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Review article

A global review identifies agriculture as the main threat to declining grassland birds

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Grasslands are globally threatened and their biodiversity, including grassland birds, is declining markedly. To inform grassland bird conservation globally, we systematically reviewed threats and conservation actions for grassland birds, extracting data from 528 papers. Across the 10 primary grassland regions of the globe, agriculture was the most frequently or joint most frequently reported threat in nine regions (reported as a threat in 73% of publications); hunting was the most frequently reported threat in the remaining region. Natural system modifications (reported as a threat in 32% of publications) and climate change and severe weather (24%) were less frequently reported threats compared with agriculture. The types of threat from agriculture varied regionally, but the most pervasive were livestock farming and ranching (reported in 58% of publications where agriculture was a primary threat) and non-timber cropping (43%). Most agricultural threats relate to intensification, but agricultural abandonment, typically the cessation of grazing, sometimes accompanied by tree planting/succession, poses an emerging threat to some grassland birds (reported in 32% of publications where agriculture was a primary threat). The most frequent conservation actions implemented to date include land/water management and protection, and species-specific management actions. Authors of reviewed publications in almost all regions recommend more land/water management, followed by calls for further land/water protection. The parlous state of grassland birds globally suggests that existing conservation actions for grasslands are inadequate. Furthermore, our review suggests that these should be primarily targeted at

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reversing the negative impacts of agriculture, in particular livestock farming and cropping.

Keywords: climate change, conversion, grazing, hunting, intensification, land use..

Around 75% of the global land surface has been significantly altered by human activities, and most indicators demonstrate declines in ecosystem integrity and biodiversity (IPBES 2019). Globally, one of the most threatened habitats is grasslands, found on every continent except Antarctica and estimated to cover 26% of global land, second only to forests in area (Panunzi 2008). Natural and anthropogenically modified grasslands supply essential ecosystem services including water provision, carbon sequestration and biodiversity (Neary & Leonard 2020).

Grasslands are, however, highly threatened, due largely to habitat loss and inadequate protection (Hoekstra *et al.* 2005). These threats to grasslands include changes in agricultural intensity (Squires *et al.* 2018); in southern Africa, for example, 23% of grassland biomes are now under cultivation, 60% have been irreversibly transformed, only around 2–4.5% are formally protected with most of the remainder used for livestock grazing, with only around 3.6% in a natural or intact state (Fairbanks *et al.* 2000, Maphisa *et al.* 2017, Skowno *et al.* 2019). Similarly, vast areas of other major grasslands such as the Eurasian steppe (Kamp *et al.* 2011) and North American prairies (Comer & Hoagland 2020) have been converted for cultivation and/or domestic livestock grazing. Further threats include habitat loss and degradation to infrastructure development for mining, energy generation and urbanization, fragmentation, shrub and tree encroachment, and climate change (Farley 2007, Daniel & Koper 2019, Gibson & Newman 2019).

Cumulatively, these threats have resulted in numerous impacts on grassland-dependent wildlife, including birds. Globally, grassland birds are decreasing precipitately. In North America and Europe, they are declining more than birds of any other biome (Burns *et al.* 2021, North American Bird Conservation Initiative 2022). In Asia, grasslands are second only to forests for the number of globally threatened bird species supported (Birdlife International 2003) and in southeast South America more than a quarter of bird species that regularly use grasslands are globally threatened or near-threatened (Azpiroz *et al.* 2012). Despite widespread declines and highly threatened avifaunas, grassland birds have, at least in some regions, been poorly studied compared with forest birds (Kamp *et al.* 2011, Douglas *et al.* 2014, Maphisa *et al.* 2017). It is nevertheless widely recognized that in the Americas, grassland birds are facing urgent conservation needs (Rosenberg *et al.* 2019) and in Africa, research is needed to understand how moist high-altitude grasslands can be managed to help conserve birds (Maphisa *et al.* 2017).

Designing conservation science agendas for important grassland areas requires an understanding of the ecological impacts of grassland management (Ahlering *et al.* 2020). However, threats and required conservation actions may vary regionally; for example, grasslands are under constant threat from drought in some regions (Gibson & Newman 2019) but at greater risk from land use change in others (Kamp *et al.* 2011). Some regions might also have more effective conservation programmes than others. This reinforces the need for a comparison of regional threats and conservation actions to help define the scope and scale of grassland bird management challenges globally.

We used a systematic literature review and synthesis to quantify the key threats and conservation actions for grassland birds across the globe's major grassland regions. Using these summaries, we explored regional commonalities and differences to better identify the needs of grassland birds worldwide.

METHODS

Definitions

We defined 'grassland' following Dixon *et al.* (2014): not permanent wetland; at least 10% vascular vegetation cover; graminoids with > 25% cover or at least exceeding other herbaceous and shrub cover; dominant over other growth forms; shrubs have < 25% cover, trees have < 10% canopy cover. We therefore included grasslands along a moisture gradient from arid to wet and included highveld, meadows, pampas, prairies, steppe and

upland wet mesic grassland habitats (Fig. 1), excluding habitats with a marked tree or shrub component such as forest-steppe, chaparral or savanna. We defined a grassland bird as 'any species that has become adapted to and reliant on some variety of grassland habitat for part or all of its life cycle, be it breeding (either nesting or feeding), migration, or wintering' (Vickery *et al.* 1999). This definition encompasses mainly grassland specialists but may also include facultative grassland species. It should be noted that most of the studies that we assessed covered grassland birds that were resident, breeding or wintering rather than on migration. We included both primary and secondary grasslands (grasslands created through anthropic activity).

We classified 11 regions containing grasslands worldwide (Table S1; BirdLife International (http://datazone.birdlife.org/species/search), excluding Antarctica (Blair *et al.* 2014). We accounted for geopolitical changes by including historical and current country names where applicable.

Publication search

In January–May 2020, we searched within each grassland region in Web of Science (Clarivate Analytics 2020) using all databases and years (1864–2020) and restricted to English language publications because it was beyond the project capacity to review non-English language publications. We divided the searches regionally to make the number of publications returned more manageable. Although we designed the searches to capture as many appropriate papers within each distinct region as possible, it is possible that a small number of abstracts, keywords and titles did not include any of the regional search string words that we included, so might have been missed by our search. However, we consider it unlikely that this would alter any of the conclusions about key threats and actions.

Keywords were searched for under the 'Topic' category, returning records that include any search terms in either the title, abstract or keyword list. Because grassland types vary geographically, we

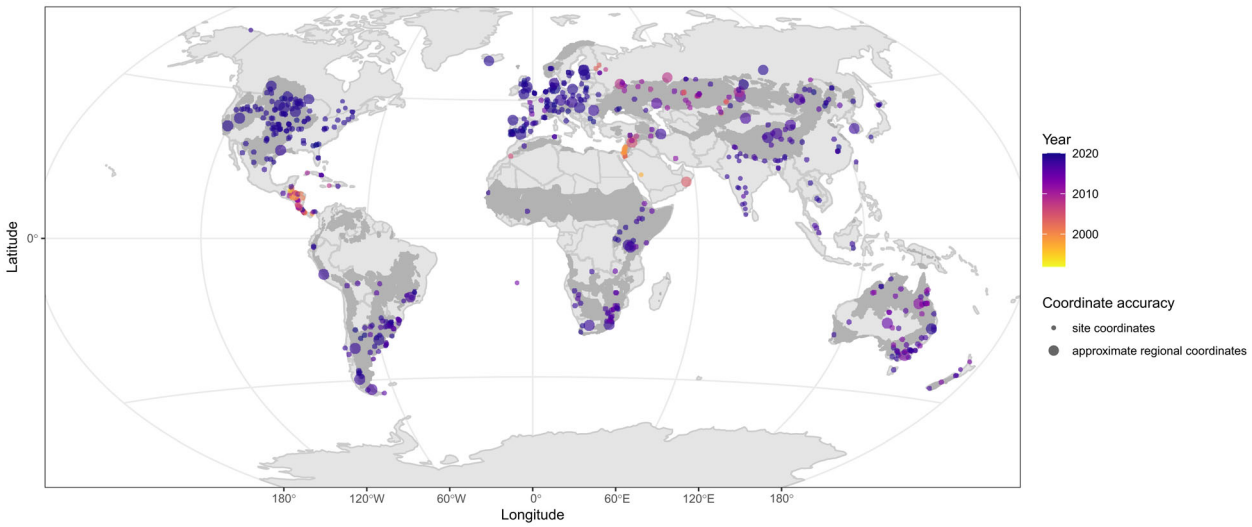

Figure 1. Study sites of publications in the review. Smaller dots represent studies for which exact coordinates were provided by the authors or that could be identified on maps from the site description. Larger dots are the centroids of larger study areas (often spanning several 100 km). A total of 664 study sites and regions from 449 reviewed papers are mapped. For 84 publications with national, continental or global focus, no locations are displayed. The shaded grey areas are defined as primary (naturally occurring) grasslands by Dixon *et al.* (2014); dots outside these areas largely represent studies from secondary grasslands (created from anthropic activities). Our definition of grassland is therefore: not permanent wetland; at least 10% vascular vegetation cover; graminoids with > 25% cover or at least exceeding other herbaceous and shrub cover; dominant over other growth forms; shrubs have < 25% cover, trees have < 10% canopy cover. This includes grasslands along a moisture gradient from arid to wet and included highveld, meadows, pampas, prairies, steppe and upland wet mesic grassland habitats, excluding habitats with a marked tree or shrub component such as forest-steppe, chaparral or savanna. Map uses a Winkel tripel projection.

allowed for multiple common terms for grasslands per region. We used Boolean search operators and wildcards (*) to account for variation in the suffixes of words included in the search string. In general, the Web of Science search string followed the format ((country OR region) AND (steppe* OR grassland* OR prairie* OR pasture* OR meadow* OR pampas* OR highveld*) AND (avian* OR aves* OR bird* OR ornith*) AND (conservation* OR management*)) (Table S2).

Publication review

We screened and subsequently reviewed up to a maximum of the 200 most recent publications returned per region, with the oldest publications reviewed varying regionally from 1992 to 2018 (Table S3). In well-studied regions this approach meant that publications were all recent, whereas in less studied regions they comprised newer and older publications. Given the available personnel, it was not feasible to process more than 200 publications per region. Although threats might increase or diminish in importance over time, this approach does mean that, particularly in well-studied regions, we are confident that we have reviewed studies addressing the most current, pressing threats. We first screened publication abstracts for eligibility, retaining papers focusing on ecology, conservation, or management of grassland birds in grassland habitats, within the focal region, excluding publications unavailable in English or inaccessible online (which was rare). Publications meeting the above inclusion criteria were reviewed in full (2–101 per region; see Table S3 and Results). We used hierarchical categories and definitions from Salafsky *et al.* (2008), with additional categories of our own, characterizing 15 primary threats (Fig. 2, Table S4), and eight primary conservation actions (Fig. 3, Table S5). Primary threats and actions were also subclassified into sub-threats from Salafsky *et al.* (2008) and our own additional categories (Fig. 2, Tables S4 and S5). Any statistically supported threats described in text, figures or tables were assigned to the categories described above. We summed the number of publications citing each primary threat per region, and 'Agriculture and aquaculture' sub-threats, the latter because this primary threat far exceeded other primary threats in terms of number of publications reporting it. We separated conservation actions into those in place ('existing' actions) and those that were recommended, including any past, existing or recommended action described in publications, even if not the focus of the study. We present a tallied summary of threats and actions globally, and a narrative summary of relevant literature per region. The 'tallying' approach adopted for summing threats and actions provided a repeatable and logistically feasible means for summarizing the large and diverse volume of literature reviewed, and identifying the most frequently cited threats and actions, and we consider this appropriate. A full meta-analysis was beyond the available peoplepower. As a result, our approach does not consider potential biases such as variation in the scale or intensity of threats per publication, and accordingly the number of species impacted by threats/actions. Where a threat to grassland birds arises due to impacts on the underlying habitats, which probably applies to numerous species, e.g. agriculture, this is less of an issue. But care should be taken in the interpretation of threats such as hunting, where only a select number of species might be subject to hunting. Similarly, for regions returning small sample sizes of relevant publications (Caribbean and to a lesser extent Middle East), we urge caution in the interpretation of threats.

RESULTS

No relevant publications were found for Oceania (excluding Australasia). Across the remaining 10 regions, data were extracted from 528 publications (Table S3).

Summary of threats

'Agriculture and aquaculture' was the threat most frequently reported to impact birds in eight regions and tied with natural system modifications for most frequently reported threat in the Caribbean (Fig. 2). In the Middle East, biological resource use (hunting and collecting) was the most frequently reported threat. Globally, agriculture and aquaculture far exceeded other threats in terms of the overall number of publications reporting it as a threat (73%), followed by natural system modifications (32%), and climate change and severe weather (24%; Fig. 2).

The frequency of reporting of different agricultural sub-threats varied regionally. 'Livestock farming and ranching' was most frequent or joint most

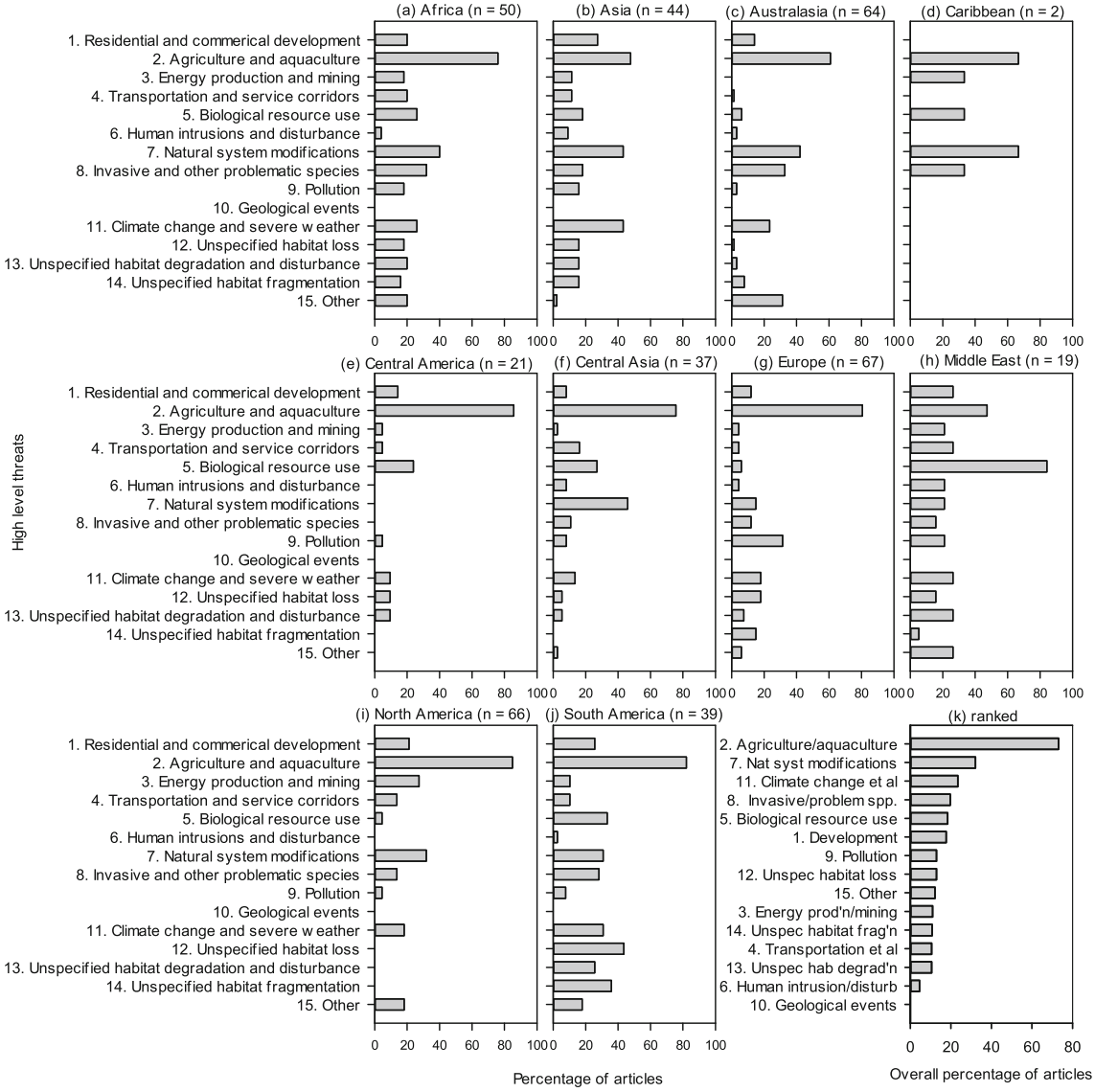

Figure 2. Major threats to grassland birds (following Salafsky *et al.* 2008) and their proportions in respective regions (a–j) expressed as the percentage of studies in which they were mentioned. 'Agriculture and aquaculture' was the most frequently, or joint most frequently, reported primary threat to grassland birds in nine out of 10 regions globally and second most frequent in the other region. No data were available for Oceania. Sample sizes are number of studies from the total sample assessed that addressed threats to grassland birds.

frequent in three regions (Australasia, Central and South America, Fig. 3; 45% of publications within 'agriculture and aquaculture'). Non-timber cropping was most frequent or joint most frequent in three regions (Asia, Caribbean and Europe, Fig. 3; 42% of publications within agriculture and aquaculture). Agricultural abandonment, typically the cessation of domestic grazing or cultivated land left fallow, also poses risks to some grassland birds as it was most frequently or joint most frequently reported in three regions (Caribbean, Central Asia and North America, Fig. 3). It should be noted that the sample size of papers addressing threats in the Caribbean was small ($n = 2$), which could result in a threat or sub-threat being assigned a disproportionately large weighting.

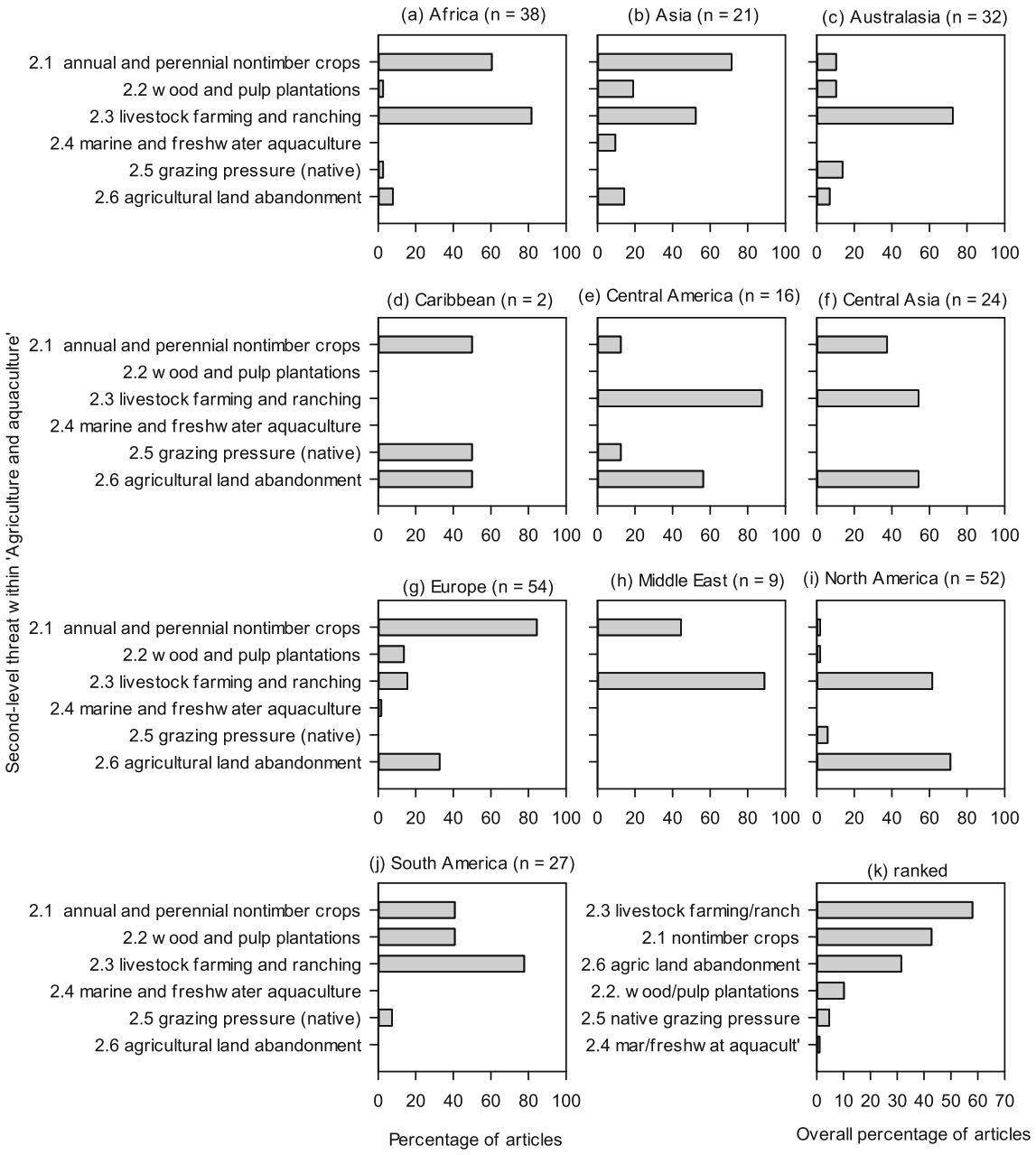

Figure 3. The relative importance of sub-threats (following Salafsky *et al.* 2008) to grassland birds within the primary threat agriculture and aquaculture varies by regions.

Summary of conservation actions

Land/water protection was the most frequently reported existing action in five regions (Fig. 4; 51% of publications). Land/water management was the most frequently reported action in four regions (Fig. 4; 58% of publications). Species interventions were the most frequently reported existing actions in the Middle East (Fig. 4) but were less common in other regions (overall, 15% of publications, Fig. 4), after law and policy, which was ranked third (25%, Fig. 4k).

Additional land/water management was the most frequently recommended action in eight

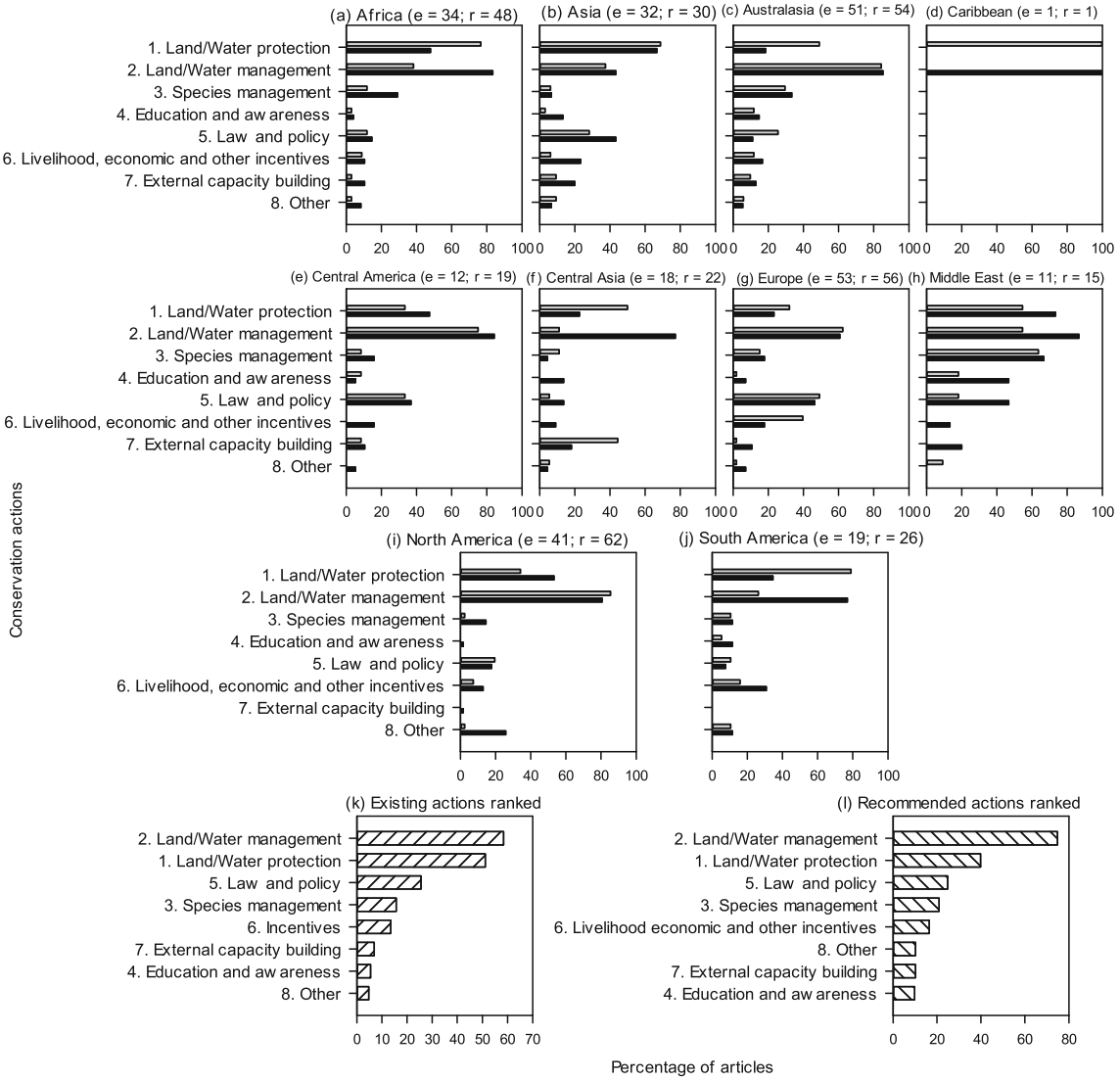

Figure 4. The frequency of existing (grey bars) and recommended (black bars) conservation actions (a–j) for grassland birds varies regionally. Sample sizes are number of studies from the total sample assessed that addressed conservation actions for grassland birds.

regions (Fig. 4) and joint most frequent in the Caribbean (Fig. 4; cited in 75% of publications). Land/water protection was the most frequently recommended action in Asia (Fig. 4) and joint most frequent in the Caribbean (Fig. 4; cited in 40% of publications).

REGIONAL SUMMARIES

Numbers in parentheses are the number of studies formally reviewed per region for threats and conservation actions following screening.

Africa (51 studies)

Agriculture is the greatest threat facing African grassland birds and has intensified with human population growth, technological development and reduction in nomadic pastoralism (Herremans 1998, Maphisa *et al.* 2019, Mahamued *et al.* 2021). Overgrazing and/or frequent fires are the two main causes of habitat degradation across many African grassland types (Jansen *et al.* 1999, Maphisa *et al.* 2016, Addisu & Girma 2019). Increasing domestic grazing pressure is degrading

land and affecting grassland birds by reducing native plant cover and diversity (Herremans 1998) and maintaining homogeneously short swards (Harris *et al.* 2019). Effects of such degradation include increased nest failure (Little *et al.* 2015, Mahamued *et al.* 2021) and reduced food availability (Herremans 1998). Infrastructure developments including water schemes, mining and wind farms also degrade and fragment grasslands (Maphisa *et al.* 2016).

Climate change may increase the frequency and severity of droughts across Africa, causing large-scale habitat shifts and grassland degradation through desertification (Santangeli *et al.* 2018). As a result, drought-induced reductions in food may increase intraspecific and interspecific resource competition. Climate change may also drive a transition from grassland to shrubs (Stanton *et al.* 2018a), with additional loss of grassland to shrub and bush encroachment through increases in disturbance regimens and overgrazing, which alters vegetation composition and structure (Herremans 1998, Stanton *et al.* 2018a).

The most common existing action is land protection (Fig. 3a), although it is minimal and insufficient. Only around 2–4.5% of grasslands in southern Africa are formally protected, of which 3.6% are in a natural/intact state (Maphisa *et al.* 2017, Skowno *et al.* 2019); however, the land that is conserved does benefit grassland birds (Little *et al.* 2015). Land/water management is the second most frequent conservation action in Africa (Fig. 4a), including feral cat control, monitoring of illegal/inappropriate grazing, wetland creation/rehabilitation, alien invasive plant clearing and prescribed burning (Van Niekerk 2017, Addisu & Girma 2019).

Further land management is recommended for Africa, along with land protection (Fig. 4a). Multiple authors recommend that this management should include responsible fire and grazing regimens to create a mosaic of suitable habitats, which should benefit a range of species (Maphisa *et al.* 2019). Protected land area should be increased, ideally connecting existing protected areas through corridors of suitable habitat and expanding reserves (Harris *et al.* 2019). The role of grasslands as water source areas and carbon offsets could incentivize protection in areas prone to water scarcity (Egoh *et al.* 2011, Di Sacco *et al.* 2021).

Asia (58 studies)

Agricultural expansion and grazing pressure pose the most frequently reported threats to grasslands and their bird communities dispersed across many parts of Asia. In the lowlands of the Indian subcontinent, conversion to and intensification of agriculture comprise the dominant threat, compounded by overgrazing (Rawat & Adhikari 2015, Varun & Dutta 2020). In the pre-Himalayan terai, the residual tall wet grasslands are small, scattered, surrounded by intensifying agriculture, and managed mainly for large mammals (Rawat & Adhikari 2015, Collar *et al.* 2017). The shola grasslands of India's Western Ghats, to which several bird species are confined, have been reduced and fragmented by timber plantations and agriculture (Rawat & Adhikari 2015). The high-elevation grasslands of the Tibetan Plateau are being degraded by overgrazing, invasive species, mining, roads, dams, urbanization and climate change (Fayiah *et al.* 2020). Plateau Pika *Ochotona curzoniae*, a keystone mammal that aerates soil, enables water infiltration, and provides nest-sites for birds and food for Saker Falcons *Falco cherrug*, are persecuted with poisons, putting carnivorous and granivorous birds at risk (Dixon *et al.* 2017). In northern China, increases in livestock are blamed for declining primary productivity and fragmented landscapes (Mu *et al.* 2013); two-thirds of grasslands in the huge West Songnen Plain were converted to (and fragmented by) agriculture and saline wasteland between 1954 and 2000 (Wang *et al.* 2009). Around the Tonle Sap, Cambodia, last home of Bengal Florican *Houbaropsis bengalensis* subspecies *blandini* and a key wintering area for raptors and seed-eating passerines, intensive rice production will shortly replace all remaining grassland (Mahood *et al.* 2020). Poaching, trapping, energy infrastructure (notably powerlines) and climate change are all further threats identified as damaging bird populations in Asian grasslands (Collar *et al.* 2017, Dixon *et al.* 2017).

Protected areas have been considered the most effective means of restoring grasslands in Asia, particularly when ecosystem services are of primary importance, as on the Qinghai Tibetan Plateau (Varun & Dutta 2020), but they must be as large and well managed as possible (Collar *et al.* 2017). The scale at which bird species and grassland

habitats need to be conserved is such that large landscape mosaics of exclosed or lightly grazed grasslands and low-intensity farmland, including community conservation reserves, represent a workable compromise, vital for the survival of three species of bustard, for example (Collar *et al.* 2017, Varun & Dutta 2020).

Other recommended conservation measures in this region include regulation of powerlines and fencing; control of hunting, poaching, dog predation and inappropriate burning of grassland; sustained campaigns of public awareness and engagement; and strong government and international support (Collar *et al.* 2017).

Australasia (74 studies)

Many Australasian grasslands, including 95% of Australia's Northern Plains (Department of Sustainability and Environment 2010), have been lost or degraded by conversion for livestock pastures and cropping, impacting a range of grassland birds including the Plains-wanderer *Pedionomus torquatus* (Baker-Gabb *et al.* 2016, Neilly & Schwarzkopf 2019) and Golden-shouldered Parrot *Psephotellus chrysopterygius* (Crowley & Garnett 1998). Conversion of grassland to forestry further threatens birds reliant on open anthropogenic habitat (Mortelliti & Lindenmayer 2015). Ground-nesting species are particularly sensitive to high grazing pressure from livestock, whereas ground-foragers are less sensitive (Baker-Gabb *et al.* 2016, Neilly & Schwarzkopf 2019).

Increasing fire frequency is another major threat and renders post-fire plant communities vulnerable to establishment by exotic plant species, increasing susceptibility to future fires and leading to functional habitat loss for some bird species (Sommer *et al.* 2018). Inappropriate fires can also reduce food abundance by destroying grass seed stores on which species such as the Gouldian Finch *Erythrura gouldiae* depend (Craig 1992, Armstrong & Legge 2011). For other species responses to fire can be complex. For example, in Partridge Pigeons *Geophaps smithii*, fires result in loss of ground nests and increase exposure to predation but can also increase foraging efficiency by increasing detectability of seeds on burnt ground and removing vegetation, thereby facilitating on-ground movement (Fraser *et al.* 2003). Climate change is predicted to increase fire frequency and reduce ranges of Australian grassland birds (Reside *et al.* 2012). Low rainfall may also compound the impacts of overgrazing on the Plains-wanderer (Baker-Gabb *et al.* 2016).

Land protection through nature reserves and national parks is the most common conservation action (Johnstone *et al.* 2015). Recommended actions include patch grazing and burning under appropriate regimens to increase habitat heterogeneity, exclosures and culling of herbivores to limit overgrazing, and payments to landowners to incentivize conservation (Baker-Gabb *et al.* 2016). Well-known species such as the Plains-wanderer could make effective local flagships for promoting grassland conservation (Johnstone *et al.* 2015).

Caribbean (two studies)

According to the two papers retained, Caribbean grasslands birds are affected by agriculture and natural system modifications (Fig. 2d). On uninhabited Navassa Island, short duration crops like cucumber and watermelons and grazing by feral goats negatively affect the grassland bird community (Earsom *et al.* 2008). Invasive rats compete with resident birds for food, and human visitors frequently set fires when camping or to clear vegetation. Grassland specialists like Yellow-faced Grassquit *Tiaris olivaceus* and Black-faced Grassquit *Tiaris bicolor* may consequently suffer food losses but probably also benefit from fires, which restrict succession to forest. Abandonment of agriculture and regeneration of grasslands into forest threatens grassland birds in the Dominican Republic (Latta *et al.* 2018; Fig. 3d).

Few conservation actions for grassland birds have been implemented in the Caribbean. The only legally protected grasslands may be those on Navassa Island (Earsom *et al.* 2008). Additional management measures, such as invasive species control and habitat restoration, are recommended for Navassa (Earsom *et al.* 2008). Given the lack of publications available for this review, further research is needed for all relevant Caribbean countries (Earsom *et al.* 2008, Latta *et al.* 2018).

Central America (39 studies)

Central America poses conservation challenges for grassland birds because of the interaction with agricultural and forest interests. Native, natural grasslands supporting birds are limited in extent, often in narrow montane zones (Kappelle &

Horn 2016). Many grasslands in the region arise through agricultural activity (Mendenhall *et al.* 2016), including pastoral grasslands in forest clearings, which fluctuate spatially and temporally with agricultural activity (Holl *et al.* 2000, Ospina *et al.* 2012, Roels *et al.* 2019). Furthermore, some grassland bird species are more abundant in modified compared with natural landscapes, making it challenging to develop conservation strategies (Roels *et al.* 2019). Other threats to grasslands and their birds include commercial forestry, forest restoration or succession, and hunting (Arguedas-Negrini 2001, Martin & Buchholz 2018, Roels *et al.* 2019). Forestry, energy generation and agriculture can lead to secondary threats such as residential and commercial development and roads (Piaskowski *et al.* 2005). Only one publication indicated that climate change is a threat to grassland birds, and land use change is considered a more immediate threat (La Sorte *et al.* 2017).

Land/water management was the most common existing conservation action, followed by law and policy, land/water protection and species management. Recommended actions were for land/water management, law and policy, and land/water protection, but livelihood, economic and other incentives were also considered important (Holl *et al.* 2000). Recommended nature conservation actions tended to focus on slowing deforestation and including alternative sources of income for local communities (Holl *et al.* 2000), although the former may not of course be directly beneficial for grassland birds. External capacity building and education were a complementary action suggested in Belize (Piaskowski *et al.* 2005).

Central Asia (44 studies)

The steppes of this region are still among the largest Palaearctic grasslands, but vast areas were converted to cropland before 1900, with another 46 million hectares during the Soviet era 1953–60 (Wesche *et al.* 2016), resulting in steppe bird declines and the probable extinction of the Slender-billed Curlew *Numenius tenuirostris* (Buchanan *et al.* 2018). Conversely, the collapse of the Soviet Union in 1991 led to the abandonment of 15 million hectares of cropland in Kazakhstan alone (Kamp *et al.* 2011). Populations of many steppe birds consequently recovered where abandoned croplands reverted to steppe (Kamp *et al.* 2011) but abandoned fields may be ecological traps for species including the Black Lark *Melanocorypha yeltoniensis* because of higher nest predation (Lameris *et al.* 2016). Moreover, recent recultivation of abandoned cropland might lead to new declines (Kamp *et al.* 2011).

Grassland birds have also been strongly affected by historical fluctuations in livestock management. Traditional semi-nomadic grazing generated a landscape of varying grazing intensities until the 1980s (Robinson *et al.* 2003), producing habitat for a diversity of grassland species. However, livestock numbers collapsed after the break-up of the Soviet Union, and vast areas are no longer grazed (Dara *et al.* 2020). The resulting biomass accumulation is associated with increased fire frequency, triggering a transition from diverse steppe to uniform swards dominated by grasses (Freitag *et al.* 2020). This has resulted in changed abundances of steppe mammals (Koshkina *et al.* 2023) and has probably also affected steppe bird communities. Remaining livestock are now concentrated around human settlements, leading to localized overgrazing. Several steppe birds avoid these areas, although some, such as the globally threatened Sociable Lapwing *Vanellus gregarius*, have benefitted (Kamp *et al.* 2011). Other threats, such as mining or powerlines, are unlikely to match agriculture in severity or extent (Kamp *et al.* 2016).

Kazakhstan has an ambitious and growing protected area programme (Baumann *et al.* 2020), while also managing individual species through action plans (e.g. Sheldon *et al.* 2012). Intensification of existing cropland with minimum agrochemical use is recommended, instead of recultivating abandoned fields; that is, land sparing rather than sharing (Kamp *et al.* 2011). Other recommendations include restocking abandoned pastures with free-ranging livestock (Kamp *et al.* 2015). Populations of wild ungulates, such as Saiga Antelope *Saiga tatarica*, should be restored to re-establish natural grazing levels (Kamp *et al.* 2016). Although some issues such as the impacts of climate change and human activity on grassland productivity have been studied on Central Asian grasslands (Chen *et al.* 2020), most grasslands outside Kazakhstan are poorly studied for their bird communities, and threats to birds in the dry lowland grasslands of Turkmenistan and Uzbekistan, and high-altitude pastures of Kyrgyzstan and Tajikistan, require assessment.

Europe (87 studies)

Agriculture and associated agrochemical use are the most frequently reported threats (Fig. 2g). The adoption of the European Union (EU) Common Agricultural Policy from the 1960s, and expansion of the EU, stimulated widespread agricultural intensification, leading to a decline in many bird populations (Donald *et al.* 2002). Birds associated with grasslands and agricultural habitats now comprise the highest proportion of threatened species across Europe (23%; Birdlife International 2022). Intensification of grassland management has included drainage, reseeding, earlier and more frequent mowing, and increased grazing densities, reducing the quality of nesting and foraging habitats and leading to increased nest and chick losses from trampling and machinery (Onrust *et al.* 2019). Densities of some bird species are lower in more intensively managed grassland (Douglas *et al.* 2021). Some grassland has also been lost in conversion to arable land (Stjernman *et al.* 2019). However, the cessation of agricultural management has also occurred, including traditionally maintained alpine hay meadows (Assandri *et al.* 2019), leading to detrimental increases in shrub and woodland for grassland birds (Kmecl & Denac 2018, Calladine *et al.* 2019, Douglas *et al.* 2020). A recent reappraisal of the EU Common Agricultural Policy allows for a 5% decrease in permanent grassland landscapes, probably leading to further loss, fragmentation and degradation of grasslands (Assandri *et al.* 2019). Climate change has been less frequently reported as a threat (Fig. 2g) but warming-induced range changes of grassland birds are likely (Calladine *et al.* 2019). Species associated with moist grasslands are considered particularly vulnerable (Regos *et al.* 2020).

Agri-environment schemes (AES) are the most common existing actions and are associated with changes in land/water management, law and policy, livelihoods, and economic and other incentives (Fig. 4g). Farms supported through AES subsidies are generally considered to contribute more to conservation than those without (Budka *et al.* 2019) although this could potentially relate to better quality habitat being entered into schemes rather than the effectiveness of the AES options (Kelly *et al.* 2021a). Protection of some grasslands has occurred through the Special Protection Areas (SPAs) network for birds (European Commission 2020) as well as the management and protection of wildlife-rich low-intensity grasslands encouraged within High Nature Value farmland systems (Mäkeläinen *et al.* 2019). Conservation initiatives can directly benefit breeding birds; for example, increased nest protection can improve chick survival rates of ground-nesting birds (Kubelka *et al.* 2018). Low grazing intensity can prevent forest succession and maintain bird diversity within agricultural grasslands (Kmecl & Denac 2018).

Recommended actions include markedly increasing the scale of AES delivery for grassland birds (Franks *et al.* 2018) and evaluating this through monitoring (Budka *et al.* 2019). Recommended alterations to agricultural practices include delayed and/or less frequent mowing, low-intensity grazing and reductions in agrochemical usage (Franks *et al.* 2018, Kubelka *et al.* 2018). However, the diverse needs of different bird species in grasslands make design of effective interventions challenging; for example, tall vegetation benefits some species but not others (Budka *et al.* 2019).

Middle East (19 studies)

The primary threat facing grassland birds is biological resource use. The hunting of a variety of birds is widespread across the region, even where prohibited (Brochet *et al.* 2019). Of particular concern is the illegal hunting of globally threatened species including the Critically Endangered Sociable Lapwing (Sheldon *et al.* 2012) and Northern Bald Ibis *Geronticus eremita* (Bowden 2015). Falcons, especially Saker Falcon and Peregrine Falcon *Falco peregrinus*, are often illegally trapped for the international falcon trade, and this is considered an important cause of the population decline of Saker Falcon in particular (Kovács *et al.* 2014).

Intense domestic grazing pressure results in desertification and shrub encroachment that threatens grassland birds in the region (Ghazanfar 2004). These changes probably impact on food availability for, and nest survival of, grassland birds, but this threat is yet to be quantified. Energy infrastructure (powerlines, electricity poles and wind turbines) that cross otherwise open grassland habitats pose a serious threat to breeding and migrating species (Bernardino *et al.* 2018, McGrady 2018). Climate change is likely to be a

marked threat to grasslands in the Middle East, primarily through desertification, leading to a reduction in biodiversity, agricultural productivity and ecosystem services (Mirzabaev *et al.* 2019). Increasing road infrastructure across Iran, Turkey and Syria is also fragmenting the land and facilitating human access and associated disturbance to once remote areas (Bowden 2015).

Existing actions for grassland birds include international management planning for threatened species such the Northern Bald Ibis (Bowden 2015), Sociable Lapwing (Sheldon *et al.* 2012) and Saker Falcon (Kovács *et al.* 2014). The designation of protected areas has been initiated, but management of these is typically under-resourced and poorly regulated (McGrady 2018). Important Bird Areas have been identified (Evans 1994), but this programme requires a comprehensive update in this region.

Recommended actions include a greater emphasis on sustainable livestock management, perhaps including the introduction of rotational grazing systems using traditional livestock. The establishment of more protected areas, improved management of existing ones and improved hunting legislation are also considered necessary (Brochet *et al.* 2019). The development of more international and national species and habitat action plans with the necessary financial and human resources to implement them would make a substantial contribution to grassland bird conservation across the Middle East.

North America (101 studies)

North American grasslands occupy large areas of the continental interior and grassland types vary regionally with environmental gradients in temperature, rainfall and elevation (Comer & Hoagland 2020). North American prairies evolved in the presence of natural disturbances such as lightning-driven fire and grazing by native ungulates, which are important for maintaining spatio-temporal heterogeneity, but the consequences of altering these has been increasingly recognized (Campomizzi *et al.* 2019). Agriculture, mainly the expansion of row cropping and livestock grazing, is the most frequently reported threat across these grasslands, followed by energy production and natural systems modification (Ogden *et al.* 2019). Both cessation of livestock grazing, which can result in decreased plant diversity, and heavy stocking rates, which can increase erosion and in some cases invasion by exotic plants, can result in grassland degradation. The reported threats and actions show some geographical variation. The Great Plains of Canada and the USA represent the largest zone – upland songbirds here are strongly affected by habitat loss to agriculture, and this area is also experiencing significant renewable and non-renewable energy development impacts (Daniel & Koper 2019). In the eastern grasslands, woody encroachment is a threat to grassland birds and can follow agricultural abandonment (Monroe *et al.* 2019). The western zone includes extensive sagebrush-steppe habitat; threats include wildfire, invasion by non-native grasses, shrub encroachment, expansion of agriculture and urban areas, oil and gas drilling, and mining (Runge *et al.* 2019). The southern zone includes shrubs and desert habitat and is of critical importance for overwintering grassland birds, but their wintering ecology is relatively poorly studied (Macías-Duarte *et al.* 2017). The southern zone is experiencing rapid habitat loss and populations of grassland birds that overwinter in the Chihuahuan Desert are considered to be declining more rapidly than other North American grassland birds (Macías-Duarte *et al.* 2017). Relatively few publications reported climate change as a threat, although some high-elevation or restricted-range populations may be susceptible to climate change (Pierce *et al.* 2019).

Land/water management, particularly livestock grazing at appropriate densities (Campomizzi *et al.* 2019), was the most common existing action in North America, followed by land/water protection, and law and policy. Direct species management was less common. The wider Conservation Reserve Program of the USA, established to reconvert croplands to perennial grasses, has reduced soil erosion, improved water quality, and restored and protected wildlife habitats (Harryman *et al.* 2019), and many bird species have consequently benefited (Reiley *et al.* 2019, Shew *et al.* 2019).

Grassland bird conservation in much of this region will depend on managing disturbance regimens, as well as protection for extant grasslands. Recommended actions focus on land/water management, followed by land/water protection. Prescribed burning, plus grazing by native or domestic ungulates at appropriate densities could increase habitat heterogeneity (Campomizzi *et al.* 2019). Minimizing road expansion, restricting noise

pollution and modifying infrastructure could reduce disturbance (Daniel & Koper 2019). Other suggested actions include reducing the extent of vertical structures, both natural (i.e. tree encroachment; Sullins *et al.* 2019) and artificial (i.e. energy development; Londe *et al.* 2019).

South America (53 studies)

South America has a multitude of highland and lowland grassland types, including paramos, puna, pampas, campos and the Patagonian steppe (IUCN 2010). In these grasslands, agricultural cropping and intensive livestock ranching, and timber plantations are the most frequently reported threats to both resident and migratory grassland birds (Phifer *et al.* 2017, Renfrew *et al.* 2017, Pedrana *et al.* 2018, Weyland *et al.* 2019). Livestock ranching has mixed effects: some grassland specialist birds react negatively to any grazing, others tolerate the presence of grazers, but overgrazing introduces numerous problems (Cerezo *et al.* 2011, Fontana *et al.* 2016, da Silva Mohr *et al.* 2017, Jacobowski *et al.* 2017, da Silva & Fontana 2020). Human settlement and urbanization result in land use change and grassland habitat loss (Freitas *et al.* 2019). Roads cause higher mortality to grassland birds than forest specialists (Aguilar *et al.* 2019). The combined effects of extreme temperatures and unpredictable rainfall patterns from climate change are expected to alter food and habitat availability and prompt range shifts in birds (Weyland *et al.* 2019).

Hunting and trapping directly threaten several grassland birds in South America including sheldgeese *Chloephaga* spp. (Pedrana *et al.* 2018) and Greater Rheas *Rhea americana* (Pedrana *et al.* 2018, Navarro *et al.* 2019). Bobolinks *Dolichonyx oryzivorus* are persecuted by farmers protecting crops (Renfrew *et al.* 2017). Seedeaters *Sporophila* spp. are harvested as pets and many consequently have Endangered status (Turbek *et al.* 2019).

The most common existing conservation strategy reported is land/water protection, followed by law and policy, land/water management, species management and economic incentives. There are grassland-friendly beef certification programmes such as the Alliance for the Grasslands and Southern Cone Grassland Alliance (Pedrana *et al.* 2018). However, protected areas cover only 1% of native grasslands (Azpiroz *et al.* 2012).

Habitat protection is a vital recommended action (da Silva Mohr *et al.* 2017) and key research findings include the importance of large patches of habitat to grassland specialist abundance and richness (Pretelli *et al.* 2018) and the recognition that specialists have different preferences within preserved areas (Isacch & Cardoni 2011). Meanwhile, land/water management strategies must reconcile avian habitat and human land use (Phifer *et al.* 2017). Grazing practices should be improved through seed management and temporal rotation, heterogeneous grazing intensities and integrated silvopastoralism (Phifer *et al.* 2017). Farmers disadvantaged by conservation actions should be compensated to incentivize uptake of beneficial practices (Renfrew *et al.* 2017, Pedrana *et al.* 2018), and appropriate livestock farming subsidized to balance out intensive crop production (da Silva Mohr *et al.* 2017).

DISCUSSION

Agriculture is the most frequently reported threat facing grassland birds globally. This is consistent with agriculture being the dominant land use on Earth (Tilman *et al.* 2011), which profoundly impacts global biodiversity (Lanz *et al.* 2018). The threat of agriculture to grasslands involves both the expansion of livestock grazing and cropping into grasslands, and its subsequent intensification, which together displace all but the least sensitive species. Conversely, the cessation of agricultural management and a shift to scrub/woodland through planting or succession (Douglas *et al.* 2020) threatens grassland birds, notably in Central Asia and North America. This suggests that, where maintenance of grassland systems and their biodiversity are an aim, sympathetic and appropriate use of agriculture is required to maintain grasslands. Climate change was ranked below agriculture in the percentage of publications that judge it a threat (23% versus 73%, respectively), consistent with the (current) dominant impact of habitat loss and other resource use on global biodiversity loss (Butchart *et al.* 2010). The relative ranking of agricultural and climatic impacts on grassland birds may change with future research, as climate change is affecting most of the core ecological processes and biodiversity globally (Scheffers *et al.* 2016).

Some threats that are common across regions have varying origins. For example, in Africa and

Central America, the threat from reforestation reflects natural succession and encroachment due to agricultural abandonment, other management effects or climate change (O'Connor *et al.* 2014, Stanton *et al.* 2018a), whereas in Europe, Asia, Australasia and South America it mainly results from plantations (Mortelliti & Lindenmayer 2015, Phifer *et al.* 2017, Douglas *et al.* 2020, World Economic Forum 2022).

Among conservation actions, authors of publications make particularly strong calls for land/water management and land/water protection. The parlous state of grassland birds globally suggests that existing conservation actions for grassland birds are globally inadequate. Below, we expand on these recommendations and make further suggestions for conservation action and research.

A recurring recommendation for land/water management in our sample of studies is to restrict livestock grazing to sustainable densities. These densities are, however, rarely, if ever, stated (see Future action for grassland bird conservation). Another recurring management recommendation is to use fire appropriately. Prescribed fire is often at frequencies far above natural (lightning-driven) cycles (Manry & Knight 1986), leading to habitat degradation, proliferation of exotic grasses and greater future fire risk. Again, appropriate fire regimens are rarely stated (see Future action for grassland bird conservation).

In terms of land/water protection, the reported area of grasslands under protection is consistently low across regions. It is estimated that only about 3% of grasslands in North America (McCracken 2005), 2–4.5% in southern Africa (Maphisa *et al.* 2017) and 1% in southeastern South America (Azpiroz *et al.* 2012) are protected. In areas such as the alpine grasslands of the Qinghai-Tibetan Plateau in Asia, protected area coverage of biodiversity hotspots (26% of hotspots) is considered inadequate (Su *et al.* 2019). Author recommendations are to expand protected area coverage but also to ensure greater effectiveness by targeting biodiversity hotspots and other important areas (Su *et al.* 2019). Authors recommend that this protection needs to be accompanied by appropriate management and sufficient operating funds, as simply delineating protected habitat is no guarantee of species' population viability in landscapes where agricultural or livestock production continues to predominate (With *et al.* 2008). Legal measures to protect grasslands require better enforcement, especially on private lands (Azpiroz *et al.* 2012).

Species within grassland bird communities have varying ecological needs (Maphisa *et al.* 2017, Elliott & Johnson 2018, Budka *et al.* 2019), often making management challenging. Our results generally suggest that management should aim to provide a mosaic of habitat types with different grass height and cover (Maphisa *et al.* 2019), to benefit the greatest range of species; this can be facilitated by ensuring the largest areas possible are under appropriate management, to capture natural variability in habitat types. Even so, the potential for trade-offs exists, both in terms of how species will respond to grassland threat (responses may not all be negative) and conservation actions (responses may not all be positive).

The large extents of grasslands, the relative scarcity and/or limited distribution of some grassland bird species, and species-specific variation in correlates of occurrence, mean that spatial models of grassland and bird species distributions and threats may be required to effectively direct conservation efforts (Niemuth *et al.* 2017). Further, the extensive scale of grasslands and global extent of this conservation issue mean that co-ordinated conservation delivery, supported by the right policies, will be needed at local, regional, national and international scales, covering single species or multi-species assemblages, and multiple stages of the annual cycle for migratory species (Vickery *et al.* 1999, McCracken 2005, Azpiroz *et al.* 2012, Lark 2020), and sometimes in grasslands in different hemispheres for individual species (e.g. Alfaro *et al.* 2019). In some regions, lack of achievement may be related to lack of co-ordination in promoting conservation, and public and political support (Azpiroz *et al.* 2012).

The global threat of agriculture to grassland birds indicates the need for solutions within the agricultural industry itself, and at a global scale. Incentivizing low-intensity agriculture on grasslands is central to conservation in Europe but is little used elsewhere (but see South America (Azpiroz *et al.* 2012)). Incentivizing lower-yield food production could, however, have unintended consequences: if food production drops in one region globally, demand will probably be met elsewhere in another, leading to intensification and habitat loss there (Tanentzap *et al.* 2015). One suggestion is that conservation efforts should focus on the most intensive

('profit-maximizing') food producers, using direct economic incentives that 'foster the culture of grassland preservation and restoration' and include Ecosystem Services Payments (Drum *et al.* 2015). Optimizing agriculture–biodiversity trade-offs through land sparing or sharing is likely to be landscape dependent where relevant to grasslands (Macchi *et al.* 2020); both sparing and sharing have been found to be required in the Eurasian steppe (Kamp *et al.* 2015) whereas land sparing yields the best outcomes for farmland (including grassland) biodiversity in eastern Europe (Feniuk *et al.* 2019). Authors argue that measures producing significant losses to private landowners should include economic compensation (Conservation Evidence 2020).

Activities that garner greater public support could have direct and indirect benefits, influencing consumer purchasing for sustainably sourced grassland products and encouraging corporate responsibility (Lark 2020), now well established for forest protection (e.g. https://www.rainforest-alliance.org/). The high biodiversity value of grasslands means that ecotourism could help to provide an incentive for protecting land; in some cases flagship mammals rather than birds may generate the greatest tourist interest (Maude & Reading 2010).

Agrochemical (pesticide) use was flagged as a notable concern in Europe but less so in other regions, although some studies have highlighted the potential role of pesticide use as a contributory factor to grassland bird declines in North America (Stanton *et al.* 2018b, Rosenberg *et al.* 2019). In some regions, such as North America, grassland bird populations do not appear to be strongly regulated by bottom-up processes that might relate to reduced food supply (Wiens & Rotenberry 1979, Martin *et al.* 1998). However, this surely varies regionally, and it seems likely that invertebrate declines have contributed to declines of insectivorous birds in some systems including European grasslands (Bowler *et al.* 2019, Tallamy & Shriver 2021).

We also note that any large-scale review is sensitive to potential biases in the literature available for review, and there are several methodological issues to bear in mind when evaluating our conclusions. Publication bias often results in the absence of non-significant results from publicly available literature, and this problem plagues any broad-scale literature review. Although we think it is unlikely that this problem influenced our conclusion regarding the importance of agriculture in explaining the decline of grassland birds, it is a problem across scientific disciplines and we encourage the publication of non-significant results by researchers as long as the studies in question had sufficient power to detect effects of management. We also note that simply counting conservation actions can be misleading, as conservation programmes can vary widely in scope. Different discrepancies in literature availability among regions might also have affected our results. We could only review publications in English, and publications in other languages influence conservation worldwide. Further, research topics change over time as cultures and knowledge change; because we tried to sample similar numbers of studies among regions rather than similar periods of time in which research was conducted, changing ecological 'fashions' might result in apparently different ecological foci in regions with differing numbers of studies. Our study design did not allow us to distinguish the reasons for different research foci among regions. However, the outcome is still of significance to conservation; where less research is being conducted, conservation actions must depend on older publications, perhaps affecting conservation strategies. We also argue that our overall conclusion regarding the relative importance of agriculture is likely to be independent of our review methods and sample sizes. Among the regions with the most studies, such as North America and Europe, it is clear that agriculture, rather than climate change, has posed the most significant recent threats; further, the relative importance of agriculture is clear among regions, regardless of sample size. It seems unarguable that agriculture is a key factor in the declines of grassland birds globally.

FUTURE ACTION FOR GRASSLAND BIRD CONSERVATION

Our review suggests an immediate global need for (1) an end to conversion of natural and semi-natural grassland to other habitats including cropping, intensively managed grassland for livestock rearing and plantation forestry; and (2) urgent establishment, and effective enforcement, of larger protected areas of grassland through national and international legislation.

Although agriculture is clearly an overriding global influence on grassland birds, there is still

much to learn through further research to aid development of effective conservation action and policies. We propose that the following are research priorities across most grasslands globally: (1) identification of the densities of native and non-native grazing animals that are required to maintain grasslands in the optimum condition for grassland birds; and (2) in regions where natural fire regimens have shaped grasslands, identification of the prescribed fire regimens that are required to maintain grasslands in the optimum condition for grassland birds; (3) the extent of species-specific variation in the ecological requirements of grassland birds and hence responses to interventions. This variation may require the maintenance of heterogeneous grassland habitats (Fuhlendorf *et al.* 2010); (4) further testing of whether land sparing or sharing optimizes grassland bird conservation, particularly outside the Eurasian steppe and Europe, where some previous work has been undertaken; (5) understanding the extent to which invertebrate and grassland bird declines are linked; and (6) a better understanding of the mechanistic effects within grasslands that will undoubtedly accompany climate change. Both (1) and (2) could be tested through large-scale manipulations of grazing density and/or fire, and their interaction (Fuhlendorf *et al.* 2010), with consideration of other interventions such as restoration of grassland where it has been converted to cropping. Where grassland restoration is implemented (e.g. Society for Ecological Restoration 2022), robust monitoring of biodiversity outcomes is essential for assessing success. Other priorities vary regionally. In many regions, there are vast areas encompassing many countries where the status of grassland birds and the threats they face are poorly known; a notable example is Central Asia outside Kazakhstan. There is also significant disparity in the utilization and understanding of the effectiveness of AES. Where AES have been widely applied in Europe, further research is needed to better understand their efficacy (Kelly *et al.* 2021a, 2021b). Outside Europe there have been numerous pilot projects and interest in introducing AES, and the extensive experience already obtained from European application of these systems could provide learning opportunities for designing effective and large-scale programmes elsewhere. Ultimately, we note that the results of this study and many others remind us that grassland birds are at significant risk from anthropic activities, and require urgent research, monitoring and action, underpinned by effective policies, to help mitigate the plummeting populations of many grassland species worldwide.

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AUTHOR CONTRIBUTIONS

David Douglas: Conceptualization; formal analysis; methodology; validation; visualization; writing – original draft; writing – review and editing. **Jessica Waldinger:** Data curation; formal analysis; validation; visualization. **Zoya Buckmire:** Data curation. **Kathrynn Gibb:** Data curation. **Juan Medina:** Data curation. **Lee Sutcliffe:** Data curation. **Christa Beckmann:** Validation; writing – original draft; writing – review and editing. **Nigel Collar:** Validation; writing – original draft; writing – review and editing. **Raymond Jansen:** Validation; writing – original draft; writing – review and editing. **Johannes Kamp:** Validation; visualization; writing – original draft; writing – review and editing. **Ian Tchagra Little:** Validation; writing – original draft; writing – review and editing. **Rob Sheldon:** Validation; writing – original draft; writing – review and editing. **Alberto Yanosky:** Validation; writing – original draft; writing – review and editing. **Nicola Koper:** Conceptualization; methodology; resources; supervision; validation; writing – original draft; writing – review and editing.

CONFLICT OF INTEREST STATEMENT

The authors have no conflict of interest to declare.

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None.

Data Availability Statement

The summary data that support the findings of this study are available from the corresponding author upon reasonable request.

REFERENCES

Addisu, A. & Girma, M. 2019. The selection, testing, and application of ecological bioindicator birds: A case study of the Bale Mountains, Southeast Ethiopia. *Momona Ethiop. J. Sci.* **11**: 187–208.

Aguilar, J.M., Nieto, A., Espinoza, N., Loja, G. & Tinoco, B.A. 2019. Assessing patterns of bird roadkills in a high Andean Ecuadorian national park. *Stud. Neotrop. Fauna Environ.* **54**: 149–156.

Ahlering, M.A., Cornett, M., Blann, K., White, M., Lenhart, C., Dixon, C., Dudash, M.R., Johnson, L., Keeler, B., Palik, B., Pastor, J., Sterner, R.W., Shaw, D., Biske, R., Feeken, N., Manolis, J. & Possingham, H. 2020. A conservation science agenda for a changing Upper Midwest and Great Plains, United States. *Conserv. Sci. Pract.* **2**: e236.

Alfaro, M., Liguori, L., Sandercock, B.K., Berazategui, M. & Arim, M. 2019. Habitat selection and space use of Upland Sandpipers at nonbreeding grounds. *Avian Conserv. Ecol.* **14**: 18.

Arguedas-Negrini, N. 2001. Distribution, habitat and behavior of grasshopper sparrows, *Ammodramus savannarum* (Passeriformes: Emberizidae) in Northeastern Nicaragua. *Rev. Biol. Trop* **49**: 703–708.

Armstrong, G. & Legge, S. 2011. The post-fire response of an obligate seeding *Triodia* species (Poaceae) in the fire-prone Kimberley, North-West Australia. *Int. J. Wildland Fire* **20**: 974–981.

Assandri, G., Bogliani, G., Pedrini, P. & Brambilla, M. 2019. Toward the next common agricultural policy reform: Determinants of avian communities in hay meadows reveal current policy's inadequacy for biodiversity conservation in grassland ecosystems. *J. Appl. Ecol.* **56**: 604–617.

Azpiroz, A.B., Isacch, J.P., Dias, R.A., Di Giacomo, A.S., Fontana, C.S. & Palarea, C.M. 2012. Ecology and conservation of grassland birds in southeastern South America: A review. *J. Field Ornithol* **83**: 217–246.

Baker-Gabb, D., Antos, M. & Brown, G. 2016. Recent decline of the critically endangered plains-wanderer (*Pedionomus torquatus*), and the application of a simple method for assessing its cause: Major changes in grassland structure. *Ecol. Manag. Restor.* **17**: 235–242.

Baumann, M., Kamp, J., Pötzschner, F., Bleyhl, B., Dara, A., Hankerson, B., Prishchepov, A.V., Schierhorn, F., Müller, D., Hölzel, N., Krämer, R., Urazaliyev, R. & Kuemmerle, T. 2020. Declining human pressure and opportunities for rewilding in the steppes of Eurasia. *Divers. Distrib.* **26**: 1058–1070.

Bernardino, J., Bevanger, K., Barrientos, R., Dwyer, J.F., Marques, A.T., Martins, R.C., Shaw, J.M., Silva, J.P. & Moreira, F. 2018. Bird collisions with power lines: State of the art and priority areas for research. *Biol. Conserv.* **222**: 1–13.

Birdlife International 2003. *Saving Asia's Threatened Birds: A Guide for Government and Civil Society*. Cambridge: Birdlife International.

Birdlife International. 2022. *European Red List of birds 2021*. Available at: http://datazone.birdlife.org/info/euroredlist2021. (accessed 31 August 2022).

Blair, J., Nippert, J. & Briggs, J. 2014. Grassland ecology. In Monson, R.K. (ed) *Ecology and the Environment, The Plant Sciences*, Vol 8: 389–423. New York: Springer.

Bowden, C.G.R. 2015. *International single species action plan for the conservation of the northern bald ibis (Geronticus eremita)*. AEWA technical series No. 55. Bonn, Germany.

Bowler, D.E., Heldbjerg, H., Fox, A.D., de Jong, M. & Böhning-Gaese, K. 2019. Long-term declines of European insectivorous bird populations and potential causes. *Conserv. Biol.* **33**: 1120–1130.

Brochet, A.-L., Jbour, S., Sheldon, R.D., Porter, R., Jones, V.R., Al Fazari, W., Al Saghier, O., Alkhuzai, S., Al-Obeidi, L.A., Angwin, R., Ararat, K., Pope, M., Shobrak, M.Y., Willson, M.S., Zadegan, S.S. & Butchart, S.H.M. 2019. A preliminary assessment of the scope and scale of illegal killing and taking of birds in the Arabian Peninsula, Iran and Iraq. *Sandgrouse* **41**: 154–175.

Buchanan, G.M., Bond, A.L., Crockford, N.J., Kamp, J., Pearce-Higgins, J.W. & Hilton, G.M. 2018. The potential breeding range of slender-billed curlew *Numenius tenuirostris* identified from stable-isotope analysis. *Bird Conserv. Int.* **28**: 228–237.

Budka, M., Jobda, M., Szałański, P. & Piórkowski, H. 2019. Effect of Agri-environment measure for the aquatic warbler on bird biodiversity in the extensively managed landscape of Biebrza marshes (Poland). *Biol. Conserv.* **239**: 279.

Burns, F., Eaton, M.A., Burfield, I.J., Klvaňová, A., Šilarová, E., Staneva, A. & Gregory, R.D. 2021. Abundance decline in the avifauna of the European Union reveals cross-continental similarities in biodiversity change. *Ecol. Evol.* **11**: 16647–16660.

Butchart, S.H.M., Walpole, M., Collen, B., Van Strien, A., Scharlemann, J.P.W., Almond, R.E.A., 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., Morcillo, M.H., Oldfield, T.E.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**: 1164–1168.

Calladine, J., Jarrett, D. & Wilson, M. 2019. Breeding bird assemblages supported by developing upland shrub woodland are influenced by microclimate and habitat structure. *Bird Study* **66**: 178–186.

Campomizzi, A.J., Lebrun-Southcott, Z.M., Van Vliet, L.D. & Morris, G.A. 2019. Rotational grazing of beef cattle to support bobolink breeding success. *Avian Conserv. Ecol.* **14**: 1–13.

Cerezo, E., Conde, M.C. & Poggio, S.L. 2011. Pasture area and landscape heterogeneity are key determinants of bird diversity in intensively managed farmland. *Biodivers. Conserv.* **20**: 2649–2667.

Chen, T., Tang, G., Yuan, Y., Guo, H., Xu, Z., Jiang, G. & Chen, X. 2020. Unravelling the relative impacts of climate change and human activities on grassland productivity in Central Asia over last three decades. *Sci. Tot. Environ.* **743**: 649.

Clarivate Analytics. 2020. *Web of Science*. Available at: www.webofknowledge.com. (accessed 31 August 2022)

Collar, N.J., Baral, H.S., Batbayar, N., Bhardwaj, G.S., Brahma, N., Burnside, R.J., Choudhury, A.U., Combreau, O., Dolman, P.M., Donald, P.F., Dutta, S., Gadhavi, D., Gore, K., Goroshko, O.A., Hong, C., Jathar, G.A., Jha, R.R.S., Jhala, Y.V., Koshkin, M.A., Lahkar, A.P., Liu, G., Mahood, S.P., Morales, M.B., Narwade, S.S., Natsagdorj, T., Nefedov, A.A., Silva, J.P., Thakuri, J.J., Wang, M., Zhang, Y. & Kessler, A.E. 2017. Averting the extinction of bustards in Asia. *Forktail* **33**: 1–26.

Comer, P.J. & Hoagland, B.W. 2020. North American temperate grasslands: Conservation at the Center of the Continent. In Goldstein, M.I. & DellaSala, D.A. (eds) *Encyclopedia of the World's Biomes*: 434–444. Amsterdam: Elsevier.

Conservation Evidence. 2020. *Pay farmers to cover the cost of conservation measures (as in agri-environment schemes)*. Available at: https://www.conservationevidence.com/actions/700. (accessed 31 August 2022)

Craig, A.B. 1992. *Aspects of Post-Fire Regeneration in Soft Spinifex (Triodia Pungens) Communities near Newman, Western Australia*. Kununurra, WA: Western Australian Department of Agriculture.

Crowley, G.M. & Garnett, S.T. 1998. Vegetation change in the grasslands and grassy woodlands of east-central Cape York peninsula, Australia. *Pacific Conserv. Biol.* **4**: 132–148.

Daniel, J. & Koper, N. 2019. Cumulative impacts of roads and energy infrastructure on grassland songbirds. *Condor* **121**: 1–21.

Dara, A., Baumann, M., Freitag, M., Hölzel, N., Hostert, P., Kamp, J., Müller, D., Prishchepov, A.V. & Kuemmerle, T. 2020. Annual Landsat time series reveal post-soviet changes in grazing pressure. *Remote Sens. Environ.* **239**: 667.

Department of Sustainability and Environment 2010. *Conservation and Protection of Northern Plains Grasslands: A Strategic Direction*. East Melbourne, VIC: Department of Sustainability and Environment.

Di Sacco, A., Hardwick, K.A., Blakesley, D., Brancalion, P.H.S., Breman, E., Rebola, L.C., Chomba, S., Dixon, K., Elliott, S., Ruyonga, G., Shaw, K., Smith, P., Smith, R.J. & Antonelli, A. 2021. Ten golden rules for reforestation to optimize carbon sequestration, biodiversity recovery and livelihood benefits. *Glob. Change Biol.* **27**: 1328–1348.

Dixon, A.P., Faber-Langendoen, D., Josse, C., Morrison, J. & Loucks, C.J. 2014. Distribution mapping of world grassland types. *J. Biogeogr.* **41**: 2003–2019.

Dixon, A., Li, X., Rahman, L., Batbayar, N. & Zhan, X. 2017. Characteristics of home range areas used by Saker falcons (*Falco cherrug*) wintering on the Qinghai-Tibetan plateau. *Bird Conserv. Int.* **27**: 525–536.

Donald, P.F., Pisano, G., Rayment, M.D. & Pain, D.J. 2002. The common agricultural policy, EU enlargement and the conservation of Europe's farmland birds. *Agric. Ecosyst. Environ.* **89**: 167–182.

Douglas, D.J.T., Nalwanga, D., Katebaka, R., Atkinson, P.W., Pomeroy, D.E., Nkuutu, D. & Vickery, J.A. 2014. The importance of native trees for forest bird conservation in tropical farmland. *Anim. Conserv.* **17**: 256–264.

Douglas, D.J.T., Groom, J.D. & Scridel, D. 2020. Benefits and costs of native reforestation for breeding songbirds in temperate uplands. *Biol. Conserv.* **244**: 483.

Douglas, D.J.T., Lewis, M., Thatey, Z. & Teuten, E. 2021. Wetlands support higher breeding wader densities than farmed habitats within a nature-rich farming system. *Bird Study* **68**: 100–111.

Drum, R.G., Ribic, C.A., Koch, K., Lonsdorf, E., Grant, E., Ahlering, M., Barnhill, L., Dailey, T., Lor, S., Mueller, C., Pavlacky, D.C. Jr., Rideout, C. & Sample, D. 2015. Strategic grassland bird conservation throughout the annual cycle: Linking policy alternatives, landowner decisions, and biological population outcomes. *PLoS One* **10**: e0142525.

Earsom, S.D., Lombard, C., Schwagerl, J., Oland, J.P. & Miranda-Castro, L. 2008. Avifauna and human disturbance observations on Navassa Island. *Caribb. J. Sci.* **44**: 246–251.

Egoh, B.N., Reyers, B., Rouget, M. & Richardson, D.M. 2011. Identifying priority areas for ecosystem service management in South African grasslands. *J. Environ. Manage.* **92**: 1642–1650.

Elliott, L.H. & Johnson, D.H. 2018. The grasshopper sparrow as an indicator species in tallgrass prairies. *J. Wildl Manage.* **82**: 1074–1081.

European Commission. 2020. *Natura 2000: Sites - Birds Directive*. Available at: https://ec.europa.eu/environment/nature/natura2000/sites_birds/index_en.htm. (accessed 31 August 2022)

Evans, M.I. 1994. *Important Bird Areas in the Middle East*. Cambridge: BirdLife International.

Fairbanks, D.H.K., Thompson, M.W., Vink, D.E., Newby, T.S. & Van den Berg, H.M. 2000. The south African land-cover characteristics database: A synopsis of the landscape. *S. Afr. J. Sci.* **96**: 69–82.

Farley, K.A. 2007. Grasslands to tree plantations: Forest transition in the Andes of Ecuador. *Ann. Assoc. Am. Geogr.* **97**: 755–771.

Fayiah, M., Dong, S.K., Khomera, S.W., Rehman, S.A.U., Yang, M. & Xiao, J. 2020. Status and challenges of Qinghai-Tibet Plateau's grasslands: An analysis of causes, mitigation measures, and way forward. *Sustainability* **12**: 1099.

Feniuk, C., Balmford, A. & Green, R.E. 2019. Land sparing to make space for species dependent on natural habitats and high nature value farmland. *Proc. R. Soc. B* **286**: 20191483.

Fontana, C.S., Dotta, G., Marques, C.K., Repenning, M., Agne, C.E. & dos Santos, R.J. 2016. Conservation of grassland birds in South Brazil: A land management perspective. *Nat. Conserv.* **14**: 83–87.

Franks, S.E., Roodbergen, M., Teunissen, W., Carrington Cotton, A. & Pearce-Higgins, J.W. 2018. Evaluating the effectiveness of conservation measures for European grassland breeding waders. *Ecol. Evol.* **8**: 10555–10568.

Fraser, F., Lawson, V., Morrison, S., Christopherson, P., McGreggor, S. & Rawlinson, M. 2003. Fire management experiment for the declining partridge pigeon, Kakadu National Park. *Ecol. Manag. Restor.* **4**: 94–102.

Freitag, M., Kamp, J., Dara, A., Kuemmerle, T., Sidorova, T.V., Stirnemann, I.A. & Hölzel, N. 2020. Post-Soviet shifts in grazing and fire regimes changed the functional plant community composition on the Eurasian steppe. *Glob. Change Biol.* **27**: 388–401.

Freitas, G.H.S., Costa, L.M., Silva, P.H.V.B.P., Chaves, A.V., Ribeiro, L.C. & Rodrigues, M. 2019. Spatial ecology and conservation of the microendemic ovenbird Cipo cinclodes (*Cinclodes espinhacensis*) from the Brazilian highlands. *J. Field Ornithol.* **90**: 128–142.

Fuhlendorf, S.D., Townsend, D.E., Elmore, R.D. & Engle, D.M. 2010. Pyric-herbivory to promote rangeland heterogeneity: Evidence from small mammal communities, rangeland. *Ecol. Manage.* **63**: 670–678.

Ghazanfar, S.A. 2004. Biology of the central desert of Oman. *Turk. J. Botany* **28**: 65–71.

Gibson, D. & Newman, J. 2019. *Grasslands and Climate Change (Ecological Reviews)*. Cambridge: Cambridge University Press. https://doi.org/10.1017/9781108163941

Harris, M.A., Voysey, M.D., Jamison, S.L. & Greve, M. 2019. Changes in bird assemblages because of vegetation homogenisation in communal livestock systems. *Koedoe* **61**: 1–18.

Harryman, S.W.H., Grisham, B.A., Boal, C.W., Kahl, S.S., Martin, R.L. & Hagen, C.A. 2019. Multiscale habitat selection of lesser prairie-chickens in a row-crop and conservation reserve program land matrix. *J. Fish Wildl. Manag.* **10**: 126–136.

Herremans, M. 1998. Conservation status of birds in Botswana in relation to land use. *Biol. Conserv.* **86**: 139–160.

Hoekstra, J.M., Boucher, T.M., Ricketts, T.H. & Roberts, C. 2005. Confronting a biome crisis: Global disparities of habitat loss and protection. *Ecol. Lett.* **8**: 23–29.

Holl, K.D., Loik, M.E., Lin, E.H.V. & Samuels, I.A. 2000. Tropical montane forest restoration in Costa Rica: Overcoming barriers to dispersal and establishment. *Restor. Ecol.* **8**: 339–349.

North American Bird Conservation Initiative. 2022. *The State of the Birds, United States of America*. Washington, DC: North American Bird Conservation Initiative. Available at: StateoftheBirds.org.

IPBES 2019. In Díaz, S., Settele, J., Brondízio, E.S., Ngo, H.T., Guèze, M., Agard, J., Arneth, A., Balvanera, P., Brauman, K.A., Butchart, S.H.M., Chan, K.M.A., Garibaldi, L.A., Ichii, K., Liu, J., Subramanian, S.M., Midgley, G.F., Miloslavich, P., Molnár, Z., Obura, D., Pfaff, A., Polasky, S., Purvis, A., Razzaque, J., Reyers, B., Chowdhury, R.R., Shin, Y.J., Visseren-Hamakers, I.J., Willis, K.J. & Zayas, C.N. (eds) *Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on biodiversity and Ecosystem Services*. Bonn: IPBES Secretariat 10.5281/zenodo.3553579 (accessed 31 August 2022)

Isacch, J.P. & Cardoni, D.A. 2011. Different grazing strategies are necessary to conserve endangered grassland birds in short and tall salty grasslands of the flooding pampas. *Condor* **113**: 724–734.

IUCN. 2010. *South American temperate grasslands. Building the regional case for their conservation*. Available at: https://www.iucn.org/content/south-american-temperate-grasslands (accessed 31 August 2022)

Jacobowski, L.I., Paulsen, R.K. & Hartz, S.M. 2017. Bird-grassland associations in protected and non-protected areas in southern Brazil. *Perspect. Ecol. Conserv.* **15**: 109–114.

Jansen, R., Little, R.M. & Crowe, T.M. 1999. Implications of grazing and burning of grasslands on the sustainable use of francolins (Francolinus spp.) and on overall bird conservation in the highlands of Mpumalanga province. *South Africa Biodivers. Conserv.* **8**: 587–602.

Johnstone, K., Miller, K.K. & Antos, M.J. 2015. Grassland conservation and the plains-wanderer: A small brown bird makes an effective local flagship. *Conserv. Soc.* **13**: 407–413.

Kamp, J., Urazaliev, R., Donald, P.F. & Hölzel, N. 2011. Post-soviet agricultural change predicts future declines after recent recovery in Eurasian steppe bird populations. *Biol. Conserv.* **144**: 2607–2614.

Kamp, J., Urazaliev, R., Balmford, A., Donald, P.F., Green, R.E., Lamb, A.J. & Phalan, B. 2015. Agricultural development and the conservation of avian biodiversity on the Eurasian steppes: A comparison of land-sparing and land-sharing approaches. *J. Appl. Ecol.* **52**: 1578–1587.

Kamp, J., Koshkin, M.A., Bragina, T.M., Katzner, T.E., Milner-Gulland, E.J., Schreiber, D., Sheldon, R., Shmalenko, A., Smelansky, I., Terraube, J. & Urazaliev, R. 2016. Persistent and novel threats to the biodiversity of Kazakhstan's steppes and semi-deserts. *Biodivers. Conserv.* **25**: 2521–2541.

Kappelle, M. & Horn, S. 2016. The Páramo ecosystem of Costa Rica's highlands. In Kapelle, M. (ed) *Costa Rican Ecosystems*. Chicago: The University of Chicago Press.

Kelly, L.A., Douglas, D.J.T., Shurmer, M.P. & Evans, K.L. 2021a. Upland rush management advocated by Agri-environment schemes increases predation of artificial wader nests. *Anim. Conserv.* **24**: 646–658.

Kelly, L.A., Douglas, D.J.T., Shurmer, M.P. & Evans, K.L. 2021b. Inter-specific variation in the potential for upland rush management advocated by Agri-environment schemes to increase breeding wader densities. *Front. Ecol. Evol.* **9**: 867.

Kmecl, P. & Denac, K. 2018. The effects of forest succession and grazing intensity on bird diversity and the conservation value of a northern Adriatic karstic landscape. *Biodivers. Conserv.* **27**: 2003–2020.

Koshkina, A., Freitag, M., Grigoryeva, I., Hölzel, N., Stirnemann, I., Velbert, F. & Kamp, J. 2023. Post-soviet fire and grazing regimes govern the abundance of a key ecosystem engineer on the Eurasian steppe, the yellow ground squirrel *Spermophilus fulvus*. *Divers. Distrib.* **29**: 395–408. https://doi.org/10.1111/ddi.13668

Kovács, A., Williams, N.P. & Galbraith, C.A. 2014. *Saker falcon Falco cherrug global action plan (SakerGAP), including a management and monitoring system, to conserve the species*. Raptors MOU technical publication 2, CMS technical series 31.

Kubelka, V., Zámečník, V., Slabeyová, K., Škorpíková, V. & Šálek, M. 2018. Threats and conservation of meadow-breeding shorebirds in The Czech Republic and Slovakia. *Wader Study* **125**: 164–174.

La Sorte, F.A., Fink, D., Blancher, P.J., Rodewald, A.D., Ruiz-Gutierrez, V., Rosenberg, K.V., Hochachka, W.M., Verburg, P.H. & Kelling, S. 2017. Global change and the distributional dynamics of migratory bird populations wintering in Central America. *Glob. Change. Biol.* **23**: 5284–5296.

Lameris, T.K., Fijen, T.P.M., Urazaliev, R., Pulikova, G., Donald, P.F. & Kamp, J. 2016. Breeding ecology of the endemic black lark Melanocorypha yeltoniensis on natural steppe and abandoned croplands in post-Soviet Kazakhstan. *Biodivers. Conserv.* **25**: 2381–2400.

Lanz, B., Dietz, S. & Swanson, T. 2018. The expansion of modern agriculture and global. Biodiversity decline: An integrated assessment. *Ecol. Econ.* **144**: 260–277.

Lark, T.J. 2020. Protecting our prairies: Research and policy actions for conserving America's grasslands. *Land Use Policy* **97**: 727.

Latta, S.C., Brouwer, N.L., Mejía, D.A. & Paulino, M.M. 2018. Avian community characteristics and demographics reveal how conservation value of regenerating tropical dry forest changes with forest age. *PeerJ* **6**: e5217.

Little, I.T., Hockey, P.A.R. & Jansen, R. 2015. Predation drives nesting success in moist highland grasslands: The importance of maintaining vegetation cover for bird conservation. *Ostrich* **86**: 1–5.

Londe, D.W., Fuhlendorf, S.D., Elmore, R.D. & Davis, C.A. 2019. Landscape heterogeneity influences the response of grassland birds to energy development. *Wildl. Biol.* **2019**: 1–11.

Macchi, L., Decarre, J., Goijman, A.P., Mastrangelo, M., Blendinger, P.G., Gavier-Pizarro, G.I., Murray, F., Piquer-Rodriguez, M., Semper-Pascual, A. & Kuemmerle, T. 2020. Trade-offs between biodiversity and agriculture are moving targets in dynamic landscapes. *J. Appl. Ecol.* **57**: 2054–2063.

Macías-Duarte, A., Panjabi, A.O., Strasser, E.H., Levandoski, G.J., Ruvalcaba-Ortega, I., Doherty, P.F. & Ortega-Rosas, C.I. 2017. Winter survival of north American grassland birds is driven by weather and grassland condition in the Chihuahuan Desert. *J. Field Ornithol.* **88**: 374–386.

Mahamued, B.A., Donald, P.F., Collar, N.J., Marsden, S.J., Ndang'ang'a, P.K., Wondafrash, M., Abebe, Y.D., Wotton, S.R., Gornall, D. & Lloyd, H. 2021. Rangeland loss and population decline of the critically endangered Liben Lark *Heteromirafra archeri* in Southern Ethiopia. *Bird Conserv. Int.* **32**: 64–77.

Mahood, S.P., Poole, C.M., Watson, J.E.M., MacKenzie, R.A., Sharma, S. & Garnett, S.T. 2020. Agricultural intensification is causing rapid habitat change in the Tonle Sap floodplain, Cambodia. *Wetl. Ecol. Manag.* **28**: 713–726.

Mäkeläinen, S., Harlio, A., Heikkinen, R.K., Herzon, I., Kuussaari, M., Lepikkö, K., Maier, A., Seimola, T., Tiainen, J. & Arponen, A. 2019. Coincidence of high nature value farmlands with bird and butterfly diversity. *Agric. Ecosyst. Environ.* **269**: 224–233.

Manry, D.E. & Knight, R.S. 1986. Lightning density and burning frequency in south African vegetation. *Vegetatio* **66**: 67–76.

Maphisa, D.H., Smit-Robinson, H., Underhill, L.G. & Altwegg, R. 2016. Drivers of bird species richness within moist high-altitude grasslands in eastern South Africa. *PLoS One* **11**: e0162609.

Maphisa, D.H., Smit-Robinson, H., Underhill, L.G. & Altwegg, R. 2017. Management factors affecting densities of common grassland birds of high elevation grasslands of eastern South Africa: Ingula as a case study. *Avian Res.* **8**: 5.

Maphisa, D.H., Smit-Robinson, H. & Altwegg, R. 2019. Dynamic multi-species occupancy models reveal individualistic habitat preferences in a high-altitude grassland bird community. *PeerJ* **7**: e6276.

Martin, T.H. & Buchholz, R. 2018. Implications of male breeding-season home range movements for population monitoring and minimum reserve area of the ocellated Turkey (*Meleagris ocellata*), a threatened Yucatán endemic. *Condor* **120**: 815–827.

Martin, P.A., Johnson, D.L., Forsyth, D.J. & Hill, B.D. 1998. Indirect effects of the pyrethroid insecticide deltamethrin on reproductive success of chestnut-collared longspurs. *Ecotoxicology* **7**: 89–97.

Maude, G. & Reading, R.P. 2010. The role of ecotourism in biodiversity and grassland conservation in Botswana. *Great Plains Res.* **20**: 109–119.

McCracken, J.D. 2005. Where the bobolinks roam: The plight of North America's grassland birds. *Biodiversity* **6**: 20–29.

McGrady, M.J. 2018. Diurnal raptor migration, including wintering, on the Arabian peninsula, an overview. *Sandgrouse Suppl.* **4**: 85–105.

Mendenhall, C.D., Shields-Estrada, A., Krishnaswami, A.J. & Daily, G.C. 2016. Quantifying and sustaining biodiversity in tropical agricultural landscapes. *Proc. Natl. Acad. Sci. U.S.A.* **113**: 14544–14551.

Mirzabaev, A., Wu, J., Evans, J., García-Oliva, F., Hussein, I.A.G., Iqbal, M.H., Kimutai, J., Knowles, T., Meza, F., Nedjraoui, D., Tena, F., Türkeş, M., Vázquez, R.J. & Weltz, M. 2019. Desertification. In Shukla, P.R., Skea, J., Calvo Buendia, E., Masson-Delmotte, V., Pörtner, H.-O., Roberts, D.C., Zhai, P., Slade, R., Connors, S., van Diemen, R., Ferrat, M., Haughey, E., Luz, S., Neogi, S., Pathak, M., Petzold, J., Portugal Pereira, J., Vyas, P., Huntley, E., Kissick, K., Belkacemi, M., Malley, J. (eds.) *Climate change and land: An IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems*. Geneva: IPCC. Available at: https://www.ipcc.ch/site/assets/uploads/sites/4/2019/11/06_Chapter-3.pdf. (accessed 31 August 2022)

Monroe, A.P., Burger, L.W. & Martin, J.A. 2019. Pasture-scale vegetation predicts Dickcissel nest-site selection and success in native and exotic grass pastures. *Condor* **121**: 1–14.

Mortelliti, A. & Lindenmayer, D.B. 2015. Effects of landscape transformation on bird colonization and extinction patterns in a large-scale, long-term natural experiment. *Conserv. Biol.* **29**: 1314–1326.

Mu, S.J., Chen, Y.Z., Li, J.L., Ju, W.M., Odeh, I.O.A. & Zou, X.L. 2013. Grassland dynamics in response to climate change and human activities in Inner Mongolia, China between 1985 and 2009. *Rangel. J.* **35**: 315–329.

Navarro, J.L., Lèche, A., Della Costa, N.S., Vera Cortez, M., Marin, R.H. & Martella, M.B. 2019. State of the art knowledge in adrenocortical and behavioral responses to environmental challenges in a threatened south American ratite: Implications to in situ and ex-situ conservation. *Gen. Comp. Endocrinol.* **273**: 52–60.

Neary, D.G. & Leonard, J.M. 2020. Effects of fire on grassland soils and water: A review. In Kindomihou, V.M. (ed) *Grasses and Grassland Aspects*. London: IntechOpen

Limited. 10.5772/intechopen.90747. (accessed 31 August 2022)

Neilly, H. & Schwarzkopf, L. 2019. The impact of cattle grazing regimes on tropical savanna bird assemblages. *Austral Ecol.* **44**: 187–198.

Niemuth, N.D., Estey, M.E., Fields, S.P., Wangler, B., Bishop, A.A., Moore, P.J., Grosse, R.C. & Ryba, A.J. 2017. Developing spatial models to guide conservation of grassland birds in the U.S., Northern Great Plains. *Condor* **119**: 506–525.

O'Connor, T.G., Puttick, J.R. & Hoffman, M.T. 2014. Bush encroachment in southern Africa: Changes and causes. *African J. Range Forage Sci.* **31**: 67–88.

Ogden, S., Haukos, D.A., Olson, K.C., Lemmon, J., Alexander, J., Gatson, G.A. & Fick, W.H. 2019. Grassland bird and butterfly responses to sericea lespedeza control via late-season grazing pressure. *Am. Midl. Nat.* **181**: 147–169.

Onrust, J., Wymenga, E., Piersma, T. & Olff, H. 2019. Earthworm activity and availability for meadow birds is restricted in intensively managed grasslands. *J. Appl. Ecol.* **56**: 1333–1342.

Ospina, S., Rusch, G.M., Pezo, D., Casanoves, F. & Sinclair, F.L. 2012. More stable productivity of semi-natural grasslands than sown pastures in a seasonally dry climate. *PLoS One* **7**: e35555.

Panunzi, E. 2008. *Are grasslands under threat? Brief analysis of FAO statistical data on pasture and fodder crops*. Available at: https://www.fao.org/uploads/media/grass_stats_1.pdf (accessed 31 August 2022)

Pedrana, J., Bernad, L., MacEira, N.O. & Isacch, J.P. 2018. Niche overlap determination through habitat suitability models: A management tool for native birds of the Argentinean pampas. *Ardeola* **65**: 25–40.

Phifer, C.C., Knowlton, J.L., Webster, C.R., Flaspohler, D.J. & Licata, J.A. 2017. Bird community responses to afforested eucalyptus plantations in the argentine pampas. *Biodivers. Conserv.* **26**: 3073–3101.

Piaskowski, V.D., Teul, M., Cal, R.N. & Williams, K.M. 2005. Habitat associations of neotropical migrants in Belize, Central America, during the non-breeding season. *Passeng. Pigeon* **67**: 61–76.

Pierce, A.K., Dinsmore, S.J. & Wunder, M.B. 2019. Decreased nest survival associated with low temperatures in a high-elevation population of mountain plover (*Charadrius montanus*). *Wilson J. Ornithol.* **131**: 502–513.

Pretelli, M.G., Isacch, J.P. & Cardoni, D.A. 2018. Species-area relationships of specialist versus opportunistic pampas grassland birds depend on the surrounding landscape matrix. *Ardeola* **65**: 3–23.

Rawat, G.S. & Adhikari, B.S. 2015. Ecology and management of grassland habitats in India. *ENVIS Bull Wildl. Prot. Areas* **17**: 244.

Regos, A., Vidal, M., Lorenzo, M. & Domínguez, J. 2020. Integrating intraseasonal grassland dynamics in cross-scale distribution modeling to support waterbird recovery plans. *Conserv. Biol.* **34**: 494–504.

Reiley, B.M., Stodola, K.W. & Benson, T.J. 2019. Are avian population targets achievable through programs that restore habitat on private-lands? *Ecosphere* **10**: e02574.

Renfrew, R.B., Hill, J.M., Kim, D.H., Romanek, C. & Perlut, N.G. 2017. Winter diet of bobolink, a long-distance migratory grassland bird, inferred from feather isotopes. *Condor* **119**: 439–448.

Reside, A.E., Van Der Wal, J., Kutt, A., Watson, I. & Williams, S. 2012. Fire regime shifts affect bird species distributions. *Divers. Distrib.* **18**: 213–225.

Robinson, S., Milner-Gulland, E.J. & Alimaev, I. 2003. Rangeland degradation in Kazakhstan during the soviet era: Re-examining the evidence. *J. Arid Environ.* **53**: 419–439.

Roels, S.M., Hannay, M.B. & Lindell, C.A. 2019. Recovery of bird activity and species richness in an early-stage tropical forest restoration. *Avian Conserv. Ecol.* **14**: 109.

Rosenberg, K.V., Dokter, A.M., Blancher, P.J., Sauer, J.R., Smith, A.C., Smith, P.A., Stanton, J.C., Panjabi, A., Helft, L., Parr, M. & Marra, P.P. 2019. Decline of the North American avifauna. *Science* **366**: 120–124.

Runge, C.A., Withey, J.C., Naugle, D.E., Fargione, J.E., Helmstedt, K.J., Larsen, A.E., Martinuzzi, S. & Tack, J.D. 2019. Single species conservation as an umbrella for management of landscape threats. *PLoS One* **14**: e0209619.

Salafsky, N., Salzer, D., Stattersfield, A.J., Hilton-Taylor, C., Neugarten, R., Butchart, S.H.M., Collen, B., Cox, N., Master, L., O'Connor, S. & Wilkie, D. 2008. A standard lexicon for biodiversity conservation: Unified classifications of threats and actions. *Conserv. Biol.* **22**: 897–911.

Santangeli, A., Spiegel, O., Bridgeford, P. & Girardello, M. 2018. Synergistic effect of land-use and vegetation greenness on vulture nestling body condition in arid ecosystems. *Sci. Rep.* **8**: 27.

Scheffers, B.R., De Meester, L., Bridge, T.C.L., Hoffmann, A.A., Pandolfi, J.M., Corlett, R.T., Butchart, S.H.M., Pearce-Kelly, P., Kovacs, K.M., Dudgeon, D., Pacifici, M., Rondinini, C., Foden, W.B., Martin, T.G., Mora, C., Bickford, D. & Watson, J.E.M. 2016. The broad footprint of climate change from genes to biomes to people. *Science* **354**: aaf7671.

Sheldon, R., Koshkin, M., Kamp, J., Dereliev, S., Donald, P. & Jbour, S. 2012. *International single species action plan for the conservation of the sociable lapwing Vanellus gregarius*. CMS Technical Series No. 28, AEWA Technical Series No. 47. Bonn, Germany.

Shew, J.J., Nielsen, C.K. & Sparling, D.W. 2019. Finer-scale habitat predicts nest survival in grassland birds more than management and landscape: A multi-scale perspective. *J. Appl Ecol.* **56**: 929–945.

da Silva, T.W. & Fontana, C.S. 2020. Success of active restoration in grasslands: A case study of birds in southern Brazil. *Rest. Ecol.* **28**: 512–518.

da Silva Mohr, L.R., Périco, E., da Silva Fonseca, V.S. & Mohr, A.R. 2017. The breeding biology, nest success, habitat and behavior of the endangered saffron-cowled blackbird, *Xanthopsar flavus* (Aves: Icteridae), at an important bird area (IBA) in Rio Grande do Sul, Brazil. *Zoologia* **34**: 1–10.

Skowno, A.L., Poole, C.J., Raimondo, D.C., Sink, K.J., Van Deventer, H., Van Niekerk, L., Harris, L.R., Smith-Adao, L.B., Tolley, K.A., Zengeya, T.A., Foden, W.B., Midgley, G.F. & Driver, A. 2019. *National Biodiversity Assessment 2018: The Status of South Africa's Ecosystems and Biodiversity. Synthesis Report*. 1–214. Pretoria: South African National Biodiversity Institute, an Entity of the Department of Environment Forestry and Fisheries.

Society for Ecological Restoration. 2022. *India: Restoration of Banni Grassland in Gujarat*. Available at: https://www.ser-rrc.org/project/india-restoration-of-banni-grassland-in-gujarat/ (accessed 31 August 2022)

Sommer, N.R., Moody, N.M., Lantz, S.M., Leu, M., Karubian, J. & Swaddle, J.P. 2018. Redbacked fairywrens adjust habitat use in response to dry season fires. *Austral Ecol.* **43**: 876–899.

Squires, V.R., Dengler, J., Feng, H. & Hua, L. 2018. *Grasslands of the World. Diversity, Management and Conservation*. Boca Raton, FL: CRC Press.

Stanton, R.A., Boone, W.W., Soto-Shoender, J., Fletcher, R.J., Blaum, N. & McCleery, R.A. 2018a. Shrub encroachment and vertebrate diversity: A global meta-analysis. *Glob. Ecol. Biogeogr.* **27**: 368–379.

Stanton, R.L., Morrissey, C.A. & Clark, R.G. 2018b. Analysis of trends and agricultural drivers of farmland bird declines in North America: A review. *Agric. Ecosyst. Environ.* **254**: 244–254.

Stjernman, M., Sahlin, U., Olsson, O. & Smith, H.G. 2019. Estimating effects of arable land use intensity on farmland birds using joint species modeling. *Ecol. Appl.* **29**: e01875.

Su, X., Han, W., Liu, G., Zhang, Y. & Lu, H. 2019. Substantial gaps between the protection of biodiversity hotspots in alpine grasslands and the effectiveness of protected areas on the Qinghai-Tibetan plateau, China. *Agric. Ecosyst. Environ.* **278**: 15–23.

Sullins, D.S., Haukos, D.A., Lautenbach, J.M., Lautenbach, J.D., Robinson, S.G., Rice, M.B., Sandercock, B.K., Kraft, J.D., Plumb, R.T., Reitz, J.H., Hutchinson, J.M.S. & Hagen, C.A. 2019. Strategic conservation for lesser prairie-chickens among landscapes of varying anthropogenic influence. *Biol. Conserv.* **238**: 213.

Tallamy, D.W. & Shriver, W.G. 2021. Are declines in insects and insectivorous birds related? *Ornithol. Appl.* **123**: duaa059.

Tanentzap, A.J., Lamb, A., Walker, S. & Farmer, A. 2015. Resolving conflicts between agriculture and the natural environment. *PLoS Biol.* **13**: e1002242.

Tilman, D., Balzer, C., Hill, J. & Befort, B.L. 2011. Global food demand and the sustainable intensification of agriculture. *Proc. Natl. Acad Sci USA* **108**: 20260–20264.

Turbek, S.P., Browne, M., Pasian, C. & Giacomo, A.S.D. 2019. First nest description of the Iberá seedeater (*Sporophila iberaensis*). *Wilson J. Ornithol.* **131**: 156–160.

Van Niekerk, J.H. 2017. Orange River francolins (*Scleroptila levaillantoides*) persist in fragmented highveld farming landscapes, South Africa. *Avian Res.* **8**: 11.

Varun, K. & Dutta, S. 2020. Understanding land-use response of bird communities in an arid ecosystem of India. *bioRxiv* 10.1101/2020.09.27.315473 (accessed 31 August 2022)

Vickery, P.D., Tubaro, P.L., Da Silva, J.M.C., Peterjohn, B.G., Herkert, J.R. & Cavalcanti, R.B. 1999. Conservation of grassland birds in the western hemisphere. *Stud. Avian Biol.-Ser.* **19**: 2–26.

Wang, Z., Song, K., Zhang, B., Liu, D., Ren, C., Luo, L., Yang, T., Huang, N., Hu, L., Yang, H. & Liu, Z. 2009. Shrinkage and fragmentation of grasslands in the west Songnen plain, China. *Agric. Ecosyst. Environ.* **129**: 315–324.

Wesche, K., Ambarlı, D., Kamp, J., Török, P., Treiber, J. & Dengler, J. 2016. The Palaearctic steppe biome: A new synthesis. *Biodivers. Conserv.* **25**: 2197–2231.

Weyland, F., Baudry, J. & Ghersa, C. 2019. Short-term effects of a severe drought on avian diversity and abundance in a pampas agroecosystem. *Austral Ecol.* **44**: 1340–1350.

Wiens, J.A. & Rotenberry, J.T. 1979. Diet niche relationships among North American grassland and shrubsteppe birds. *Oecologia* **42**: 253–292.

With, K.A., King, A.W. & Jensen, W.E. 2008. Remaining large grasslands may not be sufficient to prevent grassland bird declines. *Biol. Conserv.* **141**: 3152–3167.

World Economic Forum. 2022. *Here's why forest restoration is key to India's ambitious climate goals*. Available at: https://www.weforum.org/agenda/2022/03/forest-restoration-india-ambitious-climate-goals/ (accessed 31 August 2022)

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Table S1. Regions and constituent countries/territories considered in the study (BirdLife International Region list).

Table S2. Search terms per region.

Table S3. Excel file of the articles selected for review in each region (available online).

Table S4. Threats to grassland birds used in current study.

Table S5. Conservation actions for grassland birds used in current study.