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Waterbird communities adjust to climate warming according to conservation policy and species protection status☆

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ABSTRACT

Climate change is one of the strongest biodiversity threats. Worse still, the impact of multiple anthropic stressors on species dynamics could complicate adaptation to temperature increase. International conservation policies aim to protect ecosystems against anthropic pressures, but their ability to facilitate adaptation to climate change has yet to be assessed. Using wetland bird monitoring surveys, we evaluated the differences at the country scale of community adjustment to temperature increase of wintering waterbird communities (145 species) according to the implementation of the two main western Palearctic international conservation policies (Bern Convention and Birds Directive) in the Mediterranean basin (2786 sites, 22 countries) over a 22-year period. We showed that thermic community composition increases over time in countries which have enforced conservation policies. We found that strictly protected species under the Birds Directive and the Bern Convention contributed more to this community adjustment than the not strictly protected species. The mechanism results from a population increase in protected warm-dwelling species but not from a decline in cold-dwelling species. This study supports the ability of international conservation policies to mitigate the effect of climate change on animal communities.

1. Introduction

Climate change is an ongoing major threat to biodiversity (Scheffers et al., 2016). Species can show various responses: from adaptation and range shifts to declines and sometimes extinction (Thomas et al., 2004). However, multiple concomitant stressors such as habitat loss, degradation and overexploitation that act at global scale (Maxwell et al., 2016) are suspected to limit adaptations to climate warming (Sirami et al., 2016; Currie and Venne, 2017). International conservation policies are major legal instruments designed to reduce or control global threats to biodiversity (Donald et al., 2007; Sanderson et al., 2016). By reducing some anthropogenic pressures, conservation policies should facilitate species adaptation to temperature increase (Trouwborst, 2011, but see Mazaris et al., 2013). Their efficiency against biodiversity erosion is strongly supported (Donald et al., 2007; Hoffmann et al., 2010; Gamero et al., 2017; Orlikowska et al., 2016; Sanderson et al., 2016), but how much they could facilitate climate change adaptation through distribution shifts remains poorly explored and generally disputable (Trouwborst, 2011; van van Teeffelen et al., 2015; Thomas and Gillingham, 2015). For example, the network of Natura 2000 sites across the European Union would be not sufficient to ensure connectivity and climate change adaptation of species (van Teeffelen et al., 2015), even if protected areas have been identified as promoting community adjustment to temperature increase, i.e. species turn-over depending on their thermic affinity (Gaüzère et al., 2016). This lack of assessment is largely due to a difficulty to evaluate the pattern of responses of a large number of species targeted by international conservation policies at large temporal and spatial scales (van Teeffelen et al., 2015).

Since 1967, Wetlands International (WI) has coordinated an annual international waterbird census – one of the oldest international monitoring programs at a global scale, involving professionals and citizen volunteers. Data from this survey could be used to assess how conservation policies have affected the way wintering waterbirds respond to climate change (Amano et al., 2018). Within one of the largest world migration flyways, millions of waterbirds stopover or overwinter around the Mediterranean basin, a region which faces rapid environmental degradation (Newbold et al., 2015) as well as a substantial

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temperature increase (Mariotti et al., 2015; Guiot and Cramer, 2016). Because waterbirds depend on fragile ecosystems (Brinson and Malvárez, 2002), namely wetlands, and are important game species during winter and migration (Birdlife, 2013; Green and Elmberg, 2014; Brochet et al., 2016), they require international cooperation to ensure their conservation across breeding and wintering distribution ranges (AEWA, 2015). Accordingly, they are one of the first taxonomic groups to have benefitted from the two main international conservation policies implemented in the western Palearctic: the European Union's Wild Birds Directive (BD, 79/409/EEC) and the Convention on the Conservation of European Wildlife and Natural Habitats, or Bern Convention (BC, 19.IX.1979). However, the effect of these policies on waterbird community adjustment to temperature increase remains undervalued (Pearce-Higgins et al., 2014).

Here, we examine the ability of waterbird communities wintering in the Mediterranean to adjust their species composition to temperature increase depending on the implementation of two international conservation policies, the Birds Directive and the Bern Convention. We use data on 145 species from the WI dataset, surveyed across 22 years and 2786 sites distributed within 22 countries with varying uptake of BD and BC conservation policies, for about 100 million birds counted. Using the Community Temperature Index (CTI, Devictor et al., 2008), we measure the thermic adjustment of waterbird communities to the increase of winter temperatures for each country, for groups of countries that are (i) Member States of the European Union, enforcing the BD, (ii) and/or Contracting Parties to the BC, (iii) or neither (hereafter "BD-BC", "BC", "No-BD No-BC"), (iv) and for the entire Mediterranean basin. We test whether the contribution of strictly and not strictly protected species to the CTI trends differs depending on their protection status. We hypothesize that i) CTI trends have increased inside, but not outside, the Member States of the EU (BD) and Contracting Parties to the BC, ii) strictly protected species have contributed more to the CTI increase than not strictly protected species, and iii) this difference in contribution disappears in the countries which are not Member States of the EU or not Contracting Parties to the BC.

2. Material and methods

2.1. Waterbird monitoring data

Waterbird counts were performed as part of the International Waterbird Census (IWC), coordinated by Wetlands International (www.wetlands.org). Each year thousands of wetlands are monitored in January, providing one count event per site per year (Delany, 2005). We used data collected between 1991 and 2012 as they cover the whole waterbird community, not only Anatidae as during earlier periods. We focused on sites (wintering waterbird communities) located around the Mediterranean basin (30°N; 45°N; 10°W; 40°E; IPCC, 2014), distributed across 22 countries (Fig. 1). We retained only sites with at least two count events across the 22-year period. We then selected waterbird species as defined by the Agreement on the Conservation of African-Eurasian Migratory Waterbirds (AEWA, http://www.unep-aewa.org), totalling 145 species. Considering recent taxonomic changes and their complicated specific identification, *Larus michahellis*, *L. cachinnans*, *L. armenicus* and *L. argentatus* were all lumped into one 'species'. A total of 2786 sites have been retained, totalling 25,722 count events and 98.9 million birds.

2.2. Species Temperature Index

To calculate the Community Temperature Index (CTI), we used the Species Temperature Index (STI) which is a species-level measure of climate envelope based on the long-term average temperature over a species range (Devictor et al., 2008). This index is species dependent and, for each species, is a single value estimated across the entire geographical range. The STI is a straightforward niche metric to predict species responses to climate change (Devictor et al., 2012; Stuart-Smith et al., 2015) both for breeding and wintering birds (Godet et al., 2011; Devictor et al., 2012). We computed a winter STI following Godet et al. (2011) as the average of the mean temperature of January (1960–1990, WorldClim database http://worldclim.org/) across the wintering range of each species (winter range maps extracted from BirdLife International datazone, www.birdlife.org 2015) within the geographical zone defined by AEWA (Table S1).

In order to assess whether CTI trends were driven by an increase in warm-dwelling species and/or a decrease in cold-dwelling species, we calculated specific relative thermic originalities for each country. The "relative thermic originality" of a species is the distinctness of a species' thermic affinity (STI) compared to other species of the studied area (here country). It is obtained as the difference between the STI of a species i and the average CTI of this area: warm-dwelling species have a positive relative thermic originality and cold-dwelling species have a negative relative thermic originality. For example, if the average CTI is +10 in a country and the STI of a species +15, the relative thermic originality for this 'warm-dwelling' species in this country is +5. Consequently a warm-dwelling species in France could be a cold-dwelling species in Tunisia, like *Aythya ferina* or *Calidris alpina*.

2.3. Bird protection status

We focused on two major international conservation policies dedicated at least partly to the protection of waterbirds: the Birds Directive (BD, 91/244/EEC) and the Bern Convention (BC, 19.IX.1979).

The Birds Directive and the Bern Convention aim to maintain all bird populations in a favorable conservation status "at a level which corresponds to ecological, scientific and cultural requirements, while taking account of economic and recreational requirements, or to adapt the population of these species to that level" (79/409/EEC, 19.IX.1979). Both BD and BC ensure bird conservation by two protection tools; direct protection from harvesting and indirect protection from habitat destruction or degradation. Hunting is prohibited for species listed in BD Annex I (BD-I) and BC Appendix II (BC-II), including no disturbance harming their favorable conservation status (exceptions are possible in particular cases). Conversely, species listed in BD-II and BC-III can be hunted, but their exploitation must be regulated in order to keep the populations out of danger (for example by closing seasons or temporary/local hunting ban). However, Member States of the EU (Birds Directive) can hunt the species listed in the BD-II part 2 only in indicated countries, and species listed in the BD-III require an assessment of their conservation status by the Commission before exploitation. Habitat conservation (through the designation of protected areas to creation of biotopes) is required for all bird species to ensure a favorable conservation status, particularly for species listed in BD-I and BC-II. Special attention is also given to areas regularly used by migratory birds (including those in BD-II and BC-III), notably wetlands and particularly wetlands of international importance.

Despite such potential differences in hunting legislation between species listed in BD-II (see above), we separated waterbirds in two categories. Species 'strictly protected', are species not hunted, listed in BD-I (56 species) and in BC-II (74 species). Species 'not strictly protected' regroup species listed in BD-II (44 species), the species not evaluated in the BD (45 species) and the species listed in BC-II (71 species). In countries where both BD and BC are applied, 63 species are 'not strictly protected'. In an EU Member State (see next paragraph), species were considered as 'strictly protected' if they were strictly protected at least by one of the two policies, like *Aythya nyroca* and *Vanellus spinosus* (protected in BD only). Three species are listed both in BD-I and BD-II (*Anser albifrons*, *Philomachus pugnax* and *Pluvialis apricaria*) and were considered here both as "strictly" and "not strictly" protected.