Biological Conservation 144 (2011) 1392–1399

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

Long-term trends in the abundance of Mediterranean wetland vertebrates: From global recovery to localized declines

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ARTICLE INFO

Article history:
Received 12 May 2010
Received in revised form 30 September 2010
Accepted 7 October 2010
Available online 8 February 2011

Keywords:
Biodiversity indicator
2010 target
Conservation biogeography
Living Planet Index
Population abundance
Time series

ABSTRACT

Biodiversity loss is unevenly distributed in space and time. Species have reached critically low population sizes in some areas, and remain abundant in others. Similarly, some species may benefit from successful conservation plans, while others still experience severe population depletions driven by negative impacts of human activities. Although several indicators have been proposed to measure the fate of biodiversity, they are generally only implemented globally so their relevance for regional assessment is still unclear. Here, we calculated the first regional trend in the Living Planet Index for the Mediterranean wetlands (Med LPI), an indicator that summarizes the fate of global biological diversity based on the temporal trends in abundance of vertebrate populations. The Med LPI was based on 1641 vertebrate populations of 311 species recorded in Mediterranean wetlands from 1970–2008, in 27 different countries. We investigated whether trends in the Med LPI differed between eastern and western Mediterranean countries, which have different socio-economic contexts. Finally, we assessed whether and how the trend in the Med LPI was robust to changes in the number and identity of species considered. We found that, at the Mediterranean scale, the Med LPI increased steeply, which could be taken at first sight, as a general recovery of wetland biodiversity in this biogeographical region. However, we found highly contrasting spatial trends within the Mediterranean region: the average trend was positive for western and negative for eastern countries. Moreover, we showed that depending on the method used to estimate the trend in Med LPI, it can be sensitive to the number and identity of the species considered. We suggest that understanding the regional discrepancies of the trend in biodiversity indicators as well as their robustness to the species represented in the index will enhance progress assessment towards global and regional conservation strategies.

1. Introduction

Most governments have identified reducing the rate of biodiversity loss as one of their global priorities (the CBD 2010 target, Balmford et al., 2005a). Large-scale conservation assessments are thus necessary to provide a general perspective on the current and projected status of biodiversity (Whittaker et al., 2005; Brooks et al., 2006). Hopefully, global conservation strategies have recently benefited from the increasing number of studies investigating spatial patterns in biodiversity, helping the evaluation of global conservation priorities (Ferrier et al., 2004).

However, measuring large-scale and long-term trends in biodiversity remains a challenging issue for two main reasons. First, the range of taxa and biomes covered by standardized monitoring schemes are incomplete and biased (Balmford et al., 2005b). In particular, trends in biodiversity are mainly based on records of temperate rather than tropical areas (Collen et al., 2008), on the fate of the terrestrial megafauna and megaflora, and on few taxonomic groups. Second, biodiversity is multifaceted and there is a common agreement that no single biodiversity indicator will ever summarize the fate of biodiversity and its relationship with human pressures (Purvis and Hector, 2000). Although the relevance of any biodiversity indicators obviously depends on the question being addressed and on the data available (Baillie et al., 2008), robust and consensual measures of progress towards the 2010 target are still missing (Walpole et al., 2009).

Among available biodiversity indicators, aggregated indices of multi-sites and multi-species trends have become one of the best available proxies for measuring trends in biodiversity (Balmford

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doi:10.1016/j.biocon.2010.10.030

et al., 2003). In this respect, the Living Planet Index (LPI) has been developed to provide policy-makers, scientists, and the general public with information on trends in the abundance of vertebrate populations from around the world (Loh et al., 2005). The LPI was shown to be a heuristic instrument reflecting the fate of global biodiversity, but also in which ecosystems species are declining most rapidly (Collen et al., 2008).

The strength of such composite indices is that they are simple to communicate while providing sensitive measures of biodiversity change, and flexible enough to handle data from different sources, collected with a variety of methods, and at several scales (de Heer et al., 2005). The LPI was thus adopted as a key indicator of the state of global biological diversity at the international level, and is one of the indicators selected by the Convention on Biological Diversity as a tool for measuring progress towards the 2010 target (Balmford et al., 2005a). However, research has principally focused on species declines and/or extinctions either at site level, local or very global scales, while the comparisons of biodiversity's fate across different biogeographical contexts of land-use, climatic, and conservation history are far less common.

In this respect, assessing the long-term trend in abundance of vertebrate populations in Mediterranean wetlands is particularly relevant for several reasons. First, the Mediterranean region represents major biogeographic cross-roads in which the paleogeography and historical land-use have created a complex mosaic of habitats with high species richness, high spatial turnover in biodiversity and high rate of endemism (Médail and Quézel, 1999). Second, the Mediterranean and Black Sea wetlands are experiencing increasing pressure from human activities such as urbanization, tourism, changes in natural flood regime, drainage, pollution, and agricultural intensification (Underwood et al., 2009; Eglington et al., 2008). This has led the Mediterranean basin to be recognized as one of the first 25 Global Biodiversity Hotspots (Myers et al., 2000). Third, as Mediterranean wetlands are physically and socially connected, ecological processes occur over a much wider territory than a particular site or country (Amezaga et al., 2002).

Assessing the general trend in biodiversity in the Mediterranean wetlands should help to justify and stimulate better local conservation targets and improve short and long-term global land-use planning (Spector, 2002). The method used to create the global LPI can also be applied at sub-global scales to measure trends in the status of biodiversity for any given set or group of species and/or any geographic scale, provided that sufficient data are available. Aggregated trend indices have thus been generated for biogeographic realms, biomes, habitats, for particular taxonomic groups, and for certain countries (Collen et al., 2009; McRae et al., 2008). Yet, an overall biodiversity assessment is missing for the Mediterranean wetlands for which only the fates of particular groups and/or a particular country or site have been investigated (e.g. Moroccan waterbirds, Green et al., 2002). Therefore, comparing trends in biodiversity among different biogeographic regions within the Mediterranean basin may be useful to discern between different drivers of biodiversity change. Moreover, whether the general trend in such a biodiversity indicator is sensitive to the particular number and identity of species considered has not been explicitly tested.

Here, we address four main objectives: (1) investigating the long-term trend in the LPI for Mediterranean wetlands considered as a whole, (2) assessing whether the general trend is similar at sub-regional levels among eastern and western Mediterranean countries. (3) Regardless of any trends, some regions can be of critical conservation importance in being the stronghold for many species. We thus also compared the eastern versus western population sizes of species present in both regions. (4) Finally, we tested the robustness of the trend in the Med LPI to changes in the species considered.

2. Methods

2.1. Population data

We collected time series of total population numbers or proxies for estimate of population sizes (e.g., counts, density measurements, biomass, and number of nests) and taken from different sources. To be included in LPI calculation, data had to fit a number of criteria, following Collen et al. (2009). In brief, population size must be monitored for at least 2 points in time, the geographic location of the population as well as the data source must be available, and data must have been collected using the same method on the same population throughout the time series. We collated vertebrate population time-series published in scientific journals, or in scientific reports, books and websites of non-governmental organizations and focused on data for which a special standardization effort had been made explicit (e.g. population surveys, restoration programs, protected area assessment). We stopped collecting data when the inclusion of new time series was negligible compared to those already collected.

We collected time series for 1641 georeferenced vertebrate populations with at least two data points between 1970 and 2008. These populations covered 311 vertebrate species (among which 247 bird species, 36 freshwater fishes, 12 amphibians, 8 mammals, and 8 reptiles). These species were monitored in 27 countries distributed across the Mediterranean basin including Black sea (Fig. 1). Although still incomplete (overall, 1245 vertebrate species are known to occur in the Mediterranean basin), our dataset include the more well-monitored species of different taxonomic groups which have a range of ecology and sensitivity to human impact. Therefore, we believe that this dataset provides a good synthesis of the trends in major vertebrate populations currently monitored in the Mediterranean wetlands.

2.2. Calculating aggregated trends in abundance

Two alternative methods were used to calculate a trend in the Med LPI: (i) the chain method (Loh et al., 2005), with generalized additive modeling techniques (GAM) (Collen et al., 2009) and (ii) linear mixed modeling. In the first approach, the trend in the index is estimated following three steps (see Collen et al., 2009 for more details). First, for each species, the average change in population from each year to the next was calculated. In case of incomplete time-series, zero values were first replaced by one percent of the mean population measure value for the whole time series. Then, the population sizes for these years were derived from interpolation of the preceding and the subsequent years with measured values (see Collen et al., 2009; Craigie et al., 2010) as follows. For time series with six or more population measures we implemented Generalized Additive Models (GAMs), following Collen et al. (2009). GAMs are extension of classical linear models in which the predictor is not restricted to be linear but is the sum of smoothing functions. For long time-series, this smoothing approach better describes non-linear temporal variations in populations' sizes. Those time series with five or fewer population measures were estimated through log-linear models.

Second, the trends of all populations of the same species were averaged to produce species-specific trends. Third, the average rate of change in each year across all species was calculated. Finally, the average annual species change in each year was chained to the previous one to make a continuous index, starting with an initial value of 1 in 1970. Note that in these approaches, equal weighting are given to each species within the index. Precision of the estimates was accounted by means of 95% confidence intervals generated using a bootstrap technique in which 1000 index values are