

Neglect of Genetic Diversity in Implementation of the Convention on Biological Diversity

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Genetic diversity is the foundation for all biological diversity; the persistence and evolutionary potential of species depend on it. World leaders have agreed on the conservation of genetic diversity as an explicit goal of the Convention on Biological Diversity (CBD). Nevertheless, actions to protect genetic diversity are largely lacking. With only months left to the 2010-biodiversity target, when the 191 parties to the CBD have agreed on achieving a significant reduction of the rate of biodiversity loss, gene-level diversity is still not being monitored, and indicators and thresholds that can be used to devise strategies to conserve this important component of biodiversity are missing. Immediate action is needed to ensure that genetic diversity is not neglected in conservation targets beyond 2010.

The risks associated with depletion of genetic diversity were recognized in classic publications 4 decades ago (Frankel 1970, 1974), and this message has been repeatedly stressed ever since (e.g., Schonewald-Cox 1983; Ryman & Utter 1987; Frankham 1995; Allendorf & Ryman

2002; Hughes et al. 2008). In that time, a body of theory (Lynch & Lande 1993; Lande 1995; Lynch et al. 1995) and empirical work has emerged that demonstrates how populations and even species can collapse due to loss of genetic diversity (e.g., Newman & Pilson 1997; Briskie & Mackintosh 2004; Frankham 2005). Evidence supporting the importance of maintaining genetic variation to sustain species and ecosystems continues to accumulate (Wimp et al. 2004; Crutsinger et al. 2006; Whitham et al. 2006).

Gene-level biodiversity is recognized in the CBD (www.cbd.int) as one of three levels of diversity—ecosystems, species, and genes—that are to be conserved and sustainably used. Since its adoption in 1992, this convention has become the most important international political instrument for halting biodiversity loss. At present, 192 nations are parties to the CBD, representing every nation in the world except for Andorra, the Holy See (the Vatican), Somalia (party from mid December 2009), and the United States. Integral to the CBD is the task of

“monitor[ing], through sampling and other techniques, the components of biological diversity” to “identify processes and categories of activities which have or are likely to have significant adverse impacts on the conservation and sustainable use of biological diversity, and monitor their effects.”

In 2002 parties to the CBD committed themselves to reduce significantly by 2010 the current rates of biodiversity loss at global, regional, and national levels as a “contribution to poverty alleviation and to the benefit of all life on Earth.” This 2010 biodiversity target was subsequently endorsed by the World Summit on Sustainable Development and the United Nations General Assembly and incorporated as a new target under the UN Millennium Development Goals (<http://www.un.org/millenniumgoals/>).

To evaluate progress toward the 2010 biodiversity target for genetic variation it is necessary to assess and monitor this critical level of diversity. The CBD is not a mandatory instrument; it is the responsibility of each country to develop and implement a National Biodiversity Strategy and Action Plan (NBSAP). To assess the extent to which genetic diversity is currently recognized in national biodiversity policy programs, we used information available at the convention’s website to review NBSAPs of a subset of countries party to the CBD (<http://www.cbd.int>; sub-heading: Countries; assessed January–March 2009). Our aim was to investigate whether individual parties state in their strategies and action plans that genetic variation of wild animals and plants is to be conserved in their country and whether they explicitly recognize the need for developing monitoring programs for this diversity.

For our analysis we selected every 10th country ranked according to its gross national product (GNP; <http://www.studentsoftheworld.info/infopays/rank/PNB2.html>). If a country was not part of the CBD or not a sovereign nation, or if a document was missing, not searchable, or not in English, we chose the next country on the list. We reviewed 24 NBSAPs. Of these, 67% (16 countries) state that genetic variation should be conserved. Nevertheless, 38% (six) of these plans focus only on the genetic diversity of domesticated populations compared with 62% (10) that also recognize the genetic diversity of wild animals and plants as a conservation concern. Although most (90%; 21 countries) of the reviewed NBSAPs state that monitoring of biodiversity should be carried out, only 21% (five) explicitly acknowledge the need for developing means for monitoring diversity at the genetic level. These five countries all grouped in the upper 20% of the GNP ranking (i.e., larger countries with strong economic performance). In contrast, countries sharing the general goal of conserving genetic diversity represent the full spectrum of GNP ranks.

This pattern of widespread recognition of the genetic component of biodiversity, but a primary concern for gene pools of domesticated organisms, is also reflected among four rapidly developing countries predicted to

eclipse the combined economies of the current richest countries of the world by 2050: Brazil, Russia, India, and China (the BRICs; O’Neill 2001). We separately examined the NBSAPs for the BRIC countries and found that only one of them (Russia) explicitly stresses the need for developing monitoring programs for each level of biodiversity including genetic variation.

Existing national plans for implementation of the CBD genetic diversity goal clearly are insufficient. Less than half of the reviewed countries have included explicitly the goal of conserving genetic variation of wild animals and plants, and only 20% recognize the need for monitoring this level of variation. Failure to maintain genetic diversity undermines efforts to maintain diversity at all other levels. International support and effort are urgently needed to monitor all components of diversity, including genetic diversity.

Several international facilities have been created to assist countries in implementing the CBD. Currently, however, these facilities fail to provide adequate information or assistance to help countries implement the CBD with respect to gene-level variation. For instance, the World Conservation Monitoring Center, which is run in collaboration with the United Nations Environment Programme, “does not deal with gene-level biodiversity” (www.unep-wcmc.org; email response from UNEP-WCMC Information Office). Similarly, the Global Biodiversity Information Facility (GBIF), created to collect and provide free and open access to biodiversity data, is not constructed to deal with information on gene-level biodiversity (data portal manager at GBIF Secretariat, personal communication).

To meet the 2010 biodiversity target, several efforts have been made to identify indicators useful for detecting changes in species and ecosystem diversity. For instance, the 2010 Biodiversity Indicators Partnership (<http://www.twentyten.net>) “brings together a host of international organizations working at the forefront of biodiversity indicator development to assess progress toward the 2010 target.” The only indicator that explicitly deals with genetic variation focuses on *ex situ* crop collections and the number of food production breeds of domestic animals. Similarly, among the 11 indicators of status, trends, and threats to biodiversity proposed by the Pan European initiative “Streamlining European 2010 Biodiversity Indicators,” the one indicator focusing on genetic variation (<http://biodiversity-chm.eea.europa.eu/information/indicator/>) deals exclusively with the number of domestic livestock breeds within countries. It does not monitor the genetic diversity within breeds (Bubb et al. 2005; EEA 2007), let alone genetic diversity in domesticated plants or any wild species.

The Global Environment Facility (GEF)—the designated financial mechanism for a number of multilateral environmental agreements and conventions including the CBD—has funded only seven projects that explicitly

deal with genetic diversity among a total of 2471 funded projects (0.3% of the funded projects and 0.2% of the funds awarded by GEF; <http://www.gefweb.org/> [accessed in August 2009]). All seven projects deal with genetic diversity exploited in agriculture or forestry.

Knowledge of conservation genetics, as well as molecular genetic techniques and statistical tools to detect loss of genetic variation through genetic monitoring of species and populations, exist and can be implemented (Schwartz et al. 2007). As we move to devise conservation targets beyond 2010, we urge all nations and international conservation programs to recognize the central importance of conserving genetic diversity. Currently, Sweden appears to stand alone among CBD nations in having started to develop explicit conservation strategies to conserve genetic diversity (Swedish Environmental Protection Agency 2008), although these have not yet been put into practice. There is an urgent need for consensus on standards for genetic monitoring as an explicit component of CBD implementation (Laikre et al. 2008), and international as well as national efforts from both policy makers and researchers are needed in this respect. Without meaningful indicators and targets for conservation of this critical component of biodiversity, adaptive potential of all wild and domesticated species is likely to continue to erode.

In 2009 we celebrated Charles Darwin's 200 birthday and the 150th anniversary of the publication of *The Origin of Species*. One of Darwin's key insights, crucial to the explanation of adaptation following natural selection, was the importance of variation among individuals within populations. It is time for the importance of genetic variation for evolutionary processes to be taken into consideration in the development of international policy to conserve biodiversity.

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Literature Cited

Allendorf, F. W., and N. Ryman. 2002. The role of genetics in population viability analysis. Pages 50–85 in S. R. Beissinger and D. R. McCul-

- lough, editors. Population viability analysis. University of Chicago Press, Chicago.
- Briskie, J. V., and M. Mackintosh. 2004. Hatching failure increases with severity of population bottlenecks in birds. *Proceedings of the National Academy of Sciences of the United States of America* **101**:558–561.
- Bubb, P., J. Jenkins, and V. Kapos. 2005. Biodiversity indicators for national use: experience and guidance. United Nations Environment Programmes World Conservation Monitoring Centre (UNEP-WCMC), Cambridge, United Kingdom.
- Crutsinger, G. M., M. D. Collins, J. A. Fordyce, Z. Gompert, C. C. Nice, and N. J. Sanders. 2006. Plant genotypic diversity predicts community structure and governs an ecosystem process. *Science* **313**:966–968.
- EEA (European Environment Agency). 2007. Halting the loss of biodiversity by 2010: proposal for a first set of indicators to monitor progress in Europe. Technical report 11/2007. EEA, Copenhagen.
- Frankel, O. H. 1970. Sir William Macleay memorial lecture 1970. Variation – the essence of life. *Proceedings of the Linnean Society of New South Wales* **95**:158–169.
- Frankel, O. H. 1974. Genetic conservation: our evolutionary responsibility. *Genetics* **78**:53–65.
- Frankham, R. 1995. Conservation genetics. *Annual Review of Genetics* **29**:305–327.
- Frankham, R. 2005. Genetics and extinction. *Biological Conservation* **126**:131–140.
- Hughes, A. R., B. D. Inouye, M. T. J. Johnson, N. Underwood, and M. Velend. 2008. Ecological consequences of genetic diversity. *Ecology Letters* **11**:609–623.
- Laikre, L., L. C. Larsson, A. Palmé, J. Charlier, M. Josefsson, and N. Ryman. 2008. Potentials for monitoring gene level biodiversity: using Sweden as an example. *Biodiversity and Conservation* **17**:893–910.
- Lande, R. 1995. Mutation and conservation. *Conservation Biology* **9**:782–791.
- Lynch, M., and R. Lande. 1993. Evolution and extinction in response to environmental change. Pages 234–250 in P. M. Kareiva, J. G. Kingsolver, and R. B. Huey, editors. *Biotic interactions and global change*. Sinauer Associates, Sunderland, Massachusetts.
- Lynch, M., J. Conery, and R. Burger. 1995. Mutation accumulation and the extinction of small populations. *The American Naturalist* **146**:489–518.
- Newman, D., and D. Pilson. 1997. Increased probability of extinction due to decreased genetic effective population size: experimental populations of *Clarkia pulchella*. *Evolution* **51**:354–362.
- O'Neill, J. 2001. Building better global economic BRICs. Global economics paper 66. The Goldman Sachs Group, New York.
- Ryman, N., and F. Utter, editors. 1987. *Population genetics and fishery management*. Washington Sea Grant Publications, University of Washington Press, Seattle, Washington. Reprinted 2009 by The Blackburn Press, Caldwell, New Jersey.
- Schonewald-Cox, C. M., S. M. Chambers, B. MacBryde, and L. Thomas, editors. 1983. *Genetics and conservation. A reference for managing wild animal and plant populations*. Benjamin/Cummings, Menlo Park, California.
- Schwartz, M. K., Luikart, G., and Waples, R. S. 2007. Genetic monitoring as a promising tool for conservation and management. *Trends in Ecology & Evolution* **22**:25–33.
- Swedish Environmental Protection Agency. 2008. Förslag till Nationellt handlingsprogram för bevarande av genetisk variation hos vilda växter, djur och svampar. Redovisning av ett regeringsuppdrag. (Suggestion for a national action plan for genetic variation in wild plants, animals, and fungi. Reply to the Swedish Government [in Swedish]) Swedish National Protection Agency, Stockholm.
- Whitham, T. G., et al. 2006. A framework for community and ecosystem genetics: from genes to ecosystems. *Nature Reviews* **7**:510–523.
- Wimp, G. M., W. P. Young, S. A. Woolbright, G. D. Martinsen, P. Keim, and T. G. Whitham. 2004. Conserving plant genetic diversity for dependent animal communities. *Ecology Letters* **7**:776–780.