# How can biodiversity strategy and action plans incorporate genetic diversity concerns, plans, policies, capacity, and commitments?

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**ABSTRACT (150 words)**
Globally, national, subnational, and supranational entities are creating Biodiversity Strategy and Action Plans, to develop concrete commitments and actions to curb biodiversity loss, meet international obligations and achieve a society in harmony with nature. In light of policy makers' increasing recognition of genetic diversity in helping species and ecosystems adapt and be resilient during environmental change, this article provides an overview of how BSAPs can better incorporate conservation of genetic diversity within species. We focus on three areas: setting targets; committing to actions, policies and programmes; and monitoring and reporting.

Examples of policies, knowledge, projects, capacity building, and other endeavors are drawn from 20 recent BSAPs from around the world. We aim to enable and inspire specific and ambitious commitments in BSAPs, so guidance and suggestions are summarized and are portrayed on “the policy cycle.” With this, scientists and policy makers can translate high level commitments like the CBD into concrete nationally-relevant targets, actions and policies, and monitoring and reporting mechanisms.

**DRAFT**

The Convention on Biological Diversity (CBD) is a multilateral treaty with 196 Parties (195 countries plus the European Union), in force since 1993, which commits to biodiversity conservation, sustainable use, and equitable sharing of benefits from utilization of genetic resources. In December 2022, Parties to the CBD adopted the Kunming-Montreal Global Biodiversity Framework (GBF), setting a roadmap for reversing biodiversity decline by 2030. As a part of the GBF, each Party will update their National Biodiversity Strategies and Action Plans (NBSAPs) - documents that are used to assess, plan, undertake, monitor and review actions to achieve the goals and targets agreed to under the CBD (CBD/COP/DEC/15/6). Parties also use NBSAPs to articulate national level biodiversity targets and their alignment to the objectives of the Convention, and other national planning initiatives (e.g. South Africa’s National Development Plan for 2030). Ideally, NBSAPs should have high-level support from policy makers (e.g. legislators and country leaders) and be a product of cross-ministerial cooperation (CBD 2022). They also offer an opportunity for co-development with communities to foster broad societal ownership and investment in biodiversity. Local and regional authorities are also developing supranational and subnational biodiversity strategies (SBSAPS, https://www.cbd.int/nbsap/related-info/sbsap), such as in 26 Brazilian States and many Brazilian Municipalities (Ministério do Meio Ambiente 2017) and in ASEAN (https://beta.aseanbiodiversity.org/action-plans/), as are businesses and Indigenous groups .

Previous research showed that genetic diversity conservation had been neglected in national reports and plans under the CBD (Hoban, Campbell, et al. 2021). Genetic diversity underpins population and species persistence as well as species and ecosystem diversity and is essential for nature’s resilience in the face of pressures such as climate change (Hoban, Bruford, et al. 2021; Shaffer et al. 2022; Kardos et al. 2021; Beger et al. 2014). Conserving genetic diversity also delivers social and economic benefits, sustainable resource use, stable food supply, and mitigation of extreme events (Stange, Barrett, and Hendry 2021; Reusch et al. 2005; Hollingsworth et al. 2020). In adopting the GBF, Parties committed to maintain, manage and restore genetic diversity, focusing for the first time on all domesticated and wild species, in Goal A and Target 4 (see Figure 1). This is an expanded commitment from the previous 2011-2020 Strategic Plan, which focused on conserving genetic diversity in agricultural species, their wild relatives, and other species of socioeconomic importance.

Here, we present guidance on how targets, strategies, policies, actions and reporting towards the conservation of genetic diversity can be articulated in BSAPs (national, local, and regional). We aim to provide a general perspective to promote dialogue, inspiration, and starting points for drafting new BSAPs. We illustrate ideas with examples drawn from NBSAPs obtained through the CBD’s Clearing House Mechanism, especially those published between January 2020 (release of the “zero draft” of the Global Biodiversity Framework) to February 2024 (Australia, Barbados, Cambodia, China, European Union [EU], France, Ireland, Japan, Korea, Serbia, Spain, Tunisia, ), but also from earlier time periods to include geographic diversity and a wide range of viewpoints (Argentina, Brazil, Colombia, Indonesia, Papua New Guinea, Uruguay), and unofficial draft documents from Sweden and SADC (Southern African Development Community). We include examples for both wild and domesticated populations and breeds, though we focus more on wild populations as there are efforts already (e.g., the International Treaty on Plant Genetic Resources, Commission on Genetic Resources) to sustainably use, conserve in situ and ex situ, and monitor the diversity of breeds and varieties important to agriculture. The main sections of this paper follow three areas of CBD's guidance to Parties: setting national targets; developing actions, policies and programs to meet the targets, and noting finance and capacity needs; and monitoring, review and assessment, including the use of indicators.

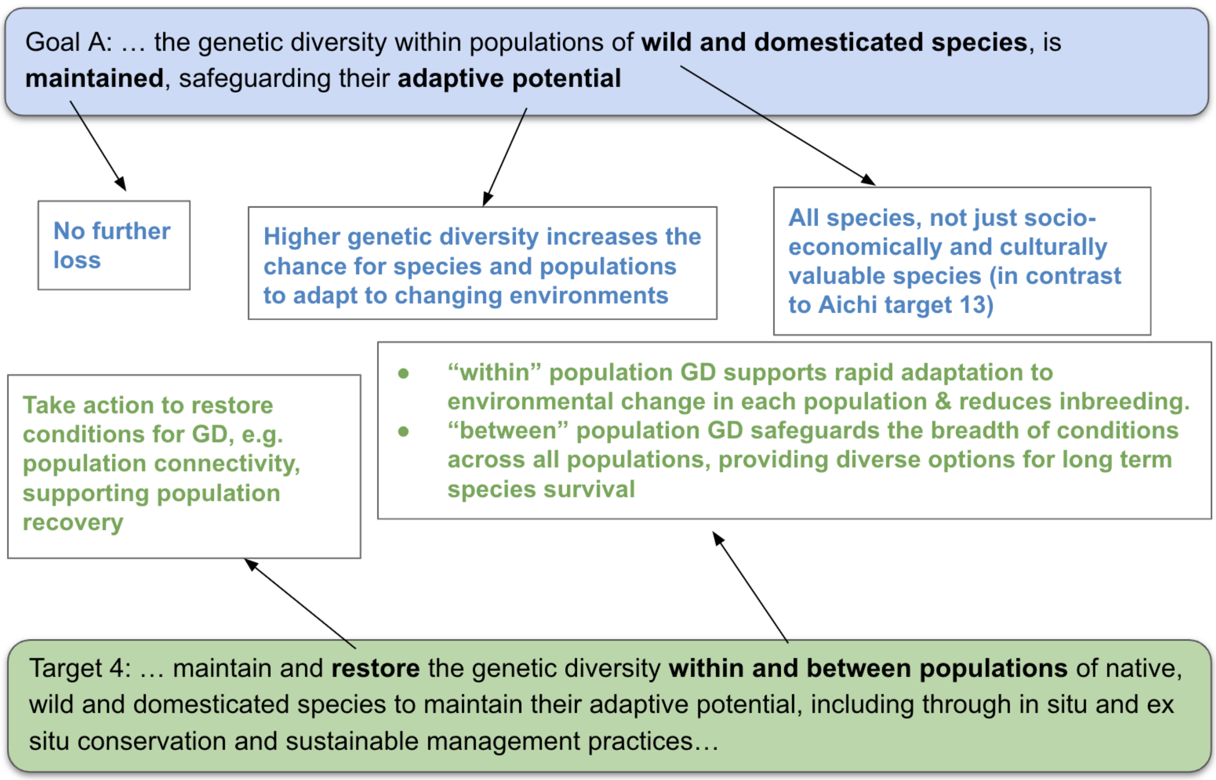


*Figure 1: Text from Goal A and Target 4 of the Kunming-Montreal Global Biodiversity Framework, adopted in December 2022, with an explanation of several terms relating to genetic diversity*

## Suggestions for setting national level targets

*It is vital for Parties to include a national target in their NBSAP on genetic diversity conservation within all species - native, wild and domesticated.* Genetic diversity is outlined as one of three components of biodiversity in Article 2 of the Convention text ("Biological diversity […] includes diversity within species, between species and of ecosystems," CBD 1992). A target specifically on genetic diversity of all species, including both wild and domesticated (terrestrial and aquatic), can help address adaptive potential, population size, inbreeding, and other processes that ultimately help to conserve genetic diversity within and between populations, as well as species and ecosystem diversity. As noted in Japan's NBSAP (Government of Japan 2023), "A decline in genetic diversity will threaten the persistence of species... Genetic diversity may be declining not only in rare species with small populations, but also in species with fragmented habitats and shrinking population sizes.” Papua New Guinea’s NBSAP (Government of Papua New Guinea 2019) emphasizes the importance of maintaining “evolutionary processes,” while Indonesia’s notes, “Erosion of sources of genetic diversity results in a serious threat to food security, shelter, and energy for the long term”.

For countries that use regional or sub-regional coordination to meet shared goals and targets, national targets may be designed or presented in light of regional targets or based on regionally negotiated frameworks. For example, SADC (SADC 2024) has a target to “Develop and execute comprehensive conservation strategies by 2035 to effectively mitigate the genetic erosion of biological resources, emphasizing the sustainable management of plant and animal genetic diversity, promotion of resilient agricultural practices, and establishment of seed banks or genetic repositories.” Meanwhile, the Pacific Islands Framework for Nature Conservation and Protected Areas 2021–2025 (SPREP 2021) has an objective to “Protect and recover threatened species and preserve genetic diversity,” and states that “Connections among protected areas are essential for their survival, to maintain genetic diversity and ‘restock’ populations after a disaster, such as a bleaching or disease event.” Individual countries can adopt such targets and go beyond by specifying (sub-) targets, local context, higher ambition, and/or how they can be applied to wild and domesticated species.

*The national genetic diversity target must be aligned with the global target*. Examples of national genetic diversity targets include (SEPA 2024) “The adaptability of species is strengthened by preserving and enhancing genetic diversity” and (Government of China 2024) “maintain and restore genetic diversity of local, wild and domesticated species.” We suggest these examples could be better aligned with the global target (GBF Target 4), such as specifically committing to maintain, restore, conserve in situ and ex situ, and sustainably manage within and between population genetic diversity (see Figure 1). These specific components of the GBF are noted in several NBSAPs: (Government of Serbia 2021) “populations require particular attention from the aspect of conservation, since they contribute significantly to the total genetic diversity of these species.” Argentina’s NBSAP states a need for, “the conservation of genetic variability, which is crucial for the demographic viability of sub-populations, and their connectivity and distribution throughout Argentina's ecoregions and subregions.” Furthermore, Ireland’s NBSAP notes: "Genetic diversity is important because it gives a better chance of survival in the face of environmental change. The breakup and loss of habitats can reduce genetic diversity by creating smaller, inbreeding populations. These populations then struggle to adapt to environmental changes such as drought."

*If possible, a national genetic diversity target may be more ambitious than the global target.* Higher ambition in genetic diversity conservation and management can help countries benefit from nature’s contributions to people and diverse natural resources. An analysis of the wording of GBF Target 4 (Hoban et al. 2023, 2020) recommended that a target include policies and strategies (in addition to management actions), such as: “Develop and initiate national-level policies and strategies, and take urgent management action, to maintain and restore the genetic diversity within and between populations of native, wild and domesticated species to maintain their adaptive potential, including through in situ and ex situ conservation and sustainable management practices, and develop and initiate national-level strategies and resources for conserving genetic diversity.” Policies could focus on legal protection (e.g. of local breeds or of distinct populations) or strategic investment of resources (e.g. funding genetic monitoring programs, habitat restoration or ex situ collections/ gene banks). Genetic conservation strategies or planning could define priority species for genetic monitoring, incorporate genetic diversity into spatial planning (including landscape connectivity), set timelines for capacity building, and prepare comprehensive reports on progress toward conserving genetic diversity (Posledovich, Ekblom, and Laikre 2021). Of course, Parties may find other ways to make their national targets more ambitious or specific, such as providing emphasis on genetic connectivity.

*Parties may wish to specify which aspects of their national target(s) on genetic diversity can be achieved with existing resources and where more resources are needed*. This may include insufficient resources within the country to monitor and report on genetic diversity or to implement actions that support genetic diversity, or lack of training or expertise. For example, ecological restoration has sometimes neglected genetic diversity concerns, resulting in the establishment of sites with low genetic diversity, decreasing adaptive potential of populations, high inbreeding, and diminished survival and productivity. Updating management practices to include genetic diversity will require training and collaboration between geneticists and practitioners. Calculating genetic indicators for wild populations, which are fairly new, may also require training. We emphasize that existence of barriers to implementation should not preclude inclusion of genetic diversity in NBSAPs. Indeed, recognising barriers can inform where capacity-building is needed and facilitate linkages among Parties and with organizations providing support.

*Parties can also emphasize genetic diversity with respect to other global and national targets*. By identifying linkages to genetic diversity throughout their NBSAPs, Parties can underline the coherence of policies across sectors, and optimize monitoring programs. Genetic diversity monitoring and indicators can serve multiple reporting needs, and therefore alleviate the reporting burden on Parties (a recurrent issue). Genetic diversity is vital for meeting various targets, including Targets 2, 3, 4, 6, 9, 10, 11, 13 (Hoban et al. 2023, 2020; Hoban, Campbell, et al. 2021; Bolam et al. 2023). These targets relate to topics such as (note these are simplified and not meant to embody the full targets' intent; the full text of targets can be found at https://www.cbd.int/gbf/targets): restoring degraded ecosystems, conserving and managing terrestrial and aquatic areas, management actions for recovering species and conserving genetic diversity, addressing the impacts of invasive species, minimizing impacts of climate change on biodiversity, sustainable management and use of wild species, enhancing sustainability in fisheries, forestry and agriculture, restoring and sustaining ecosystem services, and increasing the sharing of benefits from genetic resources and traditional knowledge. Highlighting such interlinkages can strengthen the commitment to conserving genetic diversity.

For example, when explaining Sweden's national target on restoration, SEPA (2024) states "In… implementation of the framework, it is important to take into account ecological representativeness and connectivity that contribute to genetic exchange between populations." and Government of Serbia (2021) intends to "integrate ecological corridors, as part of identified Trans-European Nature Network to prevent genetic isolation, allow for species migration, and maintain and enhance vitality of ecosystems." Indonesia's NBSAP (Government of Indonesia 2015) notes that protected areas serve to conserve both species and genetic diversity. Regarding genetic diversity and invasive species and sustainable agriculture and fisheries, (SEPA 2024) aims for the "Introduction of alien genotypes that are potentially harmful to biodiversity has been strongly limited until 2030" and that "sustainable fishing practices will include maintenance of genetic diversity and avoidance of strong selective harvest that alters species' genetic diversity," while Colombia's NBSAP notes that at least 57 non-native marine species threaten to reduce genetic diversity.

**Developing concrete actions, policies and programmes to meet the goal and targets**

*NBSAPs can also include actions that can help maintain and restore genetic diversity*, tailored to each country's capacity. Tangible actions to support genetic diversity include restoring lost habitat connectivity to facilitate gene flow, preventing the loss of distinct populations, documenting and preserving local breeds and varieties, and enabling population growth for small populations (e.g. halting poaching, removing invasive predators), to maintain evolutionary potential (Willi et al. 2022; Hohenlohe, Funk, and Rajora 2021; Fady et al. 2016). If populations cannot achieve sufficient size on their own, intensive management can include ex situ breeding and release, or translocation of individuals (Bolam et al. 2023). Actions should be both in situ and ex situ, and include laws, funding, and management (Hoban, Campbell, et al. 2021).

Example commitments include: (Kingdom of Cambodia) “Promote augmentation programs by releasing individuals into existing populations to increase their size and genetic diversity”, (Government of Uruguay 2016) “Rescue populations with risks of genetic loss or erosion” and (SEPA 2024) “Special efforts to increase the effective population size of populations of native wildlife species with an effective population size below 500 have commenced by 2025.” and “All native wild species subpopulations or geographic distribution maintained or re-established to strengthen genetic diversity, if ecological and technical conditions exist.”

In marine conservation, cooperation between Indonesia and 14 other countries aims to increase local population sizes of depleted shark populations (https://www.reshark.org/), which can benefit genetic diversity maintenance. Of course, augmentation and release should follow best practices including weighing beneficial and adverse outcomes of translocations, and consider the balance of local adaptation and genetic erosion (Weeks et al. 2011; IUCN/SSC 2013). As explained in (Government of Japan 2023), “Since there is a high possibility of genetic differentiation between native species naturally distributed in Japan and the same species distributed outside of Japan, there is concern that the introduction or artificial release… may cause hybridization.” Meanwhile, the Brazilian National Fund for Benefit Sharing helps to conserve genetic heritage ex situ (Government of Brazil 2018). Numerous countries commit to the important task of identifying and conserving genetic resources such as local breeds and varieties, and to building or enhancing genebanks.

*NBSAPs may outline what policies and programmes will facilitate positive action for genetic diversity*. Policies and programmes may be at a higher level than discrete, on the ground actions, such as designation of protected status for distinct populations or breeds and their evolutionary adaptations (as in several national endangered species laws), or increased funding in the form of grants for local and regional authorities in charge of wildlife and habitat management. Although China (Government of China 2024) commits to “Conservation and Recovery of rare and endangered species and very small populations [and preventing] changes in genetic diversity,” and Barbados (Government of Barbados 2021) states that marine protected area planning (e.g. spatial planning) should “ensure their long-term viability and to maintain biological and genetic biodiversity,” NBSAPs would ideally describe specific agency policies, programs, and/or funding mechanisms. The United States (not a Party to the CBD) proposed a law (Restoring America’s Wildlife Act) which would provide funding to fully implement management plans to help threatened species. The authority for implementation would be State wildlife and forest management agencies. Another example is Ireland's NBSAP (Government of Ireland 2024), which aims to increase opportunities under agriculture, rural development, forestry, and other relevant policies to benefit biodiversity by 2027. The plan commits the National Parks and Wildlife Service and Department of Agriculture, Food and the Marine to implementation including by supporting “Farming for Nature initiatives that specifically enhance ecological connectivity.” Meanwhile China’s State Forestry Administration and the National Development and Reform Commission has initiated a program to restore Plant Species with Extremely Small Populations (Yang et al. 2020), and Uruguay (Government of Uruguay 2016) aims to “Promote scientific production and valuation of genetic resources.” Papua New Guinea’s NBSAP

(Government of Papua New Guinea 2019)suggests that the Forestry and Fisheries Policies could have a greater “emphasis on genetic and biodiversity conservation.”

One example is a genetic conservation unit programme (GCU). GCUs are designated land or aquatic areas that maintain viable and evolving populations in situ, to support future adaptation. Designating and tracking GCUs involves identifying populations or portions of populations that are of sufficient size and contain important or unique genetic diversity. A database of GCUs can help to ensure sufficient genetic diversity is maintained, focus monitoring efforts and allow quick identification of source material for restoration. The European Forest Genetics program tracks nearly 4000 GCUs across Europe for >100 species in 35 countries (Lefèvre et al. 2020). GCUs are compatible and indeed can help to serve the needs of commercial forest management or other species harvest. GCUs are not limited to forest trees and could be applied to many plants and animals and possibly fungi (Minter et al. 2021). Existing protected and managed areas may already function as GCUs for some species groups, highlighting mutual achievement of Targets 3 and 4.

*Another option is to create national native plant or seed strategies or indicate participation in the sub-regional or regional equivalent (e.g. Pacific Community's Centre for Pacific Crop and Trees genebank).* Such strategies help to ensure that restoration of habitat will include genetically diverse and genetically appropriate plant material (Food and Agriculture Organization of the United Nations 2024). Ideally, such strategies and actions will address both wild and domesticated species. Because producing such material relies on a chain of infrastructure and logistics, a national strategy must focus on the full cycle of restoration needs (planning seed collection, sufficient farms to grow native seed, facilities for storing seed, nurseries, education, expertise to inform planting in the right place with the right preparation and care) (Basey, Fant, and Kramer 2015; Di Sacco et al. 2021). The French NBSAP notes that the “Végétal local” brand helps ensure preservation of genetic diversity by guaranteeing wild origin and not using artificial selection, while maintaining forest genetic diversity supports resilience. Serbia’s NBSAP notes that the Trans European Nature Network (Fornarini et al. 2023), a set of ecological corridors, could help facilitate gene dispersal; IUCN guidelines on connectivity also mention that an ecological network should quantify the impact on genetic diversity (IUCN/SSC 2020).

Other actions might include promoting the use of locally sourced native plant species in restoration projects, and implementing habitat restoration that prioritize conservation of genetic diversity (Hilty et al. 2020). In Japan, it is noted that there exists “Technical Guidelines for Reducing the Risk of Impacts on Genetic Diversity Related to the Release of [captive bred] Juvenile Fish.” Forestry, fisheries, agriculture and wildlife management agencies could be named as being responsible for creating such guidance. Meanwhile, genetic diversity of crop wild relatives can help innovative, sustainable agriculture. In Argentina, transitioning to multifunctional landscapes within large-scale farming systems holds significant potential for enhancing biodiversity and promoting landscape connectivity (Garibaldi et al. 2023). In Brazil, amongst the 10 countries with the highest numbers of plant genetic resources stored in long-term facilities, a national plan for keeping plant genetic resources was established with a physical structure to house 700,000 accesses (Ministry of the Environment 2023), while Tunisia (Government of Tunisia 2019) aims to develop “system for the protection of traditional knowledge related to genetic resources,” and to “Update and implement the conservation and valorization strategy of local agricultural genetic resources.”

*Training programs and workshops tailored to stakeholders are essential for raising awareness about the significance of genetic diversity and for building knowledge of relevant national and international regulations*. Educational initiatives play a crucial role in providing the knowledge, skills, and confidence needed to make informed decisions about conserving genetic diversity.

Additionally, training programs in genetic diversity can empower decision makers to initiate actions, effectively allocate resources, and advocate for impactful conservation measures. By fostering a culture of innovation, collaboration, and inclusivity, these educational efforts cultivate a new generation of leaders capable of driving positive change in biodiversity conservation. For example, in Argentina, the educational modules established under the 'Yolanda Law' (Law No. 27,592, passed in November 2020) require environmental training for all public service employees - a crucial starting point for enhancing capacity, awareness, and collaboration to fulfill the nation's biodiversity commitments. Argentina's NBSAP (Government of Argentina 2017) also emphasizes training for companies regarding understanding of genetic resources. Similarly, the SADC (SADC 2024) commits to "Develop and implement programmes for Member States to empower local communities to actively participate in monitoring and addressing genetic erosion in their region". Additionally, in Brazil, public service employees responsible for proposing, implementing, and managing nationwide conservation policies are being trained on DNA-based methods for monitoring and conserving genetic biodiversity, and participating in the consortium "Genomics of the Brazilian Biodiversity". Similarly, in its 5th National Report, Algeria commits to revise university training and education to better meet the needs of biodiversity management including specifically noting new techniques in genetic diversity conservation (People's Democratic Republic of Algeria 2014).

Such training can build on and coordinate with a wealth of prior capacity around genetic resources for food and agriculture. National Focal Points for plant, animal, forest and aquatic genetic resources within countries have experience monitoring, preparing country reports, coordinating implementation, etc. They are often supported by dedicated experts and practitioners. In addition, the Domestic Animal Diversity Information System (https://www.fao.org/dad-is/en/) already monitors population sizes of domesticated animal breeds, and their expertise in gathering, storing and presenting data would be valuable for reporting on indicators for genetic diversity of wild populations. Numerous guidance and tools are available at the FAO Biodiversity Knowledge Hub (https://www.fao.org/biodiversity/knowledge-hub/en).

**Monitoring systems, reviewing and assessment**

*NBSAPs are requested to also include monitoring, evaluation and review, including choice of appropriate indicators.* Several indicators of genetic diversity are contained in the GBF. The Headline indicator on proportion of populations (or breeds) with an effective size greater than 500 and the Complementary Indicator on proportion of populations maintained allow quantitative assessment of genetic diversity status within and among populations respectively. Australia's NBSAP alludes to both of these with the text, "Species will need to maintain large, genetically diverse populations to adapt… This fundamental requirement is challenged by other pressures reducing population size (e.g. invasive species, habitat loss) or connectivity of suitable habitat (habitat fragmentation)," and in progress measures of "number of populations of threatened or near threatened species… in government managed reserves [and]... protected by private landowners through stewardship or other arrangements." These indicators are ready for use, leverage diverse data, and are inclusive and fairly rapid (Hoban et al 2024).

Another indicator, the genetic scorecard (Hollingsworth et al. 2020) provides an assessment of genetic status, synthesizing various genetic processes and actions for genetic conservation, in a way that is accessible to help land managers, policy makers and other stakeholders effectively steward and allocate resources at a local, landscape or national scale. Indicators for genetic diversity of crop wild relatives includes an indicator on the level of protection of genetic diversity in situ and ex situ using geographic proxies (Khoury et al. 2019). Regarding domesticated species, indicators exist regarding the proportion of local breeds which are threatened and the number and diversity of accessions in medium to long-term storage facilities (CBD/COP/15/5). All of these can be compiled without any DNA sequence data, using existing data and knowledge.

*Parties and relevant stakeholders can also compile a list of local, national, and regional monitoring programs and available datasets that might be used to calculate genetic diversity indicators*. The indicators for monitoring genetic diversity currently in the GBF do not require DNA-based data, but can also leverage conventional monitoring such as counts of individuals or spatial surveys of populations as well as qualitative knowledge. The NBSAP could present a list of relevant programs and sources of information on counts of populations and occurrences over time (and/ or links to existing datasets and databases). This may include existing national, state or regional population surveys or inventories, volunteer or citizen science based programs, community based monitoring, and modes of monitoring habitat area using remote sensing. National examples include the United Kingdom National Forest Inventory and South Korea National Ecosystem Survey, or national and transnational programs to monitor large mammals like moose, caribou, and bears. These are systematic national-level surveys across many species, but many other species are monitored by state or other authorities and small NGOs. Globally, the FAO Commission on Genetic Resources for Food and Agriculture monitors the state of the world's genetic resources for food and agriculture.

*An important part of the NBSAP is producing a plan for indicator reporting.* How will genetic diversity indicators be monitored? What agencies will be involved, what are the possible data sources and data storage mechanisms, and what are realistic timelines for gathering data? This is vital to ensure that personnel and resources are allocated, that logistics are in place and that there is accountability and a chain of reporting. In Ireland's report, genetic diversity is partly assigned to the National Parks and Wildlife Service and the Department of Agriculture, Food and the Marine. In Korea's report, several agencies are named as responsible for reporting on genetic diversity, including the Ministry of Science and ICT, the Ministry of Health and Welfare, the Ministry of Environment, the Ministry of Oceans and Fisheries, the Rural Development Administration and the Korea Forest Service, reflecting the GBF aim to mainstream biodiversity across society. Of course, having too many agencies involved could have downsides (e.g. fragmented responsibilities and implementation), and clear responsibilities for each agency would be beneficial. When numerous agencies are involved, efforts are needed to ensure interoperability of data and information collected and archived. Parties needing help reporting genetic diversity indicators can find help from in-country biodiversity researchers as well as bodies that are being set up to support GBF implementation (CBD/COP/DEC/15/8).

As noted in Box 2, non-governmental organizations, farmer or landowner groups, and Indigenous Peoples (IPs) and Local Communities (LCs) are important partners in indicator reporting. Brazil's NBSAP commits to "Conserve the genetic diversity of local traditional or crioula varieties locally adapted by indigenous peoples, traditional communities and family rural producers." Collaboration can also be employed across different targets to promote synergy with GBF reporting, and facilitate methodological coordination and data and knowledge sharing. A genetic indicator pilot in Colombia materialized this in two ways, which optimized biodiversity assessment. First, workflows and outcomes from different initiatives that could provide information relevant to genetic indicators were coordinated, such as Red List assessments (e.g., (Calderón et al., 2005; Renjifo et al., 2016)), protected areas management plans, systematic data collection (e.g., (SIB, 2023)), and systematic expert consultation initiatives (e.g., (Biomodelos, 2023; Velásquez-Tibatá et al., 2019)). In turn, the estimation of genetic indicators provided data on the genetic diversity status of evaluated species, as input for their management and conservation, and could lead to the prioritization of populations for monitoring using DNA data. Genetic indicators are being implemented in other initiatives such as the Multidimensional Biodiversity Index (Soto-Navarro et al., 2021). Second, through the Key Biodiversity Areas initiative - KBA (IUCN, 2022), which identifies sites that contribute significantly to the global persistence of biodiversity based on the representation of species' populations (e.g., abundance, conservation status, distinctness), workshops were held to assess historical and current species distribution data - data necessary for both KBAs and genetic indicators. Genetic assessments also helped define population boundaries and determine the distinctiveness of an area (IUCN, 2022). This collaborative effort illustrates how genetic indicators can strengthen other biodiversity monitoring systems.

*Another option is to review relevant existing national, regional and global reports and compile the current state of knowledge, monitoring and action on genetic diversity to inform audiences such as policy makers and the public.* If in-country knowledge and capacity is insufficient, this should be noted as a capacity need. Scotland produced a report on 26 nationally important species using simple proxies that are understandable by the public and policy makers (Hollingsworth et al. 2020). Recently, (Pearman et al. 2024) counted the number of multi-year DNA monitoring programs in 38 European countries. Additional reports can focus on particular sectors or groups such as forestry, fisheries, crop wild relatives, or game species, or particularly threatened species. Existing global and national reports on genetic diversity in forests or in food and agriculture provide useful models (Black-Samuelsson, Eriksson, and Bergqvist 2020; Allender 2011; Rischkowsky and Pilling 2007). Reporting could assess the current capacity for DNA-based monitoring (e.g. reporting the number of government and academic labs with genetic equipment, number of university training programs in conservation genetics), and count the number of species that have had DNA-based studies performed or species in which DNA-based methods are supporting management and recovery. A Swedish model of such a report, co-drafted by researchers and the Swedish Environmental Protection Agency, counted the number of species being genetically monitored and summarized current genetic technology and capacity (Posledovich, Ekblom, and Laikre 2021). Several NBSAPs note that systematic and ongoing analysis of genetic diversity at a landscape scale will facilitate the achievement of the targets proposed (of numerous countries, including Spain, the Republic of Korea, and Ireland), including those related to enhancing ecological connectivity. Countries can also commit to reviewing relevant policies, plans and reports, as the Kingdom of Cambodia does ("Review plans and strategies that are in place to maintain the plant and animal genetic diversity for food and agriculture and genetic diversity of other planted species in-situ and ex-situ."). In addition, documenting and evaluating the success of past policies and actions, is critical to informing future practices and policies.

*Countries can also commit to increasing their genetic monitoring*. (SEPA 2024) proposes that "The number of native wildlife species and populations that have been analyzed with genetic diversity has increased significantly and the monitoring of genetic diversity is carried out on an ongoing basis." while China's commits to "explore surveys of the genetic diversity of wild organisms." A number of examples are included in the Republic of Korea's NBSAP: "Carry out trial research to identify and monitor on a regular basis the genetic diversity of endangered species, endemic species and species with high economic value. Use the results… for management, listing/delisting of endangered species and selection of species to be introduced for recovery." The Republic of Korea commits to specific goals: "202 cases analyzed as of 2018. 356 species will be analyzed from 2019 and 2026 (32 cases/year)" and "Evaluate regional adaptation characteristics through the development of high-density DNA markers… 5 species of tree, 90 markers (2017) → 15 species of tree, 450 markers (2022).” Another specific example is given under Republic of Korea’s Target on sustainable agriculture, forestry and fisheries, as to monitor genetic diversity “Cultivate sea forests (3,000 ha per year) to recover coastal ecosystems… and monitor their genetic diversity”. Several countries commit to better documentation of local or regional landraces, breeds, or varieties.

*As previously noted, case studies are an effective way to translate genetic issues and knowledge to non-geneticists*. We recommend NBSAPs summarize the findings of selected DNA-based studies of species of interest, and to explain any DNA-based management actions. This is not necessarily limited to developed countries. The NBSAP of the Kingdom of Cambodia describes the use of DNA based studies to distinguish hybrid from non-hybrid individuals of Siamese crocodile (*Crocodylus siamensis),* and the use of non-invasively collected (from feces) DNA samples to estimate the populations size of elephants (*Elephas maximus*) in the country. It also mentions “Development and strengthening of capacity for using DNA-based methods for species identification and genetic diversity studies, and for parentage, population structure and ecosystem health studies.” Serbia notes that projects have examined “genetic differentiation of populations in the Republic of Serbia is known for some wild species… the horned viper (*Vipera ammodytes*) or green frogs (*Rana synklepton esculenta*), or of game/mammals, such as the roe deer (*Capreolus capreolus*)... brown trout (*Salmo trutta*), grayling (*Thymallus thymallu*s).” Genetic data can also be used to study invasive species, as mentioned in the Barbados NBSAP, regarding the introduced hare (*Lepus europaeus*). Parties could collaborate with genetic scientists to summarize results of high interest, and to motivate further applications of conservation genetics in practice.

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**Box 1: Regarding “genetic resources” and “genetic diversity”**

Equitable sharing of the benefits of genetic resources is one of the objectives of the Convention, along with biodiversity conservation and sustainable use. It is important to note that “genetic resources” and “genetic diversity” are not synonymous, and that achieving Targets on genetic resources and genetic diversity will each need specific attention, policies, actions and reporting.

Genetic diversity is the amount of variation within species and their populations (or breeds), which can be observed in trait variation (examples: thermal tolerance, color, size, shape, phenology, mating calls) and which is based on DNA variation. Genetic diversity helps species adapt and avoid inbreeding depression. Maintaining genetic diversity means preventing the loss of genetic diversity and supporting conditions for adaptive change. Assessing and reporting on the genetic diversity of populations or breeds within species can include reporting effective population sizes, loss of populations, levels of neutral and adaptive diversity, levels of genetic structure, and of impacts of processes like hybridization and inbreeding (for both wild and domesticated species). It is not necessary to have DNA sequence data for this reporting, but such data does inform conservation and management action for genetic diversity. Sequence data can also be summarized in forms which do not require publishing sensitive information.

Genetic resources are “genetic material of actual or potential value… genetic material means any material of plant, animal, microbial or other origin containing functional units of heredity” (CBD, Article 2). The term is frequently used in NBSAPs and National Reports in reference to domesticated species or their wild relatives - especially regarding breeds, landraces, and similar units - but it could apply to any species. Many NBSAPs have commitments on genetic resources, such as conserving traditional varieties on farms and managing, cataloging, increasing and using samples in gene banks. Some NBSAPs and National Reports also report the numbers of species in a country with possible use in medicine or food, or numbers of wild relative species, when reporting on the status of genetic resources. We note that a metric of the number of species, while a summary of "genetic resources," is not a measure of genetic diversity within species.

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**Box 2: Challenges and opportunities for some countries on including genetic diversity in BSAPs**

All BSAPs reviewed mention genetic diversity in some form, albeit to various extents (see Supporting Information, Tables S1 & S2). For the majority of Parties yet to submit updated NBSAPs, ambitious and clear targets and actions restoring and maintaining genetic diversity within wild and domesticated species should be feasible.

Still, we acknowledge challenges faced by countries with limited financial and technical resources. Management actions, enforcement of legislation, and monitoring of genetic diversity all require substantial funds, personnel, and expertise. The GBF does commit to additional resourcing and capacity building and yet gaps remain. Technical expertise around genetic diversity may be lower in developing economies, which means that training, exchange visits, workshops, and published text and video guidance are needed.

Monitoring and management needs are also higher in countries with higher numbers of species - more species need to be evaluated and more species will need active management interventions to improve their genetic diversity status (Ragamustari and Sukara 2019). Yet generally highest diversity falls within developing economies, where least resources are often available. Even the seemingly substantial budget allocation by SADC (20+ million USD) to address genetic diversity and genetic resources over the next 10 years across SADC countries, is < 140,000 USD per year per country.

Large nations with numerous isolated or remote areas face challenges in the logistics of monitoring and in determining whether populations are isolated. For example, the sheer area and high biodiversity in countries like Brazil and Indonesia presents logistical challenges for monitoring populations and assessing census sizes, or collecting samples for genetic analysis. Countries with populations of highly mobile marine species are also presented with difficulties identifying populations; transboundary cooperation will be essential for assessing and monitoring genetic diversity of these populations. Marine organisms, invertebrates, fossorial organisms and other species which are hard to count may be challenging, though emerging technologies, Red List experts and workshops, citizen science, and Earth observation data will be helpful in tackling these challenges.

Meanwhile there are opportunities to leverage community participation. In addition to establishing community seed banks to help preserve genetic lines, Indigenous Peoples (IPs) and local communities (LCs) often have knowledge on genetic diversity in the form of unique traits, behavior, or other within-species variation. IPs and LCs can sometimes contribute knowledge on the number of individuals within a species or loss of a species from an area, contributing to monitoring and reporting. The existing knowledge and the participation of IPs and LCs could help alleviate some of the monitoring challenges noted above (large numbers of species, limited financial and technical resources, large numbers of islands), while in all countries complementing other forms of knowing and monitoring biodiversity. Other stakeholders can also help. For example, local volunteers, farmers and foresters were able to design a successful conservation management plan for a European Protected Species of amphibian, the great crested newt (*Triturus cristatus*), that combined genetic evidence with local stakeholder knowledge (O'Brien et al. 2021). Involving diverse stakeholders is therefore important for successful conservation planning.

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**Box: Summary of suggestions for practical use in developing BSAPs**

1. **Involve all stakeholders:** The NBSAP will be more likely to succeed and will deliver wider societal benefits if its development involves inclusive participation and takes a rights-based approach, in line with Section C of the GBF.
2. **Ensure national targets reflect all parts of the GBF:** An effective genetic diversity target will be aligned with the global target, which includes maintaining genetic diversity within and between populations of native, wild and domesticated species at sufficient levels for adaptive potential. The goals of the GBF also recognize that genetic variation is one of three dimensions of biodiversity.
3. **If possible, set national targets that are ambitious and specific, including means of achievement:** Parties can make national targets more ambitious by increasing specificity and scope, including policy and planning.
4. **Highlight how genetic diversity is important for meeting other GBF Targets:** NBSAPs should include crosswalks or connections of genetic diversity to other relevant targets to promote synergy and optimize coordinated reporting (see text for example targets).
5. **Describe specific actions, policies, programs, funding, and in-country legal frameworks:** NBSAPs may describe and commit to actions that can help maintain and restore genetic diversity, and the policies and programs that promote, fund, or facilitate such actions (e.g. national seed strategies, sustainable management, legal protection of subspecies and populations).
6. **Describe indicators, capacity and existing monitoring programs for reporting under the Monitoring Framework:** It is useful to describe indicators for reporting genetic diversity for both wild and domesticated species, and the country's capacity to use those indicators. Currently existing resources can be collated and monitoring programs described.
7. **Summarize state of DNA based knowledge in country:** A synopsis of the current state of DNA-based monitoring, and commitments and/or case studies of DNA-based monitoring or the use of DNA to guide management can be presented, in collaboration with in-country experts.
8. **Identify responsible agencies:** A plan for reporting, including which agencies are responsible, can help ensure that the identified actions, commitments, and reporting will have ownership.
9. **Highlight existing capacity and capacity needs:** Describing current and needed capacity regarding training, equipment, partnerships, etc. can help facilitate the capacity-building support services that are currently being set under the GBF and foster collaboration among Parties and sectors.

**Concluding remarks**

We hope that this guidance provides Parties and other entities a starting point, a checklist of possible considerations, and encouragement for including ambitious and specific targets, actions, policies and monitoring for genetic diversity in their BSAPs. It is of course important to connect the BSAP to national reporting and implementation on the ground, as noted recently (Maney et al. 2024).

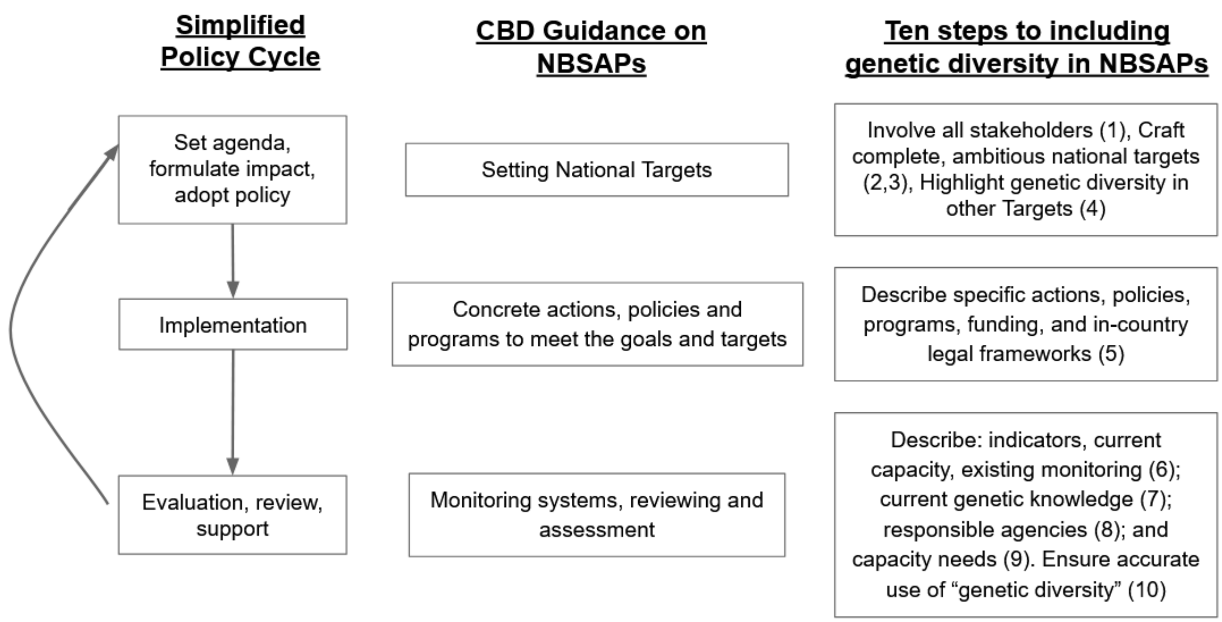


Figure 2: Presentation of the 10 steps outlined in this article, matched to the CBD Guidance on NBSAPs, and presented roughly within the Policy Cycle

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