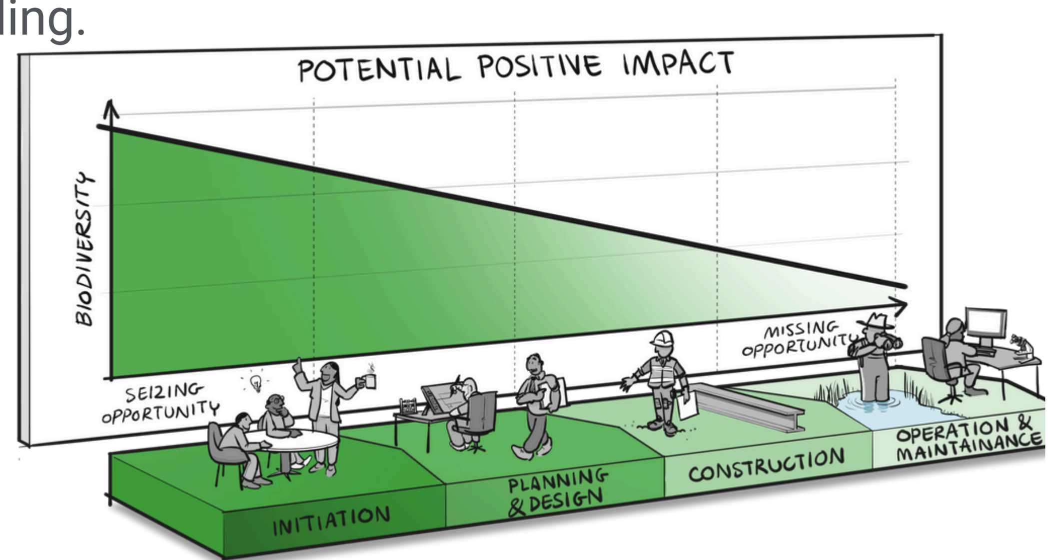


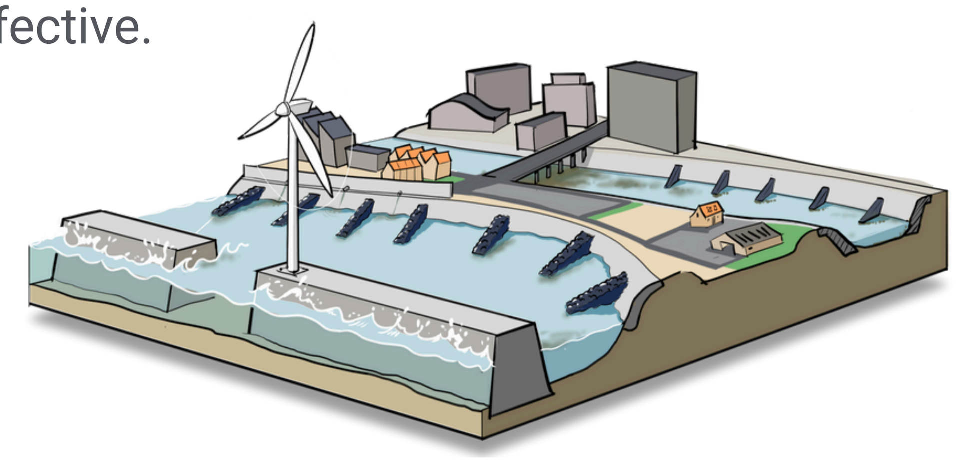
Figure 2: Positive impact potential declines from initiation to operation, underlining the need for early action.

The Shift from Grey Infrastructure to Green Instrastructure

Grey infrastructure has long addressed critical societal needs—providing protection from floods, enabling energy generation, and improving access. However, in the context of climate change, biodiversity loss and increasing spatial constraints, infrastructure can no longer be designed with a single purpose in mind. Each project now presents an opportunity to integrate ecosystem services, allowing infrastructure to align more closely with natural processes and contribute to long-term environmental resilience [1][2][3]. While green infrastructure should be prioritized wherever feasible, there are contexts—such as high-risk flood zones or dense urban areas—where grey infrastructure remains the most practical or reliable option. Recognizing these limitations helps ensure that opportunities for ecological integration are pursued where they are most viable and effective.

Beyond Single-Purpose Infrastructure

Green infrastructure projects enhance ecosystem resilience by using natural elements, such as sand engines, mangroves, and dunes, instead of rigid structures. Unlike grey infrastructure, they can sustain and expand over time, offering adaptive capacity to changing conditions. These systems not only provide essential functions like flood protection and shoreline nourishment, but also support biodiversity and respond to multiple societal needs. In flood-prone areas, giving rivers more space to follow natural processes can reduce flood risks, while creating valuable spaces for recreation. Similarly, offshore wind farms can be designed to encourage the colonization by shellfish or coral species, integrating ecological development into infrastructure projects. Together, these approaches deliver long-term benefits, including climate resilience, sustainable resource management, and improved public well-being



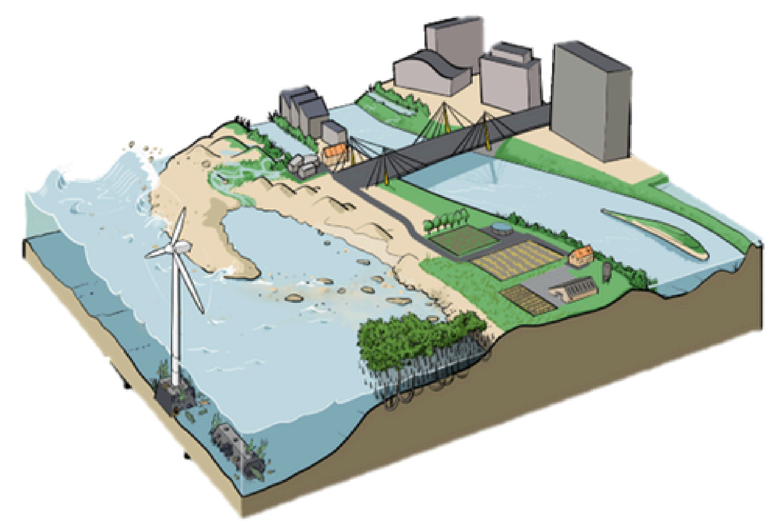


Figure 3: Grey to Green Continuum [4].

Monitoring Biodiversity Across the Project Lifecycle

Understanding the impact of interventions is crucial for supporting biodiversity. Therefore, ongoing monitoring is essential to track progress throughout the project lifecycle and support informed decision-making. From collecting baseline data during initiation to reassessing key indicators during operation and maintenance, continuous monitoring helps ensure biodiversity goals are met and provides valuable insights for future projects. Selecting the right indicators is key to effectively tracking biodiversity changes and enabling meaningful comparisons across projects.

Choosing the Right Biodiversity Indicators

Biodiversity is complex and cannot be captured by a single metric. To assess it meaningfully, indicators should be selected across different aspects of biodiversity: composition, structure, and function, preferably using a recognised framework. This ensures alignment with policy requirements such as the Marine Strategy Framework Directive (MSFD) or the Water Framework Directive (WFD) implemented in The Netherlands, and enables informed decision-making.

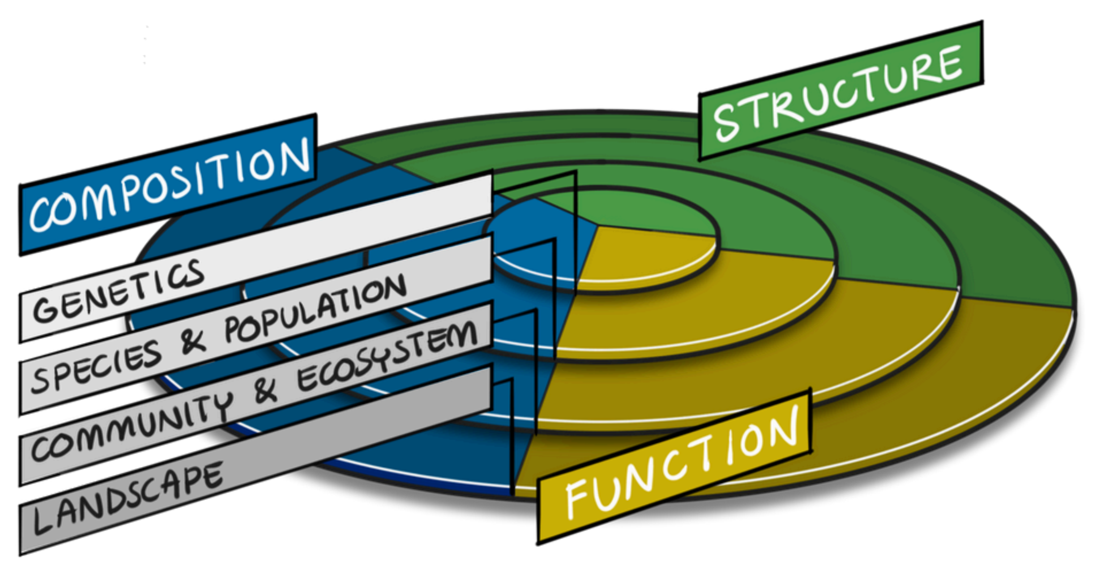


Figure 4: The spatial scales of biodiversity proposed by Noss [5]

We recommend selecting at least three complementary indicators: **species richness**, which reflects the variety of species present; **changes in habitat boundaries**, capturing spatial and structural shifts in ecosystems; and **surface water quality**, indicating key ecological conditions such as nutrient levels and oxygen content. Applying these accessible and complementary indicators allows for a minimal but sufficient understanding of biodiversity dynamics.

Monitoring Methods: From Remote Sensing to Field Data

Biodiversity monitoring involves a multidisciplinary team of ecologists, data scientists, engineers, and remote sensing specialists. Tools such as eDNA are effective for detecting species presence and assessing species richness, while boat-mounted sonar or AUVs, along with satellite imagery, help assess changes in habitat boundaries. Surface water quality is monitored through nutrient and oxygen sample analysis. Standardized indicators and expert collaboration enable companies to track biodiversity impacts throughout project phases. A full list of available biodiversity monitoring indicators and tools, including additional options, is available <u>here</u>.

Integrating Biodiversity for Future Generations

Integrating biodiversity into infrastructure projects, in line with the mitigation hierarchy, goes beyond reducing harm and can also support ecosystem functionality and its resilience when appropriately planned and implemented. As biodiversity pressures grow, infrastructure development offers an opportunity to implement green infrastructure that provides long-term benefits. By prioritizing green infrastructure, monitoring progress, and using the right indicators, companies can create projects that support environmental sustainability, climate resilience, and societal well-being for future generations.

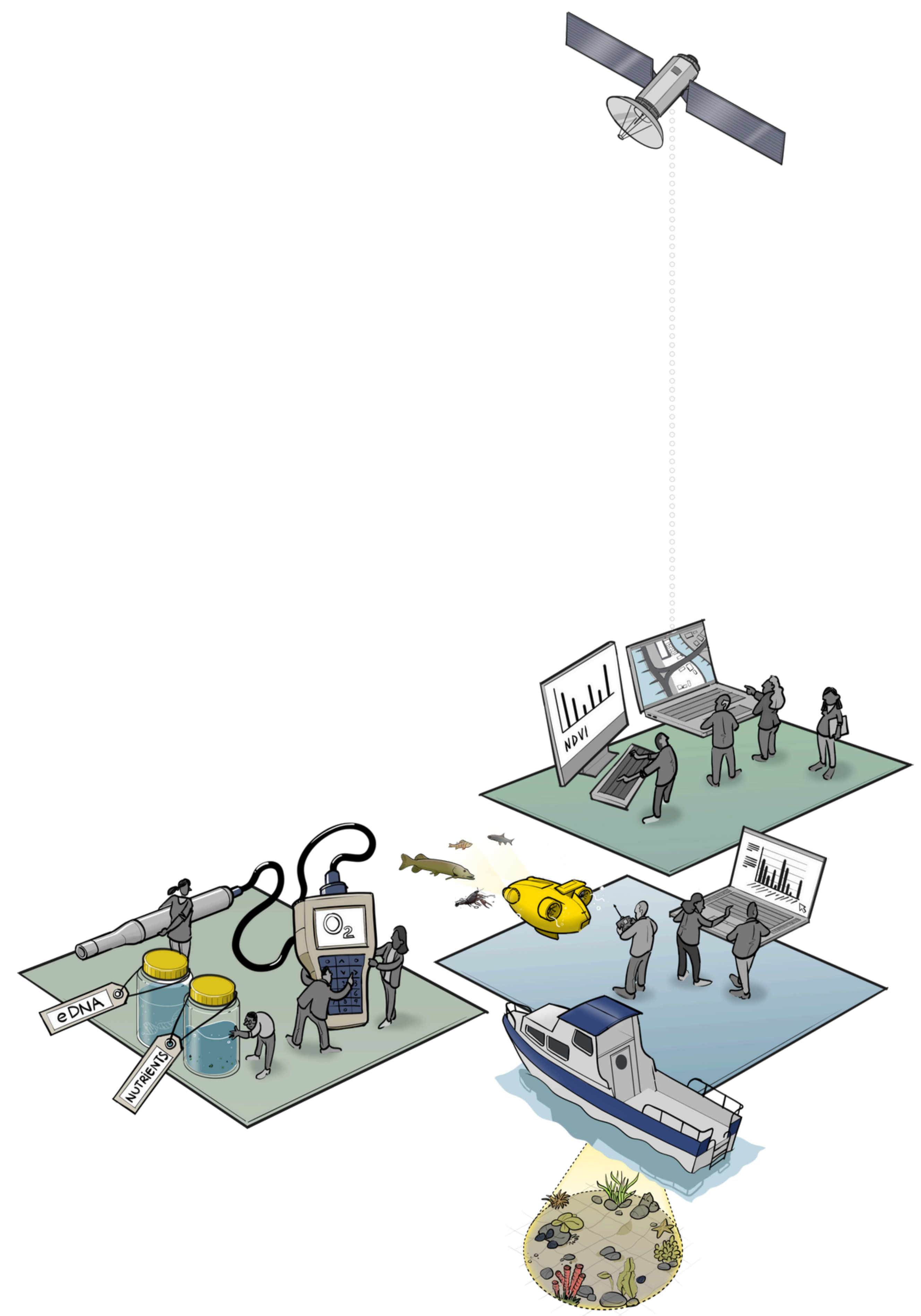


Figure 5: Biodiversity Monitoring Tools and Techniques: 1) eDNA, nutrient sampling, and oxygen measurements to assess water quality and monitor special interest species. 2) Boat-mounted side-scan sonar/multibeam echo sounder for mapping seabed habitats and monitoring habitat boundary changes. 3) NDVI and satellite imagery for large-scale vegetation health and landscape assessments

Definitions

Biodiversity: The variability among living organisms from all sources including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part. This includes variation in genetic, phenotypic, phylogenetic, and functional attributes, as well as changes in abundance and distribution over time and space within and among species, biological communities and ecosystems [6].
Building with Nature: Building with Nature is a design approach to develop Nature-based Solutions for water-related infrastructure such as flood defences, sustainable port development and for the restoration of ecosystems. It harnesses the forces of nature to benefit economy, society and the environment. [7].
Ecosystem: A dynamic complex of plant, animal and micro-organism communities and their abiotic environment interacting as a functional unit [8].
Grey Infrastructure: Hard, conventional, engineered infrastructure traditionally used to manage the coastal zone [9]
Green Infrastructure: Natural or semi-natural systems (e.g. riparian vegetation) that provide services for water resources management with equivalent or similar benefits to conventional (built) "grey" infrastructure (e.g. water treatment plants) [10].
Nature-based Solutions: Nature-based Solutions address societal challenges through actions to protect, sustainably manage, and restore natural and modified ecosystems, benefiting people and nature at the same time [11].

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EcoShape
building with nature

***EcoShape** is a consortium that focuses on developing and sharing knowledge on the Building with Nature approach. The approach is "a new philosophy in hydraulic engineering that utilizes the forces of nature, thereby strengthening nature, economy and society."*

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