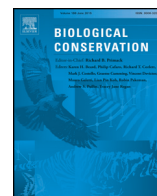




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## Taking stock of nature: Essential biodiversity variables explained

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## ABSTRACT

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.

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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)

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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 (see also Proença et al., 2016). 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 s 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, and taxonomic diversity) 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 when measured over time.

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, and oil price per barrel in pounds sterling). 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 (Fig. 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

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