Leverage Earth Observation for Genetic Diversity Monitoring

Genetic diversity monitoring is fundamental to understanding and protecting biodiversity. The Kunming-Montreal Global Biodiversity Framework (GBF) includes commitments to **monitor and report on genetic diversity** of wild species. However, this is constrained by the cost and difficulty of repeatedly obtaining DNA sequence information, especially on large scales, in inaccessible areas, or in regions with limited capacity. **Earth observation (EO) data from satellites** can help to monitor genetic diversity indicators, especially for large or remote areas. Using EO data, species genetic diversity indicators can be **more rapidly assessed** and upscaled to **country-wide extents** to create real-time monitoring systems and prioritize biodiversity conservation efforts.

Genetic diversity is defined as differences in DNA sequences from individuals and groups. These differences can be inherited and evolve, and they underlie differences in important characteristics like immunity and behavior. Within species, genetic diversity provides a set of available strategies for populations to function, persist, and adapt in changing environments.

Genetic diversity indicators have been proposed for monitoring, especially in regions where DNA data is unavailable (e.g., due to cost, time, technology, safety, accessibility barriers). The indicators include:

- The proportion of distinct **Populations Maintained** (**PM**) within a species relative to a baseline (e.g., 2011-2020). Distinct populations contain unique genetic diversity, often tied to their habitat conditions. Population loss is associated with irreversible genetic diversity loss.
- The maintenance of genetic diversity within populations is estimated as the proportion having an effective population size (N_e) above 500 (**N_e >500**). Values below this threshold indicate populations at risk of genetic erosion. N_e is often about 10% of the number of reproductively mature individuals (census number, N_c).

Earth observation (**EO**) **data** are acquired from multiple satellite missions currently in space and dating back years to decades. Satellites collect data repeatedly and at local to countrywide scales. EO data is publicly and freely available and standardized. It can be used to obtain time series and to identify and close gaps in other datasets.

Policy Brief

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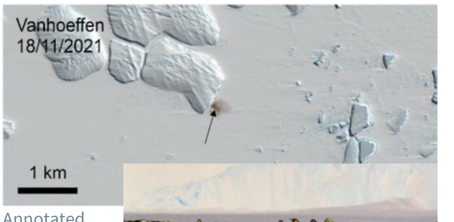
Example: Monitoring Emperor Penguins

Breeding emperor penguins form large colonies in the Antarctic that are difficult for humans to access. However, the colonies are observable using EO data, especially their guano deposits. EO data help identify and monitor the Antarctic colonies. Building on existing colony size estimates and knowledge of how these colonies form meta-populations, EO-based assessments of colony change, gain and loss can indicate changes to PM and Ne >500 and guide investments into genetic re-sampling, *in situ* recounts, and conservation.



Annotated Sentinel-2 image from Fretwell 2024, Fig. 2, DOI: 10.1017/S0954102023000329 CC BY. Penguins, Unsplash+ with Getty Images.

Operational Uses of EO Data

Species range and habitat mapping
Combined with prior information

Estimate population size and number
Combined with observational data

Detect habitat and ecosystem change
Support for baselines and frequent monitoring

Map change in features visible from space
e.g., Some traits, migration, aggregation, traces

Potential for Genetic Diversity Monitoring

Estimates of N_c from dispersal distance or density per area data allow **assessment of N_e >500**

Information on the population's location can be combined with EO-derived habitat data to **assess population distinctiveness** and otherwise support the design of comprehensive DNA studies from field sampling

EO can be a basis for monitoring systems to support **genetic diversity protection in near-real time** and **monitor threats of change to PM and N_e >500**