

Improving risk assessment for biodiversity conservation

Preservation of biodiversity is a major ecological challenge to present and future generations (1). Success will largely depend on the optimal allocation of limited funding resources to the most relevant conservation projects. In a recent issue of PNAS, Ando and Mallory (2) proposed to tackle the problem with Modern Portfolio Theory (MPT), originally devised to balance risk and return on investments in the financial industry. Although their quantitative approach is a substantial step forward, reliable practical implementation will depend crucially on the ability to model climatic connectivities and estimate conservation risks as accurately as possible (1).

MPT (2) was introduced about sixty years ago for Gaussian portfolio models. Such Gaussian models can be fully characterized in terms of their mean values and covariance parameters, and they may provide a good description of portfolios that consist of a large number of idiosyncratic positions. Real portfolios, however, are often subject to systematic risks, and Gaussian models hardly ever reflect their returns correctly. Over the past decades, substantially improved modeling approaches (3) have been developed that should be used in the case of biodiversity conservation, because climate risks in different locations are not idiosyncratic but largely driven by global factors. Realistic models will involve heavy-tailed distributions and common explanatory variables or copulas to capture relevant aspects of the true geoclimatic dependence structure. Neglecting these modeling issues will lead to misleading conclusions (3).

Equally important are adequate risk measures. Traditional MPT (2) equates risk with variance, thereby assigning equal weight to downside and upside fluctuations. This approach may be useful when assessing the downside risk of symmetrical return distributions, but these are not likely to describe climate-related extinction threats. A better alternative could be the quantile-based measure value-at-risk (VaR). VaR focuses exclusively on downside risk by computing a loss threshold that

is only exceeded with a small, predetermined probability. However, VaR also suffers from deficiencies (4, 5). First, it is insensitive to rare extreme events that can be important to biodiversity conservation. Second, VaR often does not properly account for the benefits of diversification. To overcome these shortcomings, improved shortfall risk measures (SRMs) have been systematically developed and rigorously studied in the mathematical finance literature (4, 5) over the past decade.

In practice, one can estimate conservation risks more reliably by combining the innovative approach of Ando and Mallory (2) with such better behaved SRMs. The key step consists of replacing the optimality criterion of MPT, which is given in equation 1 in ref. 2: Instead of variance, coherent or convex SRMs (4, 5) should be minimized for fixed returns. Skewness and tail properties of relevant geoclimatic risk factors, as well as their dependence structure, can substantially shift the efficient frontiers (1, 2).

In conclusion, more research is needed to constrain the probability distributions of possible climate scenarios and to reveal the interdependencies between different geographic locations. Improved climate modeling and the application of refined SRMs will be essential for the design of optimal conservation policies to preserve biodiversity for the future.

Jörn Dunkel^{a,1} and Stefan Weber^b

^aDepartment of Applied Mathematics and Theoretical Physics, University of Cambridge, Cambridge CB3 0WA, United Kingdom; and ^bInstitut für Mathematische Stochastik, Leibniz Universität Hannover, 30167 Hannover, Germany

1. Hoekstra J (2012) Improving biodiversity conservation through modern portfolio theory. *Proc Natl Acad Sci USA* 109:6360–6361.
2. Ando AW, Mallory ML (2012) Optimal portfolio design to reduce climate-related conservation uncertainty in the Prairie Pothole Region. *Proc Natl Acad Sci USA* 109:6484–6489.
3. McNeil AJ, Frey R, Embrechts P (2005) *Quantitative Risk Management, Princeton Series in Finance* (Princeton Univ Press, Princeton).
4. Artzner P, Delbaen F, Eber J-M, Heath D (1999) Coherent measures of risk. *Math Finance* 9:203–228.
5. Föllmer H, Schied A (2011) *Stochastic Finance: An Introduction in Discrete Time, de Gruyter Studies in Mathematics* (Walter de Gruyter & Co., Berlin).

Author contributions: J.D. and S.W. wrote the paper.

The authors declare no conflict of interest.

¹To whom correspondence should be addressed. E-mail: jd548@cam.ac.uk.