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Taking Stock of Nature: Essential Biodiversity Variables Explained

Neil Brummitt[a*], Eugenie Regan[b,c], Lauren V. Weatherdon[b], Corinne S. Martin[b], Ilse R. Geijzendorffer[d], Duccio Rocchini[e], Yoni Gavish[f], Peter Haase[g], Charles J. Marsh[h], Dirk S. Schmeller[h,i, j]

[a] Department of Life Sciences, Natural History Museum, Cromwell Road, London, SW7 5BD, UK.

[b] United Nations Environment Programme World Conservation Monitoring Centre, 219 Huntingdon Road, Cambridge, CB3 0DL, UK.

[c] The Biodiversity Consultancy, 3 King's Parade, Cambridge, CB2 1SJ, UK

[d] Institut Méditerranéen de Biodiversité et d'Ecologie marine et continentale (IMBE) Aix Marseille Université, CNRS, IRD, Avignon Université, Technopôle Arbois-Méditerranée Bât. Villemin – BP 80, F-13545 Aix-en-Provence cedex 04, France.

[e] Fondazione Edmund Mach, Research and Innovation Centre, Department of Biodiversity and Molecular Ecology, GIS and Remote Sensing Unit, Via E. Mach 1, 38010 S. Micehle all'Adige (TN), Italy.

[f] School of Biology, Faculty of Biological Sciences, University of Leeds, Leeds LS2 9J6, UK.

[g] Senckenberg Research Institute and Natural History Museum Frankfurt, Department of River Ecology and Conservation, Clamecystr. 12, D-63571 Gelnhausen, Germany.

[h] Helmholtz Center for Environmental Research – UFZ, Department of Conservation Biology, Permoserstrasse 15, 04318 Leipzig, Germany.

[i] Université de Toulouse; UPS, INPT; EcoLab (Laboratoire Ecologie Fonctionnelle et Environnement); 118 route de Narbonne, 31062 Toulouse, France.

[j] CNRS, EcoLab, 31062 Toulouse, France.

*Corresponding author at: Department of Life Sciences, Natural History Museum, Cromwell Road, London, SW7 5BD, UK. Phone: +44 (0)20 7942 5000. E-mail address: n.brummitt@nhm.ac.uk (N. Brummitt).

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Highlights (3 to 5; max. 85 characters each):

- Measuring trends in biodiversity against tractable and achievable conservation goals is difficult.
- Essential Biodiversity Variables (EBVs) can coordinate biodiversity measurement.
- Confusion exists regarding the relationship between EBVs and indicators.
- A stock market analogy is presented as a powerful communication tool for explaining the EBV concept and their relationship to indicators of biodiversity change.

Abstract (max. 250 words):

In 2013, the Group on Earth Observations Biodiversity Observation Network (GEO BON) developed the framework of Essential Biodiversity Variables (EBVs), inspired by the Essential Climate Variables (ECVs). The EBV framework was developed to distill the complexity of biodiversity into a manageable list of priorities and to bring a more coordinated approach to observing biodiversity on a global scale. However, efforts to address the scientific challenges associated with this task have been hindered by diverse interpretations of the definition of an EBV. Here, the authors define an EBV as a critical biological variable that characterizes an aspect of biodiversity, functioning as the interface between raw data and indicators. This relationship is clarified through a multi-faceted stock market analogy, drawing from relevant examples of biodiversity indicators that use EBVs, such as the Living Planet Index and the UK Spring Index. Through this analogy, the authors seek to make the EBV concept accessible to a wider audience, especially to non-specialists and those in the policy sector, and to more clearly define the roles of EBVs and their relationship with biodiversity indicators. From this we expect to support advancement towards globally coordinated measurements of biodiversity.

Main text:

Much has changed since 1990, when biodiversity was only a minor consideration in environmental policy (Noss, 1990). The establishment of the Convention on Biological Diversity (CBD) at the Rio Earth Summit in 1992 brought biodiversity centre-stage. However, despite Contracting Parties' agreement on the UN Strategic Plan for Biodiversity 2011-2010, and associated Aichi Biodiversity Targets (Decision X/2), biodiversity has been and is still declining globally (Butchart et al., 2010; Tittensor et al., 2014). There are many reasons why international efforts are failing to halt biodiversity loss. One major obstacle is that the complexity of biodiversity (considerable species diversity, complex ecological interactions, numerous pressures interacting synergistically to impact multiple aspects of biodiversity, etc.) often makes it difficult to track trends in the state of biodiversity against tractable and easily achievable conservation goals (Brooks et al., 2014; Noss, 1990).

In 2013, the Group on Earth Observations Biodiversity Observation Network (GEO BON) developed the framework of Essential Biodiversity Variables (EBVs) (Pereira et al., 2013), inspired by the Essential Climate Variables (ECVs) (Doherty et al., 2009; GCOS, 2004). Similar to the ECVs, the EBV framework was developed to distill the complexity of biodiversity into a manageable list of priority measurements and to bring a more coordinated approach to observing biodiversity on a global scale. Major scientific challenges are faced when distilling biodiversity into a limited number of essential variables, including i) the identification of a single variable for a critical aspect of biodiversity, ii) the translation of information between different biological and geographical realms (e.g., terrestrial and marine), iii) the heterogeneity of methods and data for measuring and recording different components of biodiversity, and iv) the selection of appropriate units and scales of measurement to ensure comparability between EBVs.

Efforts to address these scientific challenges have been hindered by diverse interpretations of the definition of an EBV. This has arisen partly as a result of the rather broad original definition: "a measurement required for studying, reporting, and managing biodiversity change" (Pereira et al., 2013). A key next step is to resolve these conflicting interpretations so that the scientific community can develop EBVs based on a coherent and consistent understanding. The objective of this paper is to achieve such a common understanding in order to advance the development and implementation of EBVs to measure biodiversity change for research and policy. By communicating the value of EBVs we aim to connect the scientific community with those in the policy sphere who are familiar with biodiversity indicators but do not yet appreciate the added value of EBVs. Here, we define an EBV as a biological variable that critically contributes to the characterization of Earth's biodiversity; they are a minimum set of common, observable values across the various dimensions of biodiversity that can be used to create indicators of system-level biodiversity trends. We use a multi-faceted stock market analogy to advance towards a commonly shared and clear understanding of the EBVs concept and its position between raw observational data and biodiversity indicators. In using this analogy we highlight some challenges in EBV development and their importance to the implementation of an EBV-based monitoring programme.

There are multiple stock markets globally, each of which hosts thousands of registered stocks belonging to many different corporations. Within a stock market, it is impossible to look at the price of every stock individually to identify trends within the market, just as it is similarly unfeasible to determine biodiversity trends by looking at a multitude of individual EBV measurements for multiple species. Therefore, the overall performance of these registered stocks in a particular sector of the market is captured in an aggregated index, the stock market index. For example, the FTSE 100 index captures, at 15 second intervals, the weighted average of the total values of the top 100 companies on the London Stock Exchange; this index can then be tracked over time to measure fluctuations in the value and performance of those companies as a group. A change in a stock market index thereby functions as the barometer of the overall impact of the current business environment on individual companies within the index, reflecting the outcome of millions of trades by thousands of traders within a given market. Similarly, for biodiversity, we can use aggregated EBV data obtained for a selection of species, or 'stocks,' to perform calculations that yield a system-level index, thereby providing an overview of biodiversity trends over space and time in multiple species, locations and scales, albeit over slower time responses. An EBV is thus a critical biological variable that characterizes change in an aspect of biodiversity (e.g., species distribution, phenology, taxonomic diversity, etc.) across multiple species and ecosystems, functioning as the interface between raw data and the calculated index—in a way, analogous to the share price that characterizes a stock's performance.

Each stock market uses its own particular measure and its own share price valuation to value each stock (e.g., share price in U.S. dollars for the New York Stock Exchange, oil price per barrel in pounds sterling, etc.). By using a common currency, a stock market ensures that prices of stocks are directly comparable within the same market, and may thus be used as building blocks for a stock market index. Similarly, multiple indicators have been developed to track biodiversity trends against policy targets. Each index shows how one or more EBVs are changing by averaging or aggregating the change in EBV values of multiple 'stocks' (= species or ecosystems). Thus, similar to share prices within a given stock market, or within a single EBV, values for different species and ecosystems should be directly comparable with one another, which represents the main practical challenge to further developing the EBV concept.

To further illustrate this relationship, we use one of the most well-known global biodiversity indicators: the Living Planet Index (LPI) (Collen et al., 2009; Loh et al., 2005). The LPI measures system-level changes in aggregated population size (using the EBV 'Population Abundance' within the EBV class 'Species Populations') of vertebrate species over large regions of the world. The population size is a measure of the 'health' of a population, and is equivalent to the price of a company's stock. Populations are re-assessed at different points in time by counting or estimating the number of individuals, ideally using a standardized methodology that is comparable across time frames. The LPI works analogously to a stock market index, where each species is equivalent to a different company's registered stock (Figure 1): both examples use an essential variable ('population size' or 'share price') to perform multiple calculations that yield an index of aggregated trends within a system. This does not indicate that prices of shares for every stock are increasing, but rather that the overall system—the stock market—accurately represents changes in the cumulative share prices of many different stocks. With the LPI, it tells us that species populations globally are declining, but not necessarily which species or where, or that all species are in decline.

Similarly, the UK Phenology Network's UK Spring Index (DEFRA, 2014a) is an index that tracks phenological changes in the annual mean observation date of four biological events (the EBV 'Phenology' within the EBV class 'Species Traits'). These annual events include the first sighting of a swallow (*Hirundo rustica*), the first recorded flight of an orange-tipped butterfly (*Anthocharis cardamines*), the first flowering of horse chestnut (*Aesculus hippocastanum*), and first flowering of hawthorn (*Crataegus monogyna*) (DEFRA, 2014a). The indicator shows system-level trends in climate-induced changes in the timing of phenological events, and can contribute to assessments of progress towards reducing pressures on biodiversity and meeting Aichi Target 10 in the CBD's Strategic Plan (DEFRA, 2014b). These four phenological events are thus analogous to the share prices of only four stocks within this index.

Distilling the complexity of biodiversity into measurable EBVs additionally enables us to compare between regions, between different taxonomic groups, and between different aspects of biodiversity. In the case of the EBV 'Population Abundance' used to create the LPI, a species may have many different populations, each of which may be measured independently. In some cases, some populations may be increasing in number while other populations are declining. This would be analogous to a company having stocks registered on different stock exchanges in different parts of the world, each with different share prices (e.g., the FTSE 100, "Dow Jones" Industrial Average or Nikkei 225 indexes for London, New York and Tokyo). Reporting on species populations under the same common EBV allows comparison and harmonization of biodiversity measurements, thereby facilitating the evaluation of progress towards global biodiversity targets.

In a stock market, values of different stocks are partially dependent upon each other, since investment in one stock comes at the expense of investment in another stock. However, the value of the stock is also dependent upon external factors such as the quality of the products the company produces relative to those of a competitor. The value of the stock thus provides valuable information on the potential return on investment for a given investor. Similarly, with EBVs there is a degree of dependence between the values of different EBVs, since species in an ecosystem are linked ecologically and each may contribute data to several EBVs, but also because the resources available for conservation are finite: investing funds in one species or region often comes at the expense of investing in another. Investing in a particular stock may therefore cause that stock to rise and another to decline; similarly, measures of EBVs may also be used to prioritize conservation actions and to assess the return on investment through monitoring changes in those EBVs.

This analogy aims to provide clarification regarding the fundamental differences between raw observational data, EBVs, and indicators, and is not intended for deeper comparison. While it is easy to draw parallels between individual stocks, species, and phenological events, these become more challenging when exploring EBVs that may influence each other (Schmeller et al., this volume). Hence, the analogy does not reflect the complexity of drawing comparisons between different properties of biodiversity: for example, in stock markets, currencies can often be substituted without losing meaning, while this is only rarely the case in biodiversity measures, where conversion of different measurement units may lead to the loss of critical information.

Two big challenges remain in implementing the EBV approach to biodiversity monitoring: the first is the practical need to record data in a more systematic and comparable manner over larger spatial and temporal scales, especially in regions without much capacity to do so; the other is technical, making sure that these data are going to be inter-operable, otherwise they cannot be used to infer wider trends. A corresponding example from ecology is perhaps instructive here. Over many decades one of the principle aims of ecological theory was the appropriate measurement of biological diversity. Differences in the formulation and interpretation of diversity indices, of which the two most well-known and widely used are still Shannon's and Simpson's diversity, together with subtle distinctions in the questions being asked, resulted in the generation of a plethora of different indices (Tuomisto, 2010a) whose values could not be directly compared (Tuomisto, 2010b). Transforming these indices instead into effective (Hill) numbers (the number of equally abundant species necessary to produce the observed value of diversity, similar to the concept of effective population size in genetics) allows them to be compared with each other (Jost 2006) and clarifies the differences between them (Tuomisto 2010c). We believe that developing a suitable effective number framework for separate EBVs (e.g. Chao et al. 2014) holds great promise for integrating diverse data that measure different aspects of diversity in different units and over different spatio-temporal scales.

Just as the stock market index guides investors in making investment decisions, the EBV framework enables the prioritization of biodiversity monitoring efforts and the collation and harmonisation of biodiversity data, and also facilitates reporting on trends in biodiversity for decision-making in the policy sphere. For the framework to be effective, it needs to be clear, understandable, and useful. The stock market analogy presented here clarifies the relationship between EBVs and indicators: a biodiversity indicator or index is analogous to a stock market index that measures the system-level change over time of one or more variables, or EBVs, while an EBV is equivalent to the share price of a stock, characterizing a value attributed to biodiversity. The EBV framework supports a coordinated approach to biodiversity measurement and thereby translates key trends in biodiversity into understandable, tangible storylines for decision-makers, removing a potential barrier to effective conservation action. EBVs—by themselves or when contributing to indicators—can provide early warning signs on the state and trajectory of the natural world. Such early warning signals facilitate the possibility of timely information on biodiversity trends and policy impacts.

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References

Brooks, T.M., Lamoreux, J.F., Soberón, J., 2014. IPBES ≠ IPCC. Trends Ecol. Evol. 29, 543–5. doi:10.1016/j.tree.2014.08.004

Butchart, S.H., Walpole, M., Collen, B., van Strien, A., Scharlemann, J.P.W., Almond, R.E., Baillie, J.E.M., Bomhard, B., Brown, C., Bruno, J., Carpenter, K.E., Carr, G.M., Chanson, J., Chenery, A.M., Csirke, J., Davidson, N.C., Dentener, F., Foster, M., Galli, A., Galloway, J.N., Genovesi, P., Gregory, R.D., Hockings, M., Kapos, V., Lamarque, J.-F., Leverington, F., Loh, J., McGeoch, M.A., McRae, L., Minasyan, A., Hernandez-Morcillo, M., Oldfield, T.E., Pauly, D., Quader, S., Revenga, C., Sauer, J.R., Skolnik, B., Spear, D., Stanwell-Smith, D., Stuart, S.N., Symes, A., Tierney, M., Tyrrell, T.D., Vié, J.-C., Watson, R., 2010. Global Biodiversity : Indicators of recent declines. Science . 328 (5982), 1164–1169. doi: 10.1126/science.1187512

Chao, A., Chiu, C.H., Jost, L., 2014. Unifying species diversity, phylogenetic diversity, functional diversity, and related similarity and differentiation measures through Hill numbers. Annual Review of Ecology, Evolution, and Systematics 45, 297–324.

Collen, B., Loh, J., Whitmee, S., McRae, L., Amin, R., Baillie, J.E.M., 2009. Monitoring Change in Vertebrate Abundance: the Living Planet Index. Conserv. Biol. 23, 317–327. doi:10.1111/j.1523-1739.2008.01117.x

DEFRA, 2014a. UK Biodiversity Indicators 2014: Measuring progress towards halting biodiversity loss. London (UK). URL: http://jncc.defra.gov.uk/pdf/UKBI2014.pdf

DEFRA, 2014b. Climate change impacts and adaptation, in: Reducing Pressures. p. 4 pp.

Doherty, S.J., Bojinski, S., Henderson-Sellers, A., Noone, K., Goodrich, D., Bindoff, N.L., Church, J., Hibbard, K., Karl, T.R., Kajfez-Bogataj, L., Lynch, A.H., Parker, D.E., Prentice, I.C., Ramaswamy, V., Saunders, R.W., Stafford Smith, M., Steffen, K., Stocker, T.F., Thorne, P.W., Trenberth, K.E., Verstraete, M.M., Zwiers, F.W., 2009. Lessons Learned from IPCC AR4: Scientific Developments Needed to Understand, Predict, and Respond to Climate Change. Bull. Am. Meteorol. Soc. 90, 497–513. doi:10.1175/2008BAMS2643.1

GCOS, 2004. Implementation plan for the global observing system for climate in support of the UNFCCC, World Meteorological Organization.

Jost, L., 2006. Entropy and diversity. Oikos 113 (2), 363–375.

Loh, J., Green, R.E., Ricketts, T., Lamoreux, J., Jenkins, M., Kapos, V., Randers, J., 2005. The Living Planet Index: using species population time series to track trends in biodiversity. Philos. Trans. Biol. Sci. 360, 289–295. doi: 10.1098/rstb.2004.1584

Noss, R.F., 1990. Indicators for Monitoring Biodiversity: A Hierarchical Approach. Conserv. Biol. 4, 355–364. doi:10.1111/j.1523-1739.1990.tb00309.x

Pereira, H.M., Scharlemann, J.P.W., Walters, M., Geller, G., Jongman, R.H.G., Scholes, R.J., Bruford, M.W., Brummitt, N., Butchart, S.H.M., Cardoso, A.C., Coops, N.C., Dulloo, E., Faith, D.P., Freyhof, J., Gregory, R.D., Heip, C., Höft, R., Hurtt, G., Jetz, W., Karp, D.S., McGeoch, M.A., Obura, D., Onoda, Y., Pettorelli, N., Reyers, B., Sayre, R., Scharlemann, J.P.W., Stuart, S.N., Turak, E., Walpole, M., Wegmann, M., 2013. Essential biodiversity variables. Science 339 (6117): 277–278. doi:10.1126/science.1229931

Tittensor, D.P., Walpole, M., Hill, S.L.L., Boyce, D.G., Britten, G.L., Burgess, N.D., Butchart, S.H.M., Leadley, P.W., Regan, E.C., Alkemade, R., Baumung, R., Bellard, C., Bouwman, L., Bowles-Newark, N.J., Chenery, A.M., Cheung, W.W.L., Christensen, V., Cooper, H.D., Crowther, A.R., Dixon, M.J.R., Galli, A., Gaveau, V., Gregory, R.D., Gutierrez, N.L., Hirsch, T.L., Hoft, R., Januchowski-Hartley, S.R., Karmann, M., Krug, C.B., Leverington, F.J., Loh, J., Lojenga, R.K., Malsch, K., Marques, A., Morgan, D.H.W., Mumby, P.J., Newbold, T., Noonan-Mooney, K., Pagad, S.N., Parks, B.C., Pereira, H.M., Robertson, T., Rondinini, C., Santini, L., Scharlemann, J.P.W., Schindler, S., Sumaila, U.R., Teh, L.S.L., van Kolck, J., Visconti, P., Ye, Y., 2014. A mid-term analysis of progress towards international biodiversity targets. Science. 346 (6206), 241–244.

doi:10.1126/science.1257484

Tuomisto, H., 2010a. A consistent terminology for quantifying species diversity? Yes, it does exist. Oecologia 164(4), 853–860.

Tuomisto, H., 2010b. A diversity of beta diversities: straightening up a concept gone awry. Part 1. Defining beta diversity as a function of alpha and gamma diversity. Ecography 33(1), 2–22.

Tuomisto, H., 2010c. A diversity of beta diversities: straightening up a concept gone awry. Part 2. Quantifying beta diversity and related phenomena. Ecography 33(1), 23–45.

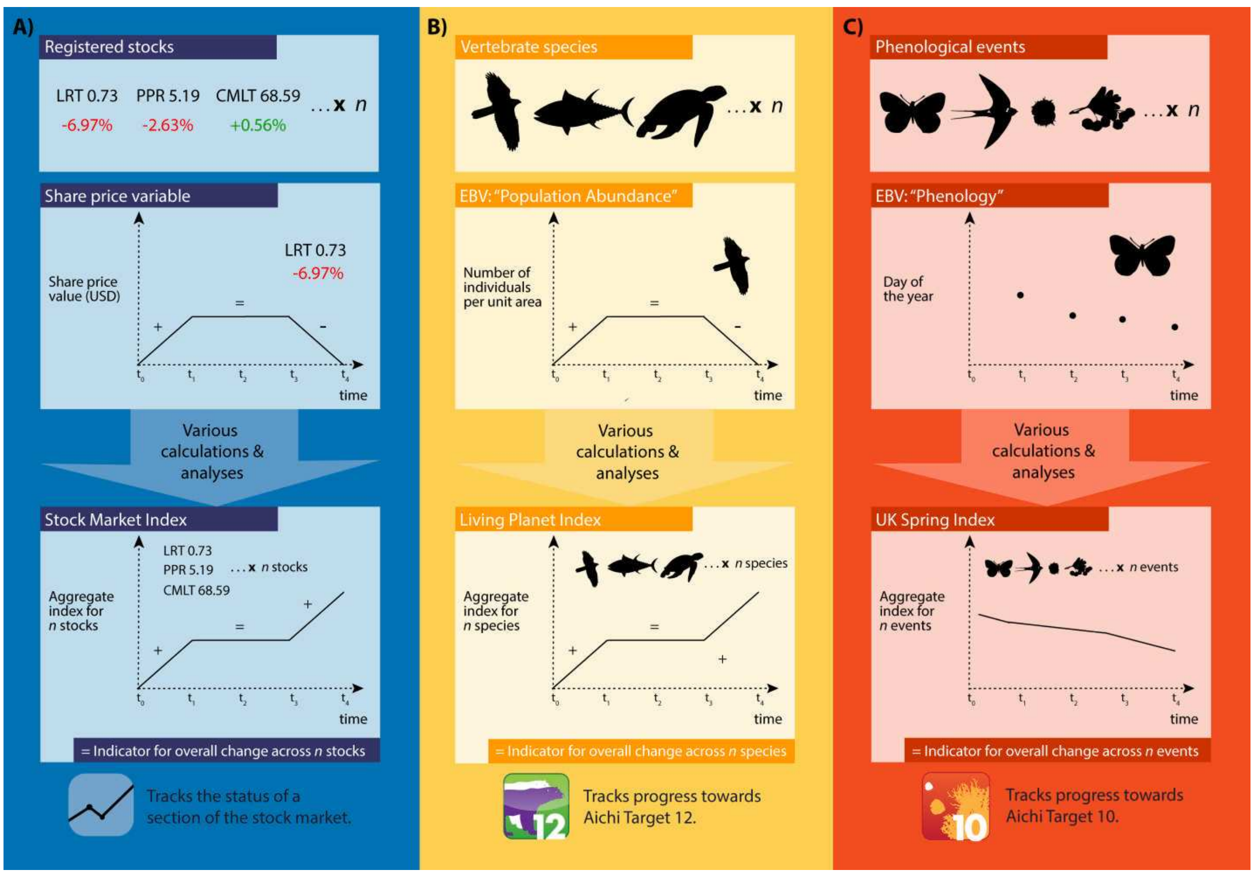

Fig. 1. **Hypothetical scenarios to reflect analogy between (A) the Stock Market Index, (B) the Living Planet Index, or LPI, and (C) the UK Phenology Network's UK Spring Index.** The LPI (B) uses the 'Population Abundance' EBV (Essential Biodiversity Variable) for multiple vertebrate species (Collen et al., 2009; Loh et al., 2005), and is being used to track progress towards Aichi Target 12 ("By 2020, the extinction of known threatened species has been prevented and their conservation status, particularly of those most in decline, has been improved and sustained") of the UN Strategic Plan for Biodiversity 2011-2010. The UK Spring Index (C) uses the 'Phenology' EBV to track phenological changes in the annual mean observation date of four biological events: first recorded flight of an orange-tipped butterfly (*Anthocharis cardamines*), the first sighting of a swallow (*Hirundo rustica*), first flowering of horse

chestnut (*Aesculus hippocastanum*), and first flowering of hawthorn (*Crataegus monogyna*) (DEFRA, 2014a). These changes are being used to track pressure from climate change and progress towards Aichi Target 10 ("By 2015 the multiple anthropogenic pressures on coral reefs, and other vulnerable ecosystems impacted by climate change or ocean acidification are minimized, so as to maintain their integrity and functioning").