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European Biodiversity Partnership

Policy brief

Harnessing the full potential of early-warning systems and predictive scenarios building on innovative approaches to biodiversity monitoring

Innovative monitoring and modelling approaches enhance early warning systems for biodiversity. Insights from BiodivERsA-funded projects inform policy action for climate resilience and conservation at regional and transnational levels.

Main findings

As illustrated below in a variety of contexts, biodiversity scenarios can be powerful tools to understand and inform actions when navigating complex pressures on biodiversity and ecosystem services. The models behind these scenarios are only as good as the data and monitoring systems on which they are based.

- **Worldwide networks of operational weather radar detect flying insects, bats and birds**. For meteorological purposes such biological data are removed, but they can instead be used to model flows of migratory birds at a regional scale. Such models facilitate reduction in impacts of wind turbines, aviation and light pollution on migratory birds.

- **Emissions of methane from inland aquatic ecosystems are large and highly variable**. Remote sensing of **spatio-temporal variability, combined with stakeholder knowledge**, was used to **develop scenarios of effects** on Amazonian floodplain habitats **under different drivers** (climate, land use intensification and dams). Such models **support decision making** at local and regional scale.

- When ecosystems heat up, **unique species of Arctic inland waters are at risk** from competition from species better adapted to warmer conditions. Such **changes affect the ecosystem services provided by freshwaters** that are **key to Indigenous Peoples and other residents** of the Arctic. A lack of coordinated monitoring makes it difficult to predict impacts on biodiversity and the ecosystem services provided.

- **Nordic seas have become more acidic due to absorption of anthropogenic carbon dioxide** combined with increased temperatures. **Changes** in acidity **are detectable earlier in deeper waters** (>2000m) than in shallow waters. Higher acidity reduces the ability of cold-water corals to build hard structures. Improved predictive modelling of climate change and development of mitigation scenarios **needs long-term monitoring** of pelagic and **deep-water biogeochemistry**.

Policy recommendations

- Using biodiversity scenarios for decision making requires stronger trans-national collaboration to collect coordinated monitoring data, combined with available remote-sensed data at regional scale. Together, these can improve ecosystem models and enable development of more reliable predictions of ecosystem changes. Policy action can facilitate this process, as illustrated in different contexts:
- **Amending OPERA meteorological data exchange policies** to ensure open **access to *uncleaned* Europe-wide** weather radar **data** would enable its continued use in monitoring flows of migratory birds at regional scale.
- Supporting consensus on modelling specifications, **and provision of stable funding and tools to secure access to and efficient processing of Earth Observation data** at **large region** scale, for example **through the GEO Wetlands Initiative**, would enable better monitoring of priority habitats at appropriate scales.
- **Arctic countries, through the Arctic Council, should consider launching a coordinated monitoring program that combines circumpolar remote sensing with on-site monitoring of freshwaters on a regional scale**. These efforts could be co-developed with Indigenous Peoples and Local Communities to supplement science-based monitoring. Such a program would improve predictive models and enable policy and management actions to mitigate climate-induced changes.
- **Northern nations** should **establish a network of early detection systems** for **deep ocean biogeochemical stressors** that are relevant for biodiversity monitoring and **sustain long-term climate and biogeochemical monitoring** of hotspots in the Nordic Seas and North Atlantic.

Context

Ecosystems are complex and affected by multiple factors at different geographical scales. Ecosystem monitoring is typically conducted at local or national scale. Where monitoring methods are coordinated, these data can be combined with regional or global scale remote-sensed data to model potential effects of changes in physical, socio-economic and other factors that influence biodiversity of ecosystems. Predictive scenarios based on such models are useful to explore uncertainties and help non-specialists understand the implications of potential policy and management interventions.

To enhance biodiversity ecosystem recovery, agreements on actions and targets must extend to the trans-national level through, for example, RAMSAR, CBD, UN Environment Programme. Prediction of changes relies on coordinated national baseline and monitoring data across regions.

Regional Organisations and commissions - such as the EU, OSPAR for the North Atlantic, CAFF for the Arctic, ACTO for the Amazon - can play a vital role in coordinating national implementation of actions at regional level. Regional strategies, such as the EU Biodiversity Strategy for 2030, OSPAR North East Atlantic Environment Strategy 2030 and their action plans (e.g. the Amazon Basin Project) must be continually updated as predictive models develop and improve.

The studies outlined below illustrate how remote-sensed products designed for other purposes, combined with local ground validation data, can be used to model, monitor and predict regional scale climate and anthropogenic- induced changes and how they might affect ecosystem services and the biodiversity on which they depend. This brief showcases across multiple environments and landscapes the added value of using innovative monitoring and predictive scenarios for early warning systems.

Aerial migrants (birds, bats, insects) are an important component of biodiversity. They provide both services to and impact on humans, and connect terrestrial, aquatic and aerial environments across continents.

The terrestrial and aerial habitats of these migrants have changed dramatically, particularly through human-driven land use alterations, increased urbanization, broad application of pesticides and rapid climate change. Understanding and predicting when and where large numbers of birds, bats and insects are in the air at a regional scale has implications for conservation as well as mitigation of human-wildlife conflicts.

Coastal and freshwater ecosystems are changing as climate changes and human activities increase. Demographic and economic growth in Amazonian river floodplains have challenged their capacity to sustain both humans and biodiversity. Threats from dams, navigation, agriculture and climate change are increasingly severe and, to date, biodiversity scenarios have not considered all these critical drivers together. In the Arctic, climate warming and associated landscape transformations put an enormous stress on the biodiversity of **Arctic lakes, streams and coasts**, in particular on the unique cold-adapted species of these ecosystems. Warming induces catchment alterations such as permafrost thaws and increased vegetation development, thereby affecting nutrient fluxes from land to water, and the biodiversity and the food webs of Arctic aquatic habitats. Projections on the status of biodiversity and ecosystem services are needed by government, industries, conservation organisations and communities for sustainable, ecosystem-based management of the arctic environment.

The **Arctic coastline** is extensive, productive and by far the preferred ecotype for human settlements. Coastal waters are also critical breeding and foraging grounds for many fishes, birds and marine mammals, and provide key ecosystem services that are vulnerable to climate induced stressors. Less sea-ice and increased coastal erosion and sediment loads physically change the near-shore bottom habitats and, thus, the biodiversity of these regions with cascading effects on food webs. The extent of protection of coastal marine ecosystems in the Arctic remains very small compared to the terrestrial environment.

This brief demonstrates how some **BiodivScen-funded research projects** developed predictive models at regional scales using available remote sensed data and innovative coordinated monitoring. These models enable scenarios of the effects of changes under different environmental and socio-economic conditions to be assessed. The brief specifically uses results from the GloBAM, BONDS, REEF-FUTURES, ACCES, and ARCTIC-BIODIVER projects.

Key results

Using operational weather radar to better understand movements of migratory birds and reduce the risk of collisions with wind turbines and aviation, and lessen the impact of light pollution

Worldwide networks of operational weather radars collect essential data for meteorological services and also detect biological targets such as flying insects, bats and birds. Cleaning data for meteorological predictions removes most information on such biological targets. Researchers have demonstrated that un-cleaned radar data are required to track flows of migratory birds at regional to continental scales.

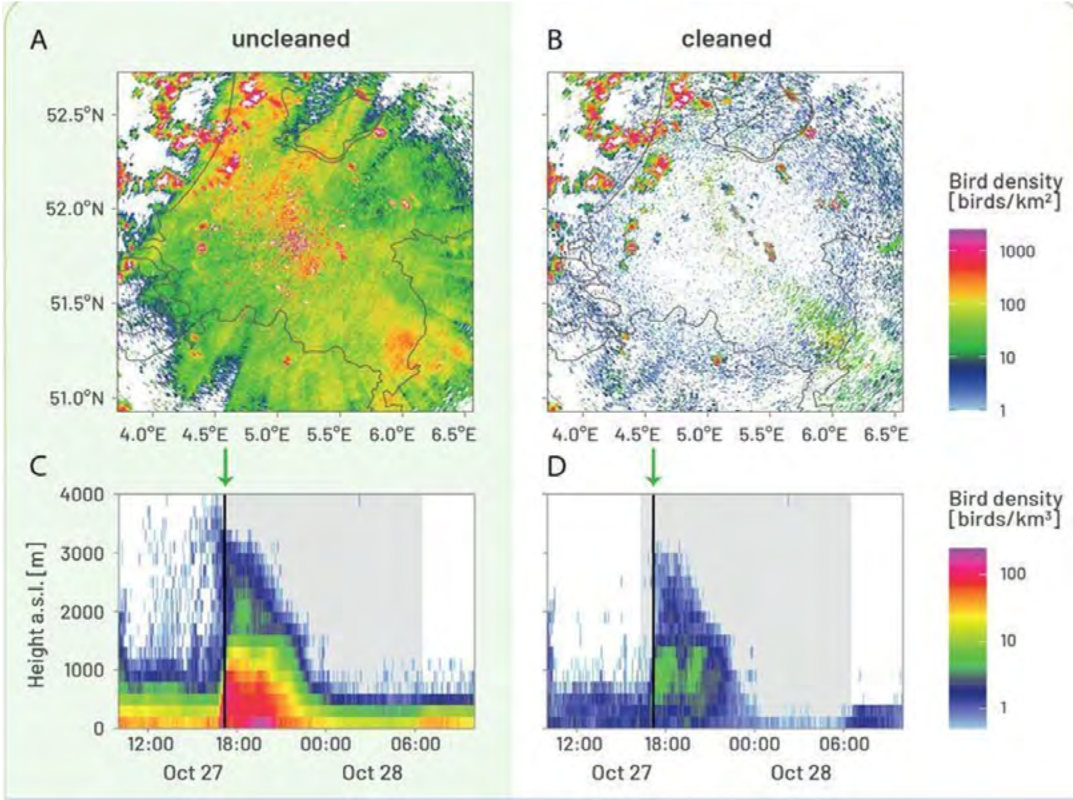


Figure 1: The effect of cleaning on the bird densities extracted from radar data by comparing (a),(c) uncleaned data to (b),(d) cleaned data. The plots in (c) and (d) show estimated altitude profiles of bird densities throughout the night. The gray background reflects the period between sunset and sunrise. After sunset, birds ascend and migrate throughout the first half of the night (c). By using cleaned data, densities are reduced by an order of magnitude (d). (Extract from Fig. 3 Shamoun-Baranes and co-workers 2022)

Raw data from operational weather radar networks across Europe and North America were used to track and quantify the biomass flows of migratory birds at regional to continental scales, over days and years. As built environments expand and land use, agriculture and climate change intensify, aerial migrants face growing threats. Researchers identified atmospheric[1], climatic[2], landscape and socio-economic factors[3] that shape aerial migrant movements and abundances. **Predictive models of bird migration intensity using weather radar data can inform policy and real-time response to reduce impacts of light pollution and risk of collisions with wind turbines and aircraft**. Large-scale seasonal migrations of birds pose a threat to aviation that can be difficult for individual airports to monitor and predict. Estimates of migration intensity combined with species occurrence can accurately predict the seasonal probability of most-damaging bird strikes with aviation[4].

Short term forecasts of migration are currently used to alter flight planning in military aviation and guide wind turbine positioning offshore in the Netherlands. Using an ensemble model (average of top 10 models) for short term forecasts was more accurate than relying on individual environmental models alone[5].

Changes to centralized meteorological data exchange policies in Europe now restrict access at regional scale to cleaned radar products alone, making them nearly useless for monitoring migratory species (see Figure A). In many other regions, weather radar data are not available for ecological research at all. Proposed modifications to European meteorological data exchange policies, to ensure that uncleaned data are available from centralised sources, could provide a model for similar policies globally through the World Meteorological Organisation. This would boost the utility of these global sensor networks beyond meteorology[6].

1. Kranstauber et al 2022
2. Nussbaumer et al 2022
3. Weisshaupt et al 2022
4. Nilsson et al 2021
5. Kranstauber et al 2022
6. Shamoun-Baranes et al 2022

Mobilising remote sensing, predictive modelling and participatory scenarios for early detection of the impacts of human activities and climate change in aquatic habitats

Predictive models to aid decision making depend on the availability of remote sensed data at regional and global scales as well as local data with which to validate the models. Researchers reviewed advances in remote sensing capability to capture spatio-temporal variability and developed models of tropical, marine and arctic aquatic habitats.

Aquatic plants represent considerable taxonomic and ecological diversity, and **emissions of methane** from inland aquatic ecosystems are large and highly variable. A comprehensive global dataset of areal coverage of major wetland types and their variability relevant to methane emissions does not exist; regional datasets provide only broad categories and limited information on seasonal variations in area or inundation[7].

Stakeholder knowledge was used to co-develop scenarios for Amazonian floodplain habitats under different socio-economic drivers (climate, land use intensification and dams), to support decision-making at local and regional scales[8].

Reef ecosystems currently provide five key ecosystem services: biomass production, nutrient cycling, regulation of the carbon cycle, cultural value and nutritional value. The governance, social, economic and environmental conditions under which these services are currently maintained or threatened were assessed under various global change scenarios. Predictive models were developed to simulate the delivery of ecosystem services over the next century. The thresholds beyond which these services may collapse were estimated[9].

Nordic seas have become more acidic since pre-industrial times, and this change can be detected down to 2000m depth. Predictive modelling of climate change and mitigation scenarios requires long-term commitment to monitoring of pelagic and deep-water biogeochemistry to enable better understanding of the impacts of climate change [10]. Cold water corals are vulnerable to increased ocean acidity which affects their ability to build hard structures from calcium carbonate. The main driver for increased acidity was found to be absorption of higher levels of anthropogenic carbon dioxide into oceanic waters, combined with increases in temperature[11]. However, changes in acidity vary between deep ocean and shallower waters[12]. Biochemical signals of anthropogenic changes are detectable in the deep ocean significantly earlier and over a longer period than for surface zones.

Different **de-icing trends and their consequences were determined for coastal regions of the high Arctic** with a view to providing scientific advice on the development of early warning systems for ecological and sociological breakpoints and regime shifts. This information can be incorporated into ecosystem-based management of coastal regions in the high-Arctic[13].

Rapid and irreversible changes in Arctic freshwaters urgently need standardised monitoring for better prediction of and adaptation to climate change impacts

Cold-adapted, unique species of Arctic inland waters are at risk as warming ecosystems lead to increased competition from northward migrating species better adapted to warmer conditions. Such changes affect the ecosystem services provided by freshwaters that are key to Indigenous Peoples and other residents of the Arctic[14]. Cold-adapted species may shift gradually to higher latitudes until they reach the northernmost border of the continents. Changes in primary producers of Arctic lakes and streams were studied in relation to temperature. Warming and eutrophication were shown to favour the growth of cyanobacteria, and disadvantage growth of diatom algae. Cyanobacteria are very low in essential fatty acids, which are key factors for the growth and reproduction of grazing invertebrates. A shift in primary producers from diatoms to cyanobacteria will support lower growth of zooplankton grazers - and ultimately fish.

7. Melack & Hess 2023
8. Chapuis et al 2022
9. Seguin et al 2023
10. Bertini & Tjiputra 2022
11. Fransner et al 2022
12. Gehlen et al 2014
13. Søreide et al 2021
14. Goedkoop et al 2021

Large-scale geological and climate data[15] were analysed with local data on macroinvertebrates to provide baseline information on spatial patterns of macroinvertebrate diversity in lakes and rivers across the circumpolar region. Lower diversity was related mainly to low temperatures but also to barriers to dispersal. Spatial variation was visible without high taxonomic precision, which means monitoring costs can be reduced. This baseline can be used to monitor and predict future changes with continued climate warming[16]. However, **monitoring of arctic freshwaters is currently inadequate** and varies at local level, making it difficult to detect and predict changes in biodiversity and the ecosystem services currently provided[17]. Standardised monitoring would improve the baseline and facilitate policy development to lessen the impact of climate-induced changes on communities living in Arctic regions.

Policy recommendations

Understanding and predicting impacts on biodiversity under different climate change scenarios is vital for biodiversity conservation, for maintaining nature's contribution to people and for mitigating human-wildlife conflicts.

Transnational models predicting biodiversity and climate changes are valuable tools to guide and support actions at national level. Such models require access to remote sensing data at regional level as well as coordinated collection of baseline and monitoring data at national level.

Adequate funding and cooperation through regional organisations is essential for development and use of such models. Much has already been achieved, but additional actions are required:

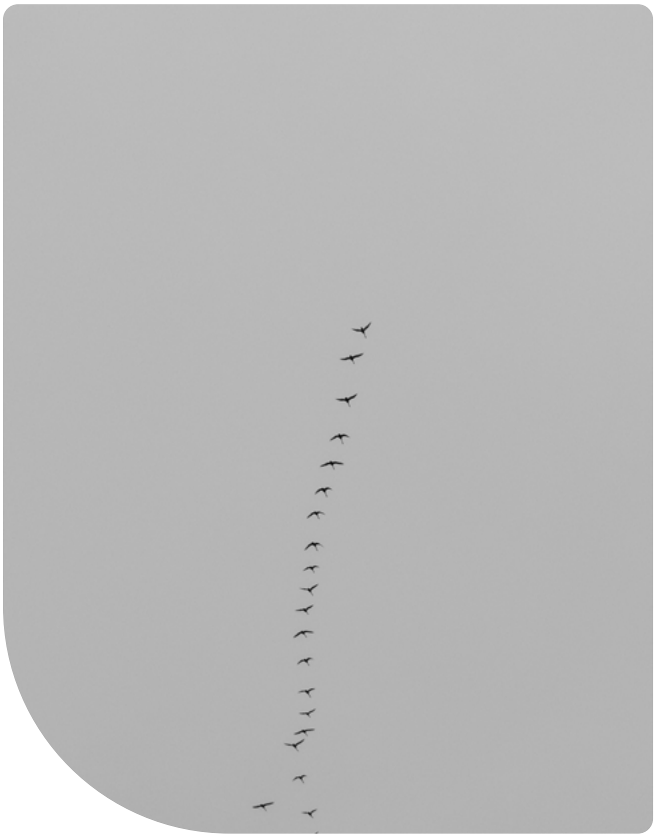
- **Amending OPERA meteorological data exchange policies to ensure open access to *uncleaned* Europe-wide weather radar data would enable its continued use in monitoring of migratory species**. Using centralised data from the existing weather radar networks is cost-effective and provides a large scale, long term data stream for development of predictive models of migration for multiple uses. 'Cleaning' of volume radar data removes the biological data required for monitoring of migratory species.

- **Weather radar data, combined with ecological research and modelling, can provide the basis for policy actions to reduce impacts on migratory species**, such as avoidance of collisions with wind turbines and aviation, or forecasting when and where non-essential lighting could be extinguished across diverse spatial and temporal scales. Use of an ensemble model (average of top 10 models) provides more accurate predictions of bird migrations than a single model.

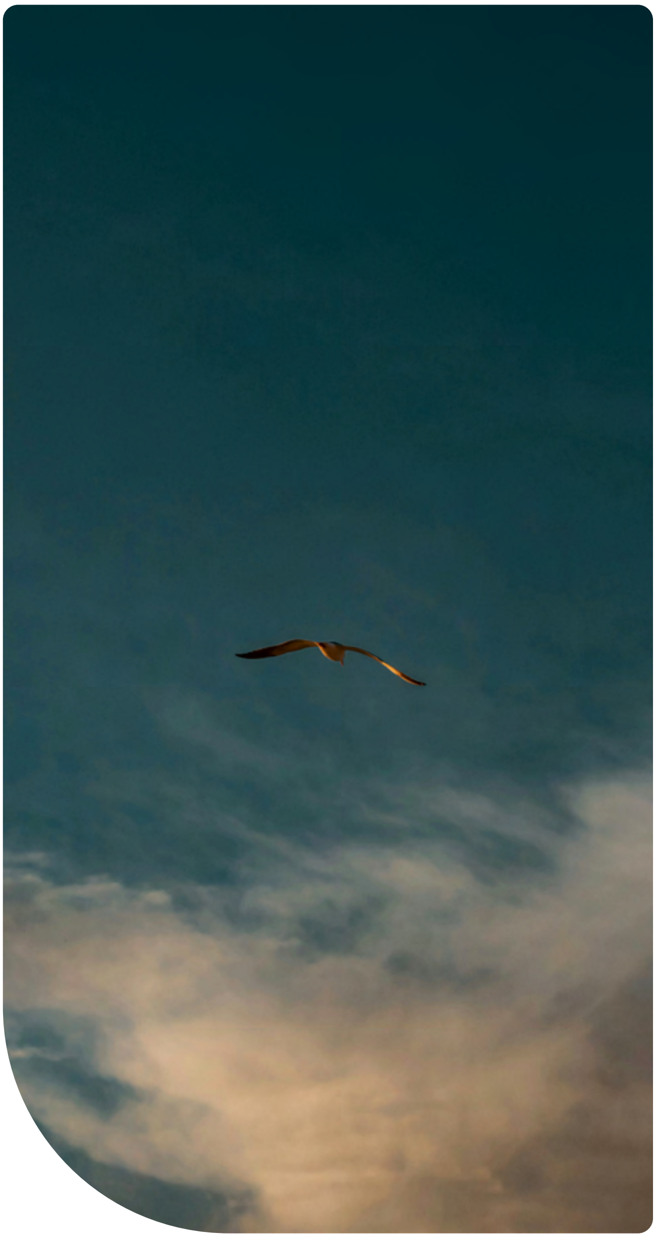
- **Supporting consensus on modelling specifications, with provision of stable funding and tools to secure access to and efficient processing of Earth Observation data processing at regional scale**, for example through the **GEO Wetlands Initiative**, would enable better monitoring of priority habitats at appropriate scales.

- **Facilitating better coordination between scientists addressing varied applications of wetlands remote sensing** (Ramsar Convention, biodiversity, water resources, sustainable development, biogeochemistry, disaster assessment) **would improve resource use efficiency and provide critical data to all communities**.

- **Coordinating national field campaigns to combine ground-based measurements with regional-scale airborne and satellite data** would improve predictive models derived from remote sensing products.



15. Huser et al 2022
16. Lento et al 2022
17. Heino et al 2020



- **Developing a time-series of satellite spectral attenuation coefficients from Earth Observation data for the low Amazon floodplain lakes** would enable monitoring of changes in light quality and penetration depth as an index of aquatic degradation.
- **Establish a network of early detection systems for deep ocean** biogeochemical stressors relevant for biodiversity monitoring to **sustain long-term climate and biogeochemical monitoring** of hotspots in the Nordic Seas and North Atlantic
- **Arctic countries should consider launching a coordinated intensified monitoring program through the Arctic Council, that combines circumpolar remote sensing with on-site monitoring of freshwaters on a regional scale**, ideally co-developed with Indigenous Peoples and Local Communities to supplement science-based monitoring.
- **Arctic countries should consider adopting new methods and technology (remote sensing, molecular methods)** to secure a long-term cost-efficient data series for the Arctic.
- **Arctic countries should consider developing and maintaining an international coastal observatory in Svalbard** to monitor environmental and ecosystem trends of the warm and cold regions as indicators of changes across the Arctic region.
- **Arctic countries should enhance broad-scale modelling efforts to include both ecological change and socio-economic development**. Such models may help predict changes and socio-economic impacts and enable planning for, and adaptation to global environmental change.

Link to sources

GloBAM
BONDS
ACCES
ARCTIC-BIODIVER
REEF-FUTURES

The scientific publications used in this policy brief can be found in the information sheet of this briefing, downloadable from: www.biodiversa.eu/policy-briefs/

Photos: Unsplash

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About this Policy brief

This Policy brief is part of a series aiming to inform policymakers on the key results of the biodiversity research projects funded by Biodiversa+ and provide recommendations to policymakers based on research results.

The series of Biodiversa+ Policy briefs can be found at www.biodiversa.eu/policy-briefs/.

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