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Summary

Populations of several long-distance migratory songbirds in Eurasia are in peril, drastically illustrated by the recent range-wide population collapse in the Yellow-breasted Bunting *Emberiza aureola*. There are signals of a strong decline also in the Rustic Bunting *E. rustica*, but no range-wide assessment of population trends in this superabundant and widespread bunting species has yet been undertaken. The conservation status of Rustic Bunting is 'Least Concern' on the global IUCN Red List, but it has recently been upgraded to 'Vulnerable' on the European Red List. To assess the Rustic Bunting's global conservation status we compiled, for the first time, population data across its breeding and wintering ranges. The analysis reveals a 75–87% decline in overall population size over the last 30 years and a 32–91% decline over the last 10 years. The trend estimates indicate that the long-term (30-year) range-wide population decline in the Rustic Bunting is of similar magnitude to two well-known examples of declining species within the same genus, the Yellow-breasted Bunting and the Ortolan Bunting *E. hortulana*. The magnitude of the range-wide population decline over the last 10 years suggests that the Rustic Bunting could be upgraded from 'Least Concern' to 'Vulnerable' or 'Endangered' on the IUCN global Red List. Agricultural intensification in the wintering range and intensified levels of disturbance, including logging and fire, in the breeding range could be important drivers of the range-wide population decline, and persecution could also contribute. Untangling threat factors and their interactions on Rustic Bunting is necessary for conservation, but hampered by our currently limited understanding of the relationships between population dynamics and different threats.

Introduction

A large number of long-distance migratory songbirds exhibit decreasing population trends in Eurasia (Sanderson *et al.* 2006, Laaksonen and Lehikoinen 2013, Vickery *et al.* 2014). Amongst the 170 long-distance migratory songbird species using the East Asian flyway, for example, one third show declining trends and 12% are classified as threatened or near-threatened (Yong *et al.* 2015). Whilst the drivers of population declines are comparatively well studied in the Afro-Palearctic migratory system (Vickery *et al.* 2014), such knowledge is scarce for the East Asian flyway (Yong *et al.* 2015). Asia has seen a strong intensification in agriculture during recent decades, and witnessed increasing urbanisation and industrialisation (Alauddin and Quiggin 2008). Anthropogenic and climate-related stressors in the form of logging, draining, and forest fires have also increased (Goldammer and Furyaev 1996, Achard *et al.* 2006) as has trapping of songbirds for consumption and religious merit release (Gilbert *et al.* 2012, Townsend 2015, Yong *et al.* 2015). Stronger environmental pressures on breeding and wintering habitats and increased levels of persecution have therefore emerged as serious threats to long-distance migratory songbird populations in East Asia.

Habitat loss and persecution are considered as threats to rare and range-restricted species, but the scale of these factors may now have reached levels whereby even superabundant and wide-ranging species are becoming threatened. For example, data for Yellow-breasted Bunting *Emberiza aureola*, compiled across its distribution in Eurasia, showed that the global population of this once very abundant species, virtually collapsed over a time period of only 25 years (Kamp *et al.* 2015). The Rustic Bunting *Emberiza rustica* shares many ecological traits with the Yellow-breasted Bunting. For example, both have very large and almost overlapping breeding ranges, being superabundant long-distance migrants, and use similar migration routes (Byers *et al.* 2013). There are some signals of a strong population decline also in the Rustic Bunting (BirdLife International 2015a), but the details and causes of the decline remain unclear.

The distribution of the Rustic Bunting spans roughly 170 degrees of longitude, across Eurasia from Fennoscandia in the west to the Kamchatka peninsula in the east (Cramp and Perrins 1994). The breeding range, which is estimated at 218 Mha (BirdLife International 2015a), is intimately linked to the boreal forest, wherein the typical breeding habitat is wet coniferous forest with birch *Betula* spp. and willow *Salix* spp. growth along slow-flowing water (Öhrn 1963, Pulliainen and Saari 1989, Kretchmar 2000). Current evidence suggests that the winter range of the Rustic Bunting is confined to East Asia comprising Japan, the Korean Peninsula, and eastern and central mainland China north of the tropic of Cancer (Byers *et al.* 2013). For the bulk of the population, autumn migration follows forested regions eastwards, turning south in Asia east of Mongolia (Cramp and Perrins 1994, Byers *et al.* 2013). While just a few birds migrate through or winter in Kazakhstan (Berezovikov and Levinskiy 2008), the Rustic Bunting is one of the most common species during migration in the Russian Far East (Averin *et al.* 2012, Heim *et al.* 2012, Heim and Smirenski 2013). Birds from Kamchatka (sometimes regarded as a separate subspecies *latifascia*) are believed to migrate south-west across the Sea of Okhotsk or south to Japan across the Sea of Japan (Valchuk *et al.* 2005). The spring migration in the Rustic Bunting appears to mirror the autumn migration, but the details of its migratory patterns including stopover sites are inadequately known.

During the breeding season, the diet of Rustic Bunting mostly consists of invertebrates, whereas it shifts to seeds, grasses, and other vegetable food in other seasons (Cramp and Perrins 1994). A variety of semi-open habitats are used during stopovers and in the winter range, including woodlands, willow thickets, clearings, rice stubble, reed beds and riverbanks (Cramp and Perrins 1994, Fujioka *et al.* 2010, Yoo *et al.* 2011, Schäfer *et al.* in prep). At its winter feeding sites, the Rustic Bunting prefers wet grassy places with plenty of seeds and presence of dense shrubs or trees (Iijima 1973, Maeda 2001). Maeda (1973) observed spatially segregated habitat use in the Rustic Bunting during winter, with flocks of several hundred birds feeding in rice paddies during daytime and roosting in loosely dispersed groups in shrubby or grassy patches in woodland areas up to 1 km from the feeding sites.

The Rustic Bunting is classified as a species of 'Least Concern' (LC) on the IUCN Red List, i.e. it is not considered globally threatened (BirdlLife International 2012). However, it has recently been upgraded to 'Vulnerable' (VU) on the European Red List (BirdLife International 2015b). Population trends have been estimated for Fennoscandia (Dale and Hansen 2013) and Europe (BirdLife International 2015a) but not for the whole distribution range. Trend assessments and expert opinions suggest that the European breeding population of Rustic Bunting has declined by 30–49% over the last 10 years in Europe, but only around one-fifth of the species' global breeding range is within Europe (Symes 2015). For large parts of the breeding range, population trends remain unknown. While earlier population assessments have focused on restricted parts of the distribution range and included a limited amount of time series data, we here present the first range-wide assessment of population trends in the Rustic Bunting based on several short and long term time series.

We compiled Rustic Bunting data from different countries to determine the range-wide rates of population change and hence assess the species's global status. We also present an overview of possible drivers underlying the decline and propose key research activities to help overcome the current lack of knowledge about the bunting's ecology which hampers effective conservation policies.

Material and methods

Data collection

We collated time series data on the Rustic Bunting from countries in the breeding range (Norway, Sweden and Finland) and from stop-over sites during migration (Japan and north-eastern China). Standardised breeding survey data were preferentially used, but since such data are scarce we also included ringing data. In case of ringing data we only included standardised time series data, i.e. data controlled for capture effort. We used nationwide breeding survey data from Sweden and Finland and breeding territory count data for the very small Norwegian population (Green and Lindström 2015a, Hansen 2015, Aleksi Lehikoinen pers. comm.). In Sweden, breeding survey counts have been carried out on fixed routes systematically distributed across Sweden since 1998 (Green and Lindström 2015a). However, the number of surveyed fixed routes within the Rustic Bunting's breeding range in northern Sweden was low during the first years. Therefore, we used Swedish breeding bird data only from the last 10 years (2005–2014). To increase the length of the overall time series we complemented the Swedish breeding survey data with Rustic Bunting data from ringing stations. The Japanese and Chinese data consisted of the number of Rustic Buntings ringed during autumn migration at ringing stations. In total, we compiled seven time series of data of up to 30 years in length, see Table 1 and Appendix S1 in the online supplementary materials for details.

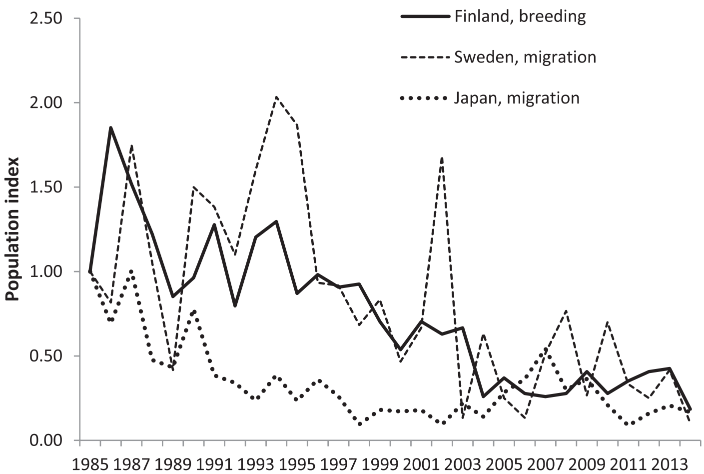
Statistical analysis

For the Swedish and Finnish breeding bird survey data, we used TRIM-estimated (Pannekoek and van Strien 2013) yearly population indices and linear trends provided to us by the national programme organisers. To make the ringing data comparable with these breeding survey data, we also used TRIM (ver. 3.54) to calculate indices and trends. In the case of the Norwegian breeding survey data we applied TRIM to the numbers of occupied territories 2008–2014 (Hansen 2015; Table 1, Figure 1b). The widespread TRIM (TRends and Indices for Monitoring data) software uses log-linear models with a Poisson error distribution and allows for missing counts. Yearly population indices were scaled (indexed) to 1 for the starting year. We employed models that controlled for over-dispersion and serial correlation, and used trend estimates based on the imputed population indices (to account for missing values) as recommended by Pannekoek

Table 1. TRIM-estimated annual decline rates for national data sets 1985–2014. *P*-levels denote significance of deviation of slope values from 1 (= no change).

Country	Time period	Annual change, %	*P*-level
Norway	2005–2014	-30	< 0.05
Sweden	1985–2014	-6.0	< 0.01
Sweden	2005–2014	-5.3	< 0.001
Finland	1985–2014	-6.1	< 0.001
Japan	1985–2014	-4.5	< 0.01
China	2005–2014	-20	< 0.05

a) Long-term (1985–2014)



b) Short-term (2005–2014)

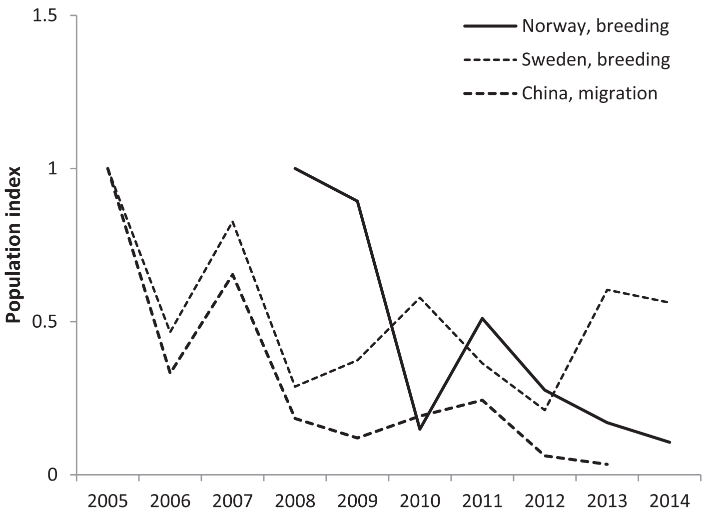


Figure 1. TRIM estimated yearly indices of Rustic Bunting numbers in long-term (a) and short-term (b) data series.

and van Strien (2013). Rangewide trends were estimated by averaging the national time-series trends. Trends were estimated for 30 years (1985–2014, long-term) and 10 years (2005–2014, short-term), respectively. Missing values amounted to 2% (n = 2) and 7% (n = 5) of the data points in the long- and short-term datasets, respectively. The small population in Norway, where the Rustic Bunting is dwindling and is estimated currently at less than 10 pairs (Hansen 2015), may have a disproportionate impact on the range-wide trend estimates. Therefore, we analysed the time-series data also without the Norwegian data.

Results

The TRIM-estimated yearly indices of the national data series revealed consistent population declines across the range (Table 1, Figure 1). For the long-term data (1985–2014), the average range-wide annual decline rate was estimated at 5.5% (± 1.0% 95% CI), which corresponds to an 82% (75–87%) reduction in population size over 30 years. The short-term (2005–2014) annual decline rate was 12.4% (± 8.6% 95% CI), corresponding to a 73% (32–91%) reduction over 10 years (Figure 1b). When we re-ran the analyses after excluding the Norwegian data, it yielded a 10-year annual decline rate of 8.9% (± 6.3% 95% CI), i.e. a 60% (23–81%) overall decline.

Discussion

Our analysis provides compelling evidence for a strong range-wide decline in Rustic Bunting populations in recent times. To put the magnitude of the population decline into perspective, we can compare it with two better-known examples of dramatic range-wide population declines within the same genus: the Yellow-breasted Bunting and the Ortolan Bunting *E. hortulana*. The decline in the Yellow-breasted Bunting was estimated at 84–95% over 34 years (Kamp *et al.* 2015). An extrapolation of our 82% (75–87%) long-term (30 year) trend in the Rustic Bunting yields an 85% range-wide decline over 34 years. For the Ortolan Bunting, Vickery *et al.* (2014) reported an 84% decline over 30 years (1980–2009), which was the strongest population decline of all long-distance migratory species in the Afro-Palearctic migratory system they studied. In the case of the Yellow-breasted Bunting, the population collapse was accompanied by a strong eastward range contraction. Although such a dramatic global range contraction has not yet been observed in the Rustic Bunting, the range contraction towards north-east within Fennoscandia has been dramatic. On the western edge of the global distribution huge areas of habitat on the former Rustic Bunting distribution are now more or less empty of the species (Valkama *et al.* 2011, Dale and Hansen 2013, Green and Lindström 2015b).

The decline rate estimates have strong relevance for the ongoing discussion about the conservation status of the Rustic Bunting on the IUCN global Red List where it is currently listed in the 'Least Concern' (LC) category. Our range-wide estimate of a 61% (73% with the Norwegian data) population decline for 2005–2014 (a time span roughly corresponding to three generations in the Rustic Bunting; Symes 2015) indicates a decline well over the 30% threshold required for classification as 'Vulnerable' (VU). Moreover, the observed population reduction exceeds the 50% threshold for the category 'Endangered' (EN) on the global Red List.

Our data samples are biased towards Fennoscandia. This is an unavoidable consequence of the fact that more data series are available from that part of the distribution range. From Russia, which holds the bulk of the breeding population, we found only scattered information on breeding densities (e.g. Rogacheva 1992 – Central Siberia, Kretchmar 2000 – noth-east Siberia), but no standardised data on long-term population development. However, numbers of Rustic Buntings captured during standardised ringing at Muraviovka Park in the Amur region of Russia show a decrease of > 90% in recent years (2012–2015) (Wieland Heim pers. obs.). The Gaofeng Bird Ringing Station located on the Chinese side of the Amur River also reports a strong recent decline (Table 1, Figure 1b). This suggests that the decline in numbers of Rustic Buntings passing through this part of East Asia during migration has been particularly strong. The negative trend expressed by the Fukushimagata Ringing Station data in Japan (Figure 1a) is also seen in the non-standardised national ringing sums of Rustic Bunting in that country for the same time period (Kiyoaki Ozaki pers. obs.). In South Korea no long-term standardised data series exist, but non-standardised short-term ringing data show that capture rates of Rustic Bunting (measured as the proportion of total ringing sums) are now about 10 times lower than they were in the mid-1960s (Chang-Yong Choi pers. obs.). Also in China there is a shortage of standardised ringing data (Bo Pettersson pers. comm.). We included the most comprehensive data series from China, from the Gaofeng Bird Ringing Station, Heilongjiang Province (Appendix S1) in our analysis, and it showed a strong

Table 2. Changes in land use practices, natural processes and persecution, and their potential impacts on Rustic Bunting populations.

Practice/process	Effect on Rustic Bunting habitat or populations	Estimated strength of impact	Trend	Reference
Breeding range				
Draining to enhance forest productivity	Habitat loss/degradation. Decreasing in the western range but may be increasing elsewhere	Moderate	Increasing?	Skogsstyrelsen (2014), Metla (2015)
Forest logging	Habitat loss. Increasing intensity in parts of the range	Moderate-strong	Increasing	Skogsstyrelsen (2014), Achard *et al.* (2006)
Wild fires	Habitat loss. Increasing, particularly in central and eastern parts in response to climate change and increased anthropogenic disturbance	Strong	Increasing	Achard *et al.* (2006), Flannigan *et al.* (2009)
Melting/retreating permafrost	Habitat loss/degradation. Drying up of wet forests related to climate change. Large areas in the eastern range potentially affected	Strong	Increasing	Soja *et al.* (2007)
Dam constructions	Habitat loss. Central and eastern parts of the range	Moderate	Unknown	Achard *et al.* (2006)
Wintering range				
Use of pesticides	Reduced food resources, potential poisoning. High application rates in China, Japan and the Republic of Korea	Strong	Increasing	Bright et al. (2008)
Multiple crop cycles	Habitat loss and/or degradation due to reduction in winter stubbles which are important feeding habitats	Strong	Increasing	Round and Gardner (2008)
Reduction in grassland area	Habitat loss. Grasslands important as feeding habitat. Significant reduction in grassland area in China 1990-2000	Strong	Increasing	Maeda (2001), Shi *et al.* (2012)
Changes in area of fallow land	Habitat loss/degradation when fallow land becomes actively managed, vice versa when use ceases. Variable trends reported across the range	Strong	Diverging	Round and Gardner (2008), Amano (2009), Long *et al.* (2009)
Transformation of farmland and woody areas to other land uses	Habitat loss in case of urban and rural settlement expansion, potential habitat enrichment after abandonment of farmland	Strong	Diverging	Long *et al.* (2009), Wu *et al.* (2009)
Planting of trees and other woody vegetation	Unknown; improved habitat conditions due creation of woody patches in rural residential areas, but potential habitat loss when food-rich farmland is turned into large-scale tree plantations	Moderate	Increasing?	Wu *et al.* (2009)

Table 2. Continued.

Practice/process	Effect on Rustic Bunting habitat or populations	Estimated strength of impact	Trend	Reference
Climate change and unfavorable weather conditions	Drought and lowered ground water table; may change vegetation structures in natural grasslands and shrub habitats	Moderate	Increasing	Tamada *et al.* (2014)
Trapping for the trade market, private use or merit release	Communal roosting habits increase susceptibility to trapping	Strong (regionally)	Persisting; increasing?	Maeda (1973), Kamp *et al.* (2015), Yong *et al.* (2015)

decline in number of Rustic Buntings over the last 10 years (Table 1, Figure 1b). To conclude, both available standardised data and anecdotal information give unequivocal support for a strong range-wide population decline in Rustic Bunting over the last decades.

Possible drivers and knowledge gaps

Little is known about the magnitude of the impact of different threat factors and their interactions with regard to the population decline of long-distance migratory songbirds in the East Asian Flyway (Yong *et al.* 2015). In Table 2 we have compiled threat factors related to changes in land use practices, natural processes and persecution that may affect population dynamics in the Rustic Bunting. To untangle the effects of different threats we need better data on population demographics. For example, using data modelling Kamp *et al.* (2015) concluded that an initial harvest rate of 2% followed by a 0.2% annual increase was sufficient to produce a population collapse in the Yellow-breasted Bunting over a time period of 34 years. Currently we do not know to what extent survival in the Rustic Bunting is affected by habitat change and persecution. Similarly, our knowledge about the effects of habitat change on Rustic Bunting productivity is limited. Poor nesting success coupled to habitat loss and degradation could be a population limiting factor, as has been suggested in case of Jankowski's Bunting *E. jankowskii* (Jiang *et al.* 2008).

Assessment of the impacts of different threat factors is also hampered by our limited understanding of the connectivity between breeding and wintering ranges in the Rustic Bunting. Lightweight, light-level geolocators and stable isotope analysis provide new tools for studying such questions, but to date they have not been used to any larger degree on migratory songbirds in Asia (Yong *et al.* 2015). Knowledge about the migration routes and the wintering areas of the Rustic Bunting will be vital for prioritizing sites for new monitoring schemes in the Far East and for planning international conservation efforts.

Supplementary Material

The supplementary materials for this article can be found at journals.cambridge.org/bci

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