Memo

Deltares

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Subject
From River to Coast, Designing with Biodiversity:
Integration of biodiveristy into Water Infrastructure Projects

1 Objectives of this infographic:

1 To emphasize the **importance** of the integration of biodiversity into marine brackish and/or riverine infrastructure projects (i.e., projects of any size with a green, gray component) and provide guidance on how to have a positive impact on biodiversity.
2 To guide the **integration** of biodiversity by providing frameworks, guidelines, methods, indicators, and tools that can be used in infrastructure projects.
3 To highlight that the complexity of biodiversity requires a **multidisciplinary team** (including ecologists, GIS specialists, etc.) to monitor biodiversity impacts through every phase of an infrastructure project, from initiation to operation and maintenance.
4 To **promote** the monitoring of biodiversity impacts by using linked indicators through data collection, maps, dashboards, assessments and other available tools in every phase of an infrastructure project, from initiation to operation and maintenance.
5 To provide a list of **tools** for the monitoring of biodiversity impacts through every phase of an infrastructure project, from initiation to operation and maintenance.

2 Scope of this infographic:

1 This infographic serves as a reference for the integration of biodiversity by protecting and enhancing it during the implementation of marine, brackish and/or riverine infrastructure projects with a gray component. These include operations such as dredging, construction, nourishments, among others. The IUCN Guidelines for planning and monitoring corporate biodiversity performance highlight 4 stages of corporate biodiversity performance: establishing priorities as to the significant pressures, species, habitats and ecosystem services (stage 1); developing ambitions, a vision, goals, objectives, actions and strategies for the inclusion of biodiversity (stage 2); determining indicators, core linked indicators, key performance indicators to monitor and report corporate biodiversity performance (stage 3); and the implementation of data collection, dashboards and map evaluation to enhance data-inclusive decision-making and lesson learning (stage 4; Stephenson & Carbone, 2021). The guidance in this infographic should help companies integrate data collection to monitor biodiversity impacts into their decision-making processes (stage 4) throughout all phases of their infrastructure projects. Further, this infographic focuses exclusively on direct biodiversity impacts (e.g., habitat removal due to dredging operations, emission of contaminants, etc.) and does not address indirect or

supply chain impacts (Laboyrie et al., 2018). Consequently, activities by external parties, such as material suppliers or logistics providers, are beyond scope.

2 In this infographic we use the definition of *biodiversity* used by the UN Convention on Biological Diversity (Secretariat for the Convention on Biological Diversity, 2011):

> "The variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems."

3 In this infographic we use the definition of *ecosystem* used by the UN Convention on Biological Diversity (Secretariat for the Convention on Biological Diversity, 2011):

> "A dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit."

4 This infographic explains the requirements for good biodiversity. Projects can enhance biodiversity in ecosystems by (De Vriend & Van Koningsveld, 2012; IPBES, 2019; WWF, 2022):

i) Increasing space for habitats and improving connectivity between habitats.
ii) Targeting keystone species.
iii) Reducing anthropogenic stressors like chemical pollution, plastic emissions, noise, etc.

5 Users are made aware about the direct drivers of biodiversity decline (IPBES, 2019):

i) Land and water use changes (e.g., wetland drainage, mangrove deforestation, river damming, coastal reclamation, navigation, etc.)
ii) Exploitation of biological stocks (e.g., overfishing, bycatch, coral harvesting, etc.)
iii) Climate change (e.g., coral bleaching, sea level rise, ocean acidification, etc.)
iv) Pollution (e.g., oil spills, nutrient runoff, plastic debris, etc.)
v) Invasive alien species (e.g., lionfish, zebra mussels, water hyacinth, etc.)

6 This infographic addresses all phases of an infrastructure project (De Vriend & Van Koningsveld, 2012; Laboyrie et al., 2018):

i) Initiation
   (1) It is recommended to gather baseline data on the biodiversity status at the project site/system during the project's initiation phase (OSPAR Commission, 2012; Laboyrie et al., 2018; Carvalho et al., 2022). Gathering baseline data would require a multidisciplinary team, comprising ecologists, GIS specialists, among other experts. A system approach should be used (System Analysis - EcoShape) to start exploring the system during the project initiation, and the planning and design phases. For the procedure on the selection of indicators please see section 5.
ii) Planning and design
   (1) Include biodiversity in the plans and design. Check the same indicators identified in the initiation phase. Compare the baseline against the expected outcome from the plans and design to identify expected biodiversity changes. Modify the plans and designs to minimize biodiversity impacts. Aim to maximize biodiversity outputs and mitigate biodiversity impacts in the plans and design (BBOP, 2012). Update indicators based on new insights as needed.
iii) Construction
   (1) Check the same indicators identified in the initiation phase. Compare the baseline against the current state to check progress towards expected biodiversity changes. Update indicators based on new insights as needed.
iv) Operation and maintenance
   (1) Check the same indicators identified in the initiation phase. Compare the baseline against the current state to check the post-construction

biodiversity changes. Update indicators based on new insights as needed. For more information on post-construction biodiversity monitoring design refer to Stephenson & Carbone (2021), Carvalho et al. (2022), Kardamaki et al. (2023) and Dalton et al. (2024).

7 The sooner biodiversity is integrated into a project, the higher the potential for a positive impact. In later project phases there are less opportunities, both physically and in terms of design freedom, to incorporate biodiversity elements (Laboyrie et al., 2018). Nonetheless, this guidance may be implemented retrospectively in case a project has already started.

3 Policy supporting the goals of this infographic:

1 The integration of biodiversity in infrastructure projects and financing is supported by international policies, frameworks and targets, such as the Science-Based Targets for Nature, Kunming-Montreal Global Biodiversity Framework (GBF) of the United Nations (UN) Convention on Biological Diversity and the UN Sustainable Development Goals. At the regional level, the EU Green Deal, the EU Biodiversity Strategy for 2030 and the Corporate Sustainability Reporting Directive (CSRD) mandate for the protection and restoration of ecosystems and biodiversity and establish requirements for corporate impact disclosure. At the national level, frameworks such as the Biodiversity Net Gain in the UK and the Nature Program (Programma Natuur) in the Netherlands require positive outcomes for biodiversity. As these national programs and policies are very country specific this infographic will not go in depth on this subject, but relevant policies should be investigated per project.

2 In general, any infrastructure project that could impact biodiversity must consider ratified national, regional and international laws for corporate sustainability and reporting.

4 Hierarchy of biodiversity:

1 Biodiversity is a complex, multifaceted concept that cannot be fully captured by a single metric. However, Noss (1990) proposed a Hierarchy of Biodiversity with the following organizational levels for biodiversity:
   i) Composition: Indicators monitor the species assemblages in the ecosystem (e.g., species abundance)
   ii) Structure: Indicators monitor the biophysical parameters of the ecosystem (e.g., connectivity)
   iii) Function: Indicators monitor the processes taking place in the ecosystem (e.g., primary production).

2 The spatial scales of biodiversity proposed by Noss (1990): It is recommended to begin with a broad scope (e.g., landscape change analysis) based on the project's spatial extent, and then narrow the focus as necessary (e.g., allelic diversity analysis). Some examples of indicators for each spatial scale of biodiversity are listed below. For more examples of indicators for each spatial scale refer to Noss (1990) and Knight et al. (2020).
   i) Landscape: Indicators monitor landscape types (composition); landscape patterns (structure); landscape processes, disturbances and land-use trends (function). Examples include:
      (1) Distribution (composition)
      (2) Connectivity (structure)
      (3) Nutrient cycling (function)

ii) Community/Ecosystem: Indicators monitor communities, ecosystems (composition); physiognomy and habitat structure (structure); interspecific interactions and ecosystem processes (function). Examples include:
   (1) Species richness (composition)
   (2) Water availability (structure)
   (3) Predation rates (function)

iii) Population/Species: Indicators monitor species, population (composition); population structure (structure); demographic processes, life histories (function). Examples include:
   (1) Relative abundance (composition)
   (2) Range of dispersion (structure)
   (3) Recruitment rate (function)

iv) Genetics: Indicators monitor genes (composition); genetic structure (structure); genetic processes (function). Examples include:
   (1) Allelic diversity (composition)
   (2) Effective population size (structure)
   (3) Rate of genetic drift (function)

5 Impacts monitoring framework recommended in this infographic:

To integrate the organizational levels and spatial scales of biodiversity in monitoring the biodiversity impacts of a project, we follow the Biodiversity Metrics Framework introduced by Knight et al. (2020). This framework allows for the simultaneous evaluation of the entire Hierarchy of Biodiversity from Noss (1990). It offers a standardized approach for biodiversity monitoring through a Biodiversity Scorecard and a Definitions and Descriptions component. This framework captures the complexity of biodiversity and can be uniformly applied across different projects by utilizing the biodiversity indicators outlined in section 7 and the tools detailed in section 8.

1 The Biodiversity Scorecard: a table outlining the indicators needed to monitor the system, based on the Hierarchy of Biodiversity (Noss, 1990). It includes:
   v) Three columns, one for each organizational level of biodiversity (composition, structure, function).
   vi) Four rows, one for each spatial scale of the system (landscape, communities/ecosystem, populations/species and genetic).
   vii) The cells where rows and columns intersect represent an element of the Hierarchy of Biodiversity, for example, the system's genetic composition. For examples of indicators for each element see the list in section 4b.

2 Definitions and Descriptions: it complements the Biodiversity Scorecard by describing a mitigation program in two ways:
   viii) By emphasizing the indicators required by policy.
   ix) By providing information from scientific literature explaining key biodiversity components essential to preserve the ecosystem.

6 Biodiversity indicators:

Biodiversity indicators provide information about the state of biodiversity and ecosystems. These can be proxy indicators for biodiversity (i.e., total area of protected areas, surface water quality, etc.) that give information about the ecosystem and indirectly about the biota. The selected indicators should cover the various levels and spatial scales of biodiversity (Noss, 1990; Knight et al., 2020; Dalton et al., 2024). We recommend using a minimum of three indicators (See indicators bolded in Table 1). A full list of tested indicators can be found in the Convention on Biological Diversity website (n.d.; https://www.cbd.int/indicators/testedindicators.shtml). Examples of indicators for different applications:

1 Examples of Indicators for general application:
   i) Total area of protected areas (use IUCN definition of protected areas)
   ii) Number of endemic/threatened/endangered/vulnerable species by group
   iii) Population growth and fluctuation trends of special interest species
   iv) Change in habitat boundaries
   v) Change in presence, location, area, numbers of invasive plant or animal species

2 Examples of Indicators of marine and coastal biodiversity. Additional indicators can be found in the monitoring requirements of the Marine Strategy Framework Directive:

i) Change in proportion of fish catches by species per specific season
   ii) Threatened fish species as a percentage of total fish species known
   iii) Coral chemistry and growth pattern
   iv) Annual rate of mangrove conversion
   v) Algae index

3 Examples of Indicators of inland waters biodiversity. Additional indicators can be found in the monitoring requirements of the Water Framework Directive:

i) Surface water quality: Nitrogen, Dissolved oxygen, pH, pesticides, heavy metals, temperature
   ii) Changes in vegetation type along water courses
   iii) Fish diversity
   iv) Benthic macroinvertebrates: communities
   v) Macrophytes: species composition and depth distribution

7 Tools for biodiversity monitoring:

The same indicators should be used to monitor biodiversity throughout all of the phases of the project. The goal is to compare the baseline state of the ecosystem (before the project) to the post-construction status (after project implementation).

Table 1 *Examples of biodiversity monitoring indicators and relevant available tools. The three bolded indicators are recommended as a minimum for biodiversity monitoring.*

Biodiversity monitoring indicators	**Examples of existing guidelines, methods and tools**
Total area of protected areas (use IUCN definition of protected areas)	World Database on Protected Areas, Natura 2000 Network Viewer, Integrated Biodiversity Assessment Tool (IBAT)
Number of endemic/threatened/endangered/vulnerable species by group	IUCN Red List of Threatened Species, World Wildlife Fund's Living Planet Report
Population growth and fluctuation trends of special interest species	eDNA, DNA databases, ShellBank
Change in habitat boundaries	Global Swimways – Fish Migration around the globe, Maps - Dam Removal Europe, Linkage Mapper | Linkage Mapper
Change in presence, location, area, numbers of invasive plant or animal species	Tools for Understanding Biodiversity Impacts | NatureServe, Invasive Alien Species in Belgium: Species List (biodiversity.be)
Change in proportion of fish catches by species per specific season	Global Fishing Watch
Annual rate of mangrove conversion	Including Local Ecological Knowledge (LEK) in Mangrove Conservation & Restoration, Freshwater Ecosystems Explorer, World Database of KBAs (keybiodiversityareas.org)
Surface water quality	UK Environmental Change Network (ECN) Monitoring protocol, Freshwater Ecosystem Explorer

Biodiversity monitoring indicators	Examples of existing guidelines, methods and tools
Changes in vegetation type along water courses	Vegetation Monitor, Tree Registrer, Satellite data analysis with Google Earth Engine,
Species diversity (i.e., fish diversity, benthic macroinvertebrates communities)	FishBase, Standardize Monitoring Protocols, Freshwater Ecology Database

A monitoring tools list collected for this infographic is available at EcoShape.org

8 References

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9 Definitions

1 Water infrastructure: “infrastructure (structures and facilities) situated in or along a water environment (e.g. seas, rivers, lakes, coasts, shorelines)”(Laboyrie et al., 2018).
2 Habitat: “the place or type of site where an organism or population naturally occurs” (Secretariat for the Convention on Biological Diversity, 2011).
3 Protected area: “a geographically defined area which is designated or regulated and managed to achieve specific conservation objectives” (Secretariat for the Convention on Biological Diversity, 2011).

10 Explanation EcoShape and contact information

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.”

Address: Utrechtseweg 9, 3811 NA Amersfoort, The Netherlands
Email: info@EcoShape.nl

11 Theoretical Example – Dredging of eroded site to restore mangrove forest

1 Initiation: establish a baseline for the system using the Biodiversity Metrics Framework:
   i. Definitions and Descriptions:
      1. Check policy to identify required biodiversity indicators
      2. Check the scientific literature to learn about the system
   ii. The Biodiversity Scorecard (consider the Hierarchy of Biodiversity to identify indicators)
      1. Biodiversity indicators selected:
         A. Change in habitat boundaries (structure)
         B. Population growth and fluctuation trends of special interest species (composition)
         C. Surface water quality (function)
   iii. Select tools for the monitoring of biodiversity impacts (See Table 1)

1. Baseline established:
    A. Change in habitat boundaries (structure) – status at baseline – 100%
    B. Population growth and fluctuation trends of special interest species (composition) – status at baseline – 100%
    C. Surface water quality (function) – status at baseline – 100%

2 Planning and Design: Plan and design with biodiversity in mind. Check the same indicators identified in the initiation phase to identify expected biodiversity changes. Modify the plans and designs to minimize biodiversity impacts. Aim to maximize biodiversity outputs. Update indicators based on new insights as needed.

i. Change in habitat boundaries (structure) – expected status after design – 95% (Decrease – reconsider plans and design)
ii. Population growth and fluctuation trends of special interest species (composition) – expected status after design – unknown
iii. Surface water quality (function) – expected status after design – 80% (Decrease – reconsider plans and design)

3 Construction: Check the same indicators identified in the initiation phase, if possible, to check progress towards expected biodiversity changes. Update indicators based on new insights as needed.

i. Change in habitat boundaries (structure) – status during construction – 80% (Decrease – check against plans and design and determine if an intervention is required)
ii. Population growth and fluctuation trends of special interest species (composition) – status during construction – 70% (Decrease – check against plans and design and determine if an intervention is required)
iii. Surface water quality (function) – status during construction – 70% (Decrease – check against plans and design and determine if an intervention is required)

4 Operation and Maintenance: Check the same indicators identified in the initiation phase to check progress towards expected biodiversity changes. Update indicators based on new insights as needed.

i. Change in habitat boundaries (structure) – status post-construction – 100% (same as baseline – no change)
ii. Population growth and fluctuation trends of special interest species (composition) – status post-construction – 110% (improvement from baseline – positive outcome)
iii. Surface water quality (function) – status post-construction – 90% (reduction from baseline – negative outcome; determine if an intervention is required)

12 Annex – Infographic