Ecology and conservation under ageing and declining human populations

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ABSTRACT

1. Much research and media attention has revolved around the environmental impacts of growing global human populations. While the conclusions remain contested, these assessments have largely neglected the ecological and conservation impacts of other key regional processes such as declining populations, ageing demographics, and rural-to-urban migration.

2. These demographic shifts are increasingly prevalent across many regions of the world, and will have significant direct effects on natural resource management and biodiversity conservation by altering individual consumption patterns, land use, land stewardship, and natural disturbances. Given that the scientific foundation around this topic is still developing, we first present an initial examination of some of the key environmental impacts, aiming to elevate awareness and encourage further research in these areas.

3. Beyond the ecological implications, declining populations, ageing demographics, and rural-to-urban migration carry intricate social and cultural consequences that can affect people and nature interactions. Ecological studies that focus on single dimensions of biodiversity or ecosystem responses often overlook these complexities. Demographic changes are likely to be accompanied by shifts in environmental attitudes and connections with nature, all of which will influence our capacity to adapt to or mitigate environmental changes. Finally, environmental policy and practice frameworks are potentially unprepared and their success could be sensitive to these socio-cultural and demographic shifts.

4. *Synthesis and applications*: This brief overview demonstrates that population decline, ageing, and rural-to-urban migration can have extensive implications for biodiversity and the socio-cultural relationships between people and nature. However, the significance, dynamics, and consequences of these processes are still largely overlooked. We believe that these changes warrant specific attention from the research, policy and practice communities, as understanding the outcomes and feedbacks associated with depopulation, ageing populations, loss of culture and tradition, and ecological change could aid in designing landscapes and informing management that enhances both human well-being and biodiversity conservation.

Introduction

Much research and media attention has revolved around the impact of growing global human populations on the availability of natural resources (Crist et al., 2017; Cafaro et al., 2022). Indeed, this issue has engendered great debate in recent years, with an emerging consensus among conservationists that wealth and consumption matter as much as or more than does population size alone (Ganivet, 2020). Yet this debate has largely ignored variable rates of population growth, fertility and mortality rates across different countries. For example, the populations of 61 countries across different continents are expected to decrease between 2022 and 2050 (United Nations, 2022). How declining populations with associated ageing demographics will influence ecology and conservation remains unclear, although there is growing evidence that these changes are important for biodiversity, but are also variable and context-dependent (Mehring et al., 2020).

Here, we highlight three human demographic changes that, despite receiving relatively little recognition in these contexts to date, are having far-reaching consequences for conservation and management of natural resources (Meyerson et al., 2007; Jarzebski et al., 2021). First, in contrast to global trends, a population decline is already happening across several European and Asian countries (Coleman & Rowthorn, 2013) and it is anticipated to soon manifest across the Americas and Oceania (Götmark et al., 2018). Second, a deceleration of population growth rates is always associated with general population ageing. The ageing of the demographic profile is also enabled by improved health care and it is already advanced in many high-income countries and is growing rapidly in many lower and middle-income regions (Jarzebski et al., 2021). Third, in addition to these long-term population dynamics, rural-to-urban migration can quickly change the age-related geographical distribution of people, with movements from rural areas to economic centres of wealth resulting in land abandonment, a rapid expansion of urban areas, and sometimes gender and age imbalance between stayers and movers.

All three of these demographic changes will have important direct influences on natural resource management and biodiversity conservation, but also important indirect effects through several socio-cultural ramifications affecting human-nature interactions (Fig. 1). Although researchers have highlighted the importance of different forms of human migration (Meyerson et al., 2007), work to date remains limited and the scientific evidence base on this topic is still forming (Mehring et al., 2020). Our aim is to make an initial exploration of some of the key effects, hoping to raise the profile of and stimulate new research in these areas.

We structure this by identifying risks and opportunities for biodiversity and by exploring some of the key socio-cultural outcomes of these understudied demographic changes that are likely to have the greatest effect on the use and management of ecosystems.

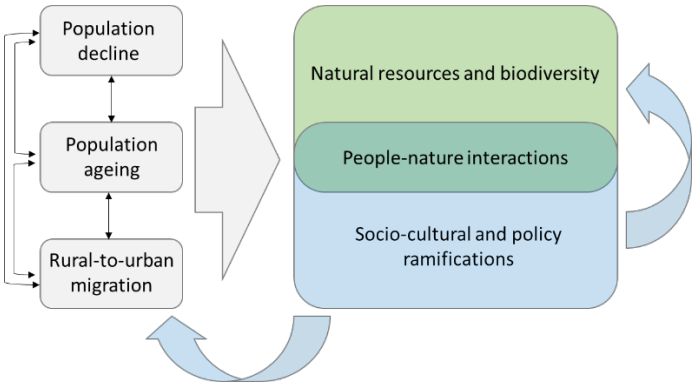

Fig. 1 Population decline, population ageing, and rural-to-urban migration are often intermingled processes that can have multiple direct impacts on natural resources and biodiversity but also indirect effects through complex socio-cultural feedbacks affecting people and people-nature interactions.

Direct effects on natural resources and biodiversity

Local population declines are particularly common in marginal economic areas also within wealthy countries (Daskalova & Kamp, 2023). In less than 50 years, the proportion of the human population living in rural areas has decreased by ~25%, in particular in Europe, North America, and Australia, and relocation to towns and cities is one of the major causes of land abandonment. Population redistribution has led to land-use changes, commonly involving the transformation of extensively and traditionally farmed land and pastures into shrublands and forests (Navarro & Pereira, 2012). Land abandonment might be an opportunity for habitat restoration and rewilding under certain circumstances. For example, it presents opportunities for developing a broad range of nature-based solutions by sequestering above-ground and soil carbon, enhancing flood protection and hydrological services, and delivering recreational and cultural services (Chazdon et al., 2016; Quintas-Soriano et al., 2022). On the other hand, land abandonment may be too ephemeral to provide major benefits for climate change mitigation, unless policy takes steps to reduce reconversion (Crawford et al., 2022).

Applied ecological research could play an important role in understanding and identifying opportunities for biodiversity and ecosystem service benefits and trade-offs, and which risks need to be accounted for. For example, land abandonment can have both positive and negative effects for biodiversity,

favouring woodland and shrubland species over farmland species in the Mediterranean (Sirami et al., 2008). Similarly, butterflies from colder climatic niches that use open habitats were negatively impacted by land abandonment, while populations of species with different climate and habitat needs were enhanced by land abandonment (Sugimoto et al., 2022). It is likely that biodiversity responses will depend on the taxon, environmental context and also on the definition of land abandonment (Queiroz et al., 2014). Furthermore, biodiversity responses to abandoned land will also interact with future climatic conditions. For instance, bird species from low-temperature niches, open habitat specialists and forest generalists would experience future declines while forest specialists would increase moderately under future human depopulation and climate warming (Katayama et al., 2024). Applied ecology can also inform debates about whether or not we should interfere with post-abandonment ecological dynamics. Rewilding is hotly contested among conservationists in Europe and North America, with calls to return to traditional reference systems contrasting with more radical alternatives including moving species outside their current native ranges or accepting novel ecosystems that are different from any past analogues (Corlett, 2016). In many cases, the risks and unseen consequences could be critical. For example, large scale land abandonment could contribute to landscape homogenization and might be linked also to the loss of semi-natural habitats with high conservation values (Marini et al., 2011). This is typical for temperate regions such as Europe, where a large number of priority habitats for conservation and red-listed species are linked to traditional land management (Geppert et al., 2020). Abandonment might also be linked to an increase in large scale disturbances such as fires due to increased fuel loads (Archer et al., 2017) and reduced capacity to control fire under lower land stewardship (Sjöström & Granström, 2023; Uriarte et al., 2012).

Rural-to-urban migration is causing urban land to expand even in regions with overall declining population, leading to habitat conversion and potential degradation of semi-natural peri-urban habitats (Li et al., 2022). In the tropics rural-urban migration can be encouraged by the processes of land accumulation by capitalised elites, forcing out the small-scale rural land managers and leading to homogenisations of the landscapes (Carmenta et al., 2023). Also in Western Europe, despite the overall declining population, the soil sealing rate is still increasing and is listed as the major threat to European soil resources (Montanarealla et al. 2015). Urbanisation is expected to continue in the future and can have severe consequences on endangered species and habitats located in peri-urban areas that are often not included in protected areas (Geppert et al.,

2020). As low-income neighbourhoods are those more impacted by this rural-to-urban migration and usually host lower biodiversity than richer neighbourhoods (Leong et al., 2018), negative pressures on urban biodiversity and habitats are expected to increase asymmetrically in most cities causing environmental and social inequities (Chamberlain et al. 2020). Here, applied ecology should inform policy on how to integrate biodiversity conservation into urban planning of growing cities. For instance, recent technological developments related to smart working have suggested that rethinking new models of work organisation with greater flexibility where workers can work from home could help reduce rural-to-urban movements (Roberto et al., 2023). For tropical rural areas brining forms of support (e.g. health care provision) to Indigenous People and local communities that enable them to remain in their territories is proposed as an important conservation strategy (Carmenta et al., 2023), particularly since the land held and managed by these communities are key for biodiversity and today represent the majority of the remaining low-intensity anthromes globally (Garnett et al., 2018).

A general deceleration of human population growth is also associated with an ageing population. Currently, despite a relatively large body of research on consumption patterns and emissions, there is no consensus on the impact of population ageing on the environment. Some studies indicate that ageing societies in centres of wealth usually shift towards the use of energy-intensive goods and services associated with higher emission levels (Balsalobre-Lorente et al., 2021; Zheng et al., 2022), while others have found that the higher income levels and living habits of the elderly make them more inclined towards certain environmentally friendly behaviours (Yang et al., 2021). Age-related increases in consumption are probably context dependent, varying with wealth, education and the environmental context. Here, research should focus on explaining this large variability in consumption patterns and environmental behaviour of young vs. elderly people before generalising the impact of ageing populations on the environment. Research also needs to address the very different global contexts, as demographics in ageing populations are also highly localised and influenced by a range of factors. For instance, global life expectancy decreased from 72.8 years in 2019 to 71.0 years in 2022 due to the COVID-19 pandemic. In Australia and New Zealand, life expectancy increased by 1.2 years in the same period due to low death rates in the pandemic but in other countries such as Botswana, Mexico and the Russian Federation, life expectancy declined by four years or more (United Nations, 2022).

Socio-cultural and policy ramifications

The complex social and cultural ramifications of these understudied demographic processes could have important repercussions on people and nature relationships and the factors that mediate them (e.g. knowledge, values, use). However, these interactions and feedbacks are often overlooked in ecological studies investigating single dimensions of biodiversity and/or ecosystem responses. Demographic projections show that understanding how ageing societies engage with, benefit from and influence nature will become increasingly relevant across most of the world as the century progresses (United Nations, 2022). While the literature on the direct effects of population decline on biodiversity and the environment is forming, there has been less attention on shifts in cultural services and associated values related to ageing and rural-to-urban migration and how these can affect biodiversity conservation and natural resource use and management (Parry et al., 2010; Pillemer et al., 2011; Quintas-Soriano et al., 2022). Because cultural ecosystem services are co-produced by nature and people, they are deeply affected by both demographic and environmental changes (Stoll et al., 2015). Further, the relational values that are enabled by and derived from being embedded in particular forms of nature, will be impacted as familiarity, use, and integration with nature shifts alongside these population changes (Carignano Torres et al., 2016).

Although it is difficult unequivocally to link particular changes in socio-ecological systems to particular changes in cultural benefits, rural depopulation imposes a clear challenge to preserve a high diversity of cultural services and the people-nature interactions that are delivering high biological and cultural diversity (Garnett et al., 2016). For instance, Indigenous and local knowledge, the biocultural fabric of traditional land- and sea-uses and concomitant relational values and cultural services will all be lost or attenuated as people leave a territory (Atapattu, 2020). A widespread loss of agricultural, husbandry and fishery traditions and other cultural services and associated benefits and values is occurring worldwide from tropical to arctic regions and the loss of value plurality is a great concern in many regions globally (Pascual et al., 2023). The deep relationship between biological and cultural diversity suggests that land abandonment and depopulation of biodiversity hotspot areas will lead to severe losses of cultural values, norms, and knowledge of its inhabitants (Bridgewater & Rotherham, 2019). For instance, most Indigenous and rural communities around the world often possess an extremely rich body of ecological knowledge about local environmental resources and biodiversity that is rapidly disappearing, losing information pivotal to the conservation of several endangered species (Turvey et al., 2018). More broadly, shifts from rural to urban living will commonly be accompanied

by an impoverishment of people's personalised ecologies (i.e., their nature interactions), the so-called 'extinction of experience' (Soga & Gaston, 2016). These personalised ecologies are linked to health and well-being benefits (Bratman et al., 2019; Hartig et al., 2014; Keniger et al., 2013), and to attitudes and behaviour towards nature (Cooper et al., 2015; Soga et al., 2016). The latter may have important implications for future policy and management of nature (Gaston et al., 2023), and these links are thus an important topic of future research investigation. Here, more research is needed to evaluate the importance of environmental experience and education in urban citizens during childhood, but also to understand what forms of conservation interventions are best suited to enable, amplify and empower Indigenous Peoples and local communities to remain in their territories - if desirable.

Also, the depletion of a young and skilled workforce as a corollary of depopulation has non-negligible repercussions on conservation issues. First, there might be an attenuation in active participation and innovation in local conservation strategies. For example, the loss of labour resulting from rural-to-urban migration of young people is already affecting the ability of local communities to carry out climate-safe fire management in regions of the Brazilian Amazon (Nóbrega Spínola et al., 2020). Second, when young people leave rural landscapes, they miss the level of traditional knowledge on natural resource management such as agro-forestry or small-scale farming. These losses could be permanent also in the case of future in-migrations to rural areas due to the very different values held by urban citizens moving into rural areas (González-Leonardo et al., 2022). Changes in human resources and knowledge in depopulating or ageing rural zones could have fundamental influence on the response capacity to environmental challenges and the success of management interventions, and more research on this is urgently needed.

The preponderance of an ageing population might also augment the demand for health and other social services, shifting resources and attention away from environmental concerns. Equally, it may increase the influence of those who have more personal experience of long-term shifts in the state of nature, with younger generations having experienced shifting baselines (Pauly, 1995; Soga & Gaston, 2018). However, it remains unclear whether pro-environmental attitudes and behaviours, such as direct involvement in conservation actions, differ between societies dominated by different age cohorts (Hughes et al., 2019). Similarly, differing attitudes towards conservation among those who choose to stay in rural areas versus those who migrate to cities or the impact of gender imbalances arising from these demographic shifts could be areas that will require

206 further research. Exposure, embeddedness and use of nature usually result in higher values held for nature,
207 values that are not only instrumental, but also relational, emotive, care and stewardship (Zelenski et al., 2015;
208 Geppert et al., 2024). Clearly, demographic changes are likely to be accompanied by changes in environmental
209 attitudes and connections with nature, all of which will influence our ability to adapt or mitigate change.

210 Finally, policy frameworks are probably not well prepared and thus vulnerable to the influences of
211 these shifts. This is partly because the temporal scale of population dynamics is much longer than the average
212 political mandate. However, it is also because the changes seem to be immune to policy interventions tested
213 so far, with efforts to reverse population change failing to alter demographic trends (e.g. Gu et al., 2021).
214 Beyond human demography, more research is necessary about how extant policies either inhibit or propel
215 conservation efforts in the light of these population trends. A key gap is understanding the push and pull factors
216 operating and - if desirable - what mechanisms might be needed to enable people to remain in rural territories.
217 For instance, the provision of health care stations in rural areas has proved an effective strategy to improve
218 nature stewardship and biodiversity conservation (Chapman et al., 2015) as access to education and healthcare
219 drive decision-making in Amazonian communities (Parry et al., 2010). Results of these studies should inform
220 policy adaptations, ensuring that conservation initiatives are responsive, adaptable, and congruent with the
221 changing demographic landscape. Addressing this quandary requires the infusion of public awareness
222 campaigns and an integration of policies that harmoniously balance social service provision with the
223 imperatives of environmental conservation. Understanding these dynamics will facilitate the formulation of
224 tailored conservation strategies, ensuring an inclusive approach that meets the diverse needs and challenges by
225 these distinct groups of people.

226 **Conclusion**

227 Altogether, this brief overview and range of examples demonstrate that population decline, ageing and rural-
228 to-urban migration can have far-reaching implications for biodiversity and socio-cultural relationships between
229 people and nature, but the importance, dynamics and consequences of these processes are still largely
230 overlooked (Jarzebski et al., 2021). Beside the demographic process considered here, international migration
231 is also causing important movements of people. As data on international migration flows exist for only a small
232 number of countries (United Nations, 2022) and the decision-making process behind migrants choosing their
233 destination remains elusive, more research should focus on this process that has the potential to be highly

damaging locally. We believe these changes require specific attention within the research, policy and practice communities, as understanding the outcomes of and feedbacks resulting from depopulation and ageing populations, loss of culture and tradition, and ecological change could help design landscapes that improve both human well-being and biodiversity conservation (Daskalova & Kamp, 2023). As these issues span the ecological and social sciences and engage concepts of environmental justice, we believe that two of the BES journals could provide important venues for novel research in this area: Journal of Applied Ecology for research exploring ecological outcomes and new management alternatives and People and Nature for articles focussing on the links between changing demographics, and changes in people's experiences of, benefits and costs from, and attitudes and behaviour towards nature.

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