Biological Conservation 272 (2022) 109646

Contents lists available at ScienceDirect

Biological Conservation

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

Overpopulation is a major cause of biodiversity loss and smaller human populations are necessary to preserve what is left

Philip Cafaro[a,*], Pernilla Hansson[b], Frank Götmark[b]

[a] Colorado State University, Fort Collins, CO, USA
[b] University of Gothenburg, Sweden

ARTICLE INFO

Keywords:
Population
Overpopulation
Consumption
Overconsumption
Sustainability

ABSTRACT

Global biodiversity decline is best understood as too many people consuming and producing too much and displacing other species. Wild landscapes and seascapes are replaced with people, our domestics and commensals, our economic support systems, and our trash. Conservation biologists have documented many of the ways that human activity drives global biodiversity loss, but they generally neglect the role of overpopulation. We summarize the evidence for how excessive human numbers destroy and degrade habitats for other species, and how population decrease opens possibilities for ecological restoration. We discuss opportunities for further research into how human demographic changes help or hinder conservation efforts. Finally, we encourage conservation biologists to advocate for smaller populations, through improved access to modern contraception and explicit promotion of small families. In the long term, smaller human populations are necessary to preserve biodiversity in both less developed and more developed parts of the world. Whether the goal is to save threatened species, create more protected areas, restore degraded landscapes, limit climate disruption, or any of the other objectives key to preserving biodiversity, reducing the size of the human population is necessary to achieve it.

1. Introduction

Human overpopulation is a major driver of biodiversity loss and a key obstacle to fairly sharing habitat and essential resources with other species (Crist, 2019). Yet those concerned to further conservation, including conservation scientists, rarely advocate for smaller human populations (exceptions include Foreman and Carroll, 2014; Driscoll et al., 2018). Speaking out about population matters can be challenging, but failure to address the root causes of biodiversity loss will doom conservationists' efforts (Shragg, 2015; Diaz et al., 2019). Successfully conserving Earth's remaining biodiversity requires challenging growth and addressing the excessive size of human populations and human economies, which are intimately connected. In what follows, we show that overpopulation is a major factor causing biodiversity loss (Section 2) and that population decreases open exciting possibilities for ecological restoration (Section 3). We discuss research opportunities to clarify how human demographic changes help or hinder conservation efforts (Section 4). We also argue that conservation biologists should actively promote smaller human populations, since they are necessary to preserve biodiversity (Section 5).

2. Overpopulation and biodiversity loss

The concept of human overpopulation, once common, is now rarely used in the scientific literature (Götmark et al., 2021). Here we stipulate that overpopulation exists where 1) people are displacing wild nature so thoroughly that they are extinguishing numerous species; 2) people are degrading ecosystems so thoroughly that future human generations likely will have a hard time living decent lives; and (3) one or both of these environmental catastrophes cannot be avoided without significantly decreasing the size of the human population.

According to these criteria, most nations of the world, and the world as a whole, are currently overpopulated (Lianos and Pseiridis, 2016; Tucker, 2019). Overpopulation is a product of human numbers times per capita consumption; the higher the per capita consumption level, the lower the ecologically sustainable population (Dasgupta, 2019; Tamburino and Bravo, 2021). Since both human numbers and per capita consumption are increasing worldwide, the world is becoming more overpopulated with each passing year. So are almost all nations around the world, even those with stable or declining populations, since in almost all cases, per capita consumption is rising faster than countries' populations are falling, leading to increasing environmental impacts.

* Corresponding author.
E-mail addresses: philip.cafaro@colostate.edu (P. Cafaro), frank.gotmark@bioenv.gu.se (F. Götmark).

https://doi.org/10.1016/j.biocon.2022.109646
Received 5 January 2022; Received in revised form 10 June 2022; Accepted 21 June 2022
Available online 30 June 2022
0006-3207/

Global biodiversity decline is best understood as growing numbers of people and their rapidly expanding economic support systems crowding out other species. Conservation biologists standardly list five main direct drivers of biodiversity loss: habitat loss, overexploitation of species, pollution, invasive species, and climate change. The *Global Assessment Report on Biodiversity and Ecosystem Services* found that in recent decades habitat loss was the leading cause of terrestrial biodiversity loss, while overexploitation (overfishing) was the most important cause of marine losses (IPBES, 2019). All five direct drivers are important, on land and at sea, and all are made worse by larger and denser human populations.

Agriculture is a leading cause of terrestrial habitat loss: growing human populations need to be fed and expanding markets provide incentives to convert natural forests or grasslands to agricultural fields or livestock pasture (Crist et al., 2017; D'Odorico et al., 2018). Increasing rural populations have led to agricultural habitat conversion (Scharlemann, 2005) and increasing urban populations increase demand for food, leading to further habitat loss (Marques et al., 2019). Intensification of existing farmland (e.g., increased pesticides and fertilizers) has also decreased its quality for wildlife (Donald et al., 2001). Discussions of how to feed the additional 2 billion people expected by mid-century (United Nations, 2019) routinely advocate for greater efficiency to avoid habitat loss (IPCC, 2019). But it seems likely this huge added agricultural demand will be met with greater efficiency *and* the conversion of more wild lands to support human sustenance, as in the past. The hope that increased efficiency and management improvements will lead to "land sparing" in the face of future large increases in agricultural demands is belied by history: from 1850 to 1995, the proportion of global land area in cropland and pasture increased from about 10 % to 40 %, despite impressive productivity increases (Goldewijk and Battjes, 1997).

Besides huge agricultural conversions for human use, over the past century, immense areas of natural habitats were lost to urbanization and sprawl to accommodate burgeoning needs for housing, factories, commercial buildings, transport infrastructure, and recreational developments. Thompson and Jones (1999), Seto (2011) and Qiu et al. (2018) all found a direct correlation between increased population densities and loss of species and natural areas to urban development. Weber and Sciubba (2018), Colsaet et al. (2018) and Kolankiewicz et al. (2021) all found that areas with rapidly growing populations had higher rates of habitat lost to sprawl than areas with more slowly growing populations.

In addition to habitat loss, habitat degradation is also linked to increased population density. For example, habitat fragmentation by human settlements, transportation, and utility corridors reduces the conservation value of natural areas (Radeloff et al., 2015; Krishnadas et al., 2018). More people lead to more roadkill, more invasive species, more poaching, more pollution, and more wildlife disturbance overall. Often population increase occurs along new roads and railroads (Estrada, 2017; Hughes, 2017) and particularly in the developing world, immense new transport systems threaten to degrade many natural areas (Ahmed et al., 2014; Ng et al., 2020).

In response to habitat loss and degradation, conservationists seek to preserve habitat in formally protected areas (PAs), ideally through systematic conservation planning (Watson et al., 2014). Conservation biologists emphasize the importance of PAs in preserving Earth's remaining biodiversity (Locke, 2014; Dinerstein et al., 2017; Noss, 2020). National parks, wilderness areas and other strictly protected designations are most effective, with multiple use and community conservation areas a second-best option (Shahabuddin and Rao, 2010). But PAs may be "downgraded, downsized, or degazetted" (PADDD), leading to habitat loss. Symes et al. (2016) found that one important cause of PADDD is increased population densities within or near PAs. Habitat within PAs can also become degraded without formal legal impairment. Qiu et al. (2018) found that increased human population density near PAs in Yunnan province, China, decreased wetland habitat usefulness for birds and mammals. In India's Western Ghats, the habitat value of PAs declined 32 % as local human population densities increased (Krishnadas et al., 2018).

A second major driver of biodiversity loss is direct overexploitation of species: overhunting, overfishing, or overharvesting. Many forests in Africa and Southeast Asia suffer from "empty forest syndrome," where seemingly good habitat is missing many "bushmeat" species, particularly larger mammals (Sterling et al., 2006; Stanford, 2012). Navarro and Pereira (2015a) report that decreasing human populations lead to less hunting pressures on European natural areas, while Estrada (2017) reports that growing populations increase hunting pressures on primates worldwide. Stanford (2012) connects the extirpation of many primate populations in Africa and Asia to overhunting and summarizes the role rapid population growth has played in driving Africa's commercial bushmeat trade.

As previously mentioned, the IPBES (2019) concluded that overfishing is the leading cause of declining ocean biodiversity. Such overharvesting is partly a function of burgeoning demand caused by population increase. Proposed solutions to overfishing focus on increased regulation, decreased subsidies and greater efficiency in fishing operations. But the rapid increase in deep ocean fish catches post-World War II was caused by the confluence of new technologies and exploding human demand, driven in part by rapid population increases (D'Odorico et al., 2018). Similarly, demand for rhino horn, tiger bones and other animal parts used in traditional Chinese medicine has greatly increased as the Chinese population increased in both wealth and numbers (Hughes, 2017).

The last three important direct drivers of biodiversity loss (invasive species, pollution, and climate change) are also caused, in part, by excessive populations. McKinney (2001) found non-native plant and fish diversity both increase with population growth. Driscoll et al. (2018) explain how increased human populations drive new developments that spread invasive species; for example, timber exports driven by increased human demand can contain exotic fungi or insects that attack indigenous species. Expanding prevalence of invasive species in PAs may also be linked to increased visitor use, just as trail erosion or arguments over scarce campsites often increase with more visitors. Population increases worsen air pollution, which can decrease breeding bird diversity (York and Rosa, 2012; Gagné et al., 2016). They increase water pollution, including both ecotoxicity and eutrophication, which in turn can extirpate rare or even previously common species. Turvey (2008) links population increase and rapid economic growth to the toxification of China's Yangtze River and the subsequent extinction of the baiji dolphin (*Lipotes vexillifer*), although causal factors were doubtless complex.

As for global climate change, human population growth is one of its two leading causes. The IPCC's *6th Assessment Report* (2022) states: "Globally, GDP per capita and population growth remained the strongest drivers of CO2 emissions from fossil fuel combustion in the last decade." Between 1970 and 2000, these two drivers contributed roughly equally to driving up greenhouse gas emissions. Since 2000, economic growth has contributed more than demographic growth to increased emissions, but population growth's contribution remains substantial and atmospheric carbon continues to increase, far outstripping all efficiency improvements. Total emissions, which need to be sharply reduced to limit climate disruption, instead continue to grow. According to the IPCC (2022): "Global GHG emissions have continued to rise since AR5, though the average rate of emissions growth slowed, from 2.4% (from 2000 to 2010) to 1.3% for 2010–2019. … Important driving factors include population and GDP growth. The pause in emissions growth reflected interplay of strong energy efficiency improvements and low-carbon technology deployment, but these did not expand fast enough to offset the continued pressures for overall growth at [the] global level."

3. Population decreases open up ecological restoration possibilities

Just as population increases clearly contribute to biodiversity losses, so population decreases can aid in restoring biodiversity. All else being equal, smaller human numbers opens more space for wild species. One sees this particularly clearly in Europe, densely populated, but also the first continent to end humanity's modern population explosion. Europe's overall population has stabilized in recent years and its rural population has declined 20 % since 1960, contributing to extensive abandonment of less productive farmland (Keenleyside and Tucker, 2010; United Nations, 2019). Within the past two decades, up to 7.6 million hectares of agricultural land have gone out of production in Eastern Europe, southern Scandinavia and Europe's mountainous regions, as have 10–20 % of the agricultural lands in the Baltic states (Leal Filho et al., 2017). Overall, these trends have been valuable for wildlife, particularly larger herbivores and carnivores, which have naturally recolonized many former agricultural areas (Deinet et al., 2013; Chapron et al., 2014; Boitani and Linnell, 2015). So have many native shrub and tree species; for example, along the river valleys of southern France (Schnitzler, 2014).

Ecological restoration can accelerate and lock in these trends (Corlett, 2016; Götmark and Götmark, 2017), turning what is often viewed as a negative (“rural depopulation”) into a positive (“rewilding” the landscape and restoring a nation's natural heritage) (Queiroz et al., 2014). Consider two examples from Rewilding Europe, an umbrella organization working to restore large natural areas across the continent (Rewilding Europe, 2021a). Most of their projects include the ecological restoration of marginal agricultural lands that are no longer needed to feed or support declining populations, including these two, in the Danube Delta and Portugal's Côa Valley.

On the border between Ukraine and Romania, the Danube Delta is Europe's largest remaining natural wetland complex (World Wildlife Fund, 2020a) (Fig. 1). The delta harbors the greatest number of fish species in Europe, including four species of endangered sturgeon, supports innumerable water birds, and provides irreplaceable resting grounds on the great Palearctic-African migration flyway connecting northern Europe and Africa (Rewilding Europe, 2021b). Partially developed for industrial agriculture during the second half of the twentieth century, the regions surrounding the delta experienced decreasing populations during the past three decades, on both the Romanian (Eurostat, 2020) and Ukrainian sides (Brinkhoff, 2021). Large areas of agricultural land were abandoned, often in a deteriorated state but with excellent opportunities to revive the natural landscape. Dikes have been removed, low-lying areas reflooded, and spawning areas restored, greatly increasing fish and waterfowl numbers (World Wildlife Fund, 2020b). Many species have been actively reintroduced, including the Eagle Owl (*Bubo bubo*) and the iconic Dalmatian Pelican (*Pelecanus crispus*), wild konik horses (*Equus ferus caballus*) and water buffalo (*Bubalus bubalis*), and the kulan (wild ass, *Equus hemionus kulan*) in adjacent upland steppes (Endangered Landscapes Programme, 2020a). Because fertility rates remain low in Romania and Ukraine (United

Fig. 1. (a) The Danube Delta, despite having historically experienced alteration to aid in navigation, is Europe's largest remaining natural wetland area. It is regarded by WWF as one of the 200 most valuable ecological areas on Earth (World Wildlife Fund, 2020a). Photo by Diego Delso, delso.photo, CC BY-SA. (b) The Dalmatian Pelican (*Pelecanus crispus*) has seen declining numbers during the last century (Catsadorakis, 2019). It requires minimum disturbance to nest, nesting on islands or reedbeds surrounded by water (Crivelli, 1996), and the Danube Delta is an important site for the global conservation of the species, hosting most of Europe's remaining population (Endangered Landscapes Programme, 2020a). Photo by Maxim Yakovlev, CC BY-SA 4.0. (c) Located 50 km northeast of the wetlands, yet functionally connected to it, is the Tarutino steppe, which is the largest remaining tract of Eurasian Pontic Steppe and protected together with the delta (Endangered Landscapes Programme, 2020a). Photo by Maxim Yakolev, CC BY-SA 4.0. (d) Kulan (*Equus hemionus kulan*) had been missing from the ecosystem for hundreds of years, mainly due to hunting (Endangered Landscapes Programme, 2020b) and agricultural development but has now been reintroduced to the Tarutino steppe (Endangered Landscapes Programme, 2020a). It will aid in keeping the steppe open, while forming an additional prey base for native predators (Endangered Landscapes Programme, 2020b). Kulan and other large herbivores also play an important role in connecting the steppe with the wetlands, as they migrate between them (Endangered Landscapes Programme, 2020a). Photo by Michael Oppermann, CC BY-SA 3.0.

Nations, 2019), future human population decreases are likely to facilitate even more rewilding in the Danube delta, designated as a Biosphere Reserve by UNESCO.

Fewer people have also facilitated rewilding in northeastern Portugal's Côa Valley. The region has experienced some of the highest rural abandonment rates in Europe (Rewilding Europe, 2021c), with the population decreasing since the 1990s (Almeida, 2007). Since creation of the Côa Valley Rewilding Area in 2011 and establishment of the Faia Brava Reserve, the area's wildlife has started to recover. Populations of rabbit (*Oryctolagus cuniculus*) and red-legged partridge (*Alectoris rufa*) have increased, both important prey of the endangered Iberian lynx (*Lynx pardinus*) (Rewilding Europe, 2021c). Recovery of the lynx population has been facilitated by breeding centers in southern Spain and Portugal (Iberian Lynx Ex situ Conservation Programme, 2021); other endangered animals are reappearing naturally, such as the wolf (*Canis lupus*) and Iberian imperial eagle (*Aquila adalberti*), which had almost disappeared due to human persecution and displacement. Roe deer (*Capreolus capreolus*) and red deer (*Cervus elaphus*) have expanded in the Côa Valley, important prey species for wolves (Rewilding Europe, 2021c). These successes show that through a combination of demographic decrease and favorable restoration efforts, long-settled landscapes can, over time, become largely self-sustaining ecosystems with high biodiversity values. Portugal's national population has been decreasing since 2009 and its fertility rate was around 1.37 in 2017 (OECD, 2020), so this decrease is likely to continue. Under status quo fertility and immigration levels, Portugal's population would decline from 10.2 million to 6.9 million by 2100 (Cafaro and Dérer, 2019), greatly aiding rewilding efforts.

Rewilding areas with declining human populations are not limited to Europe. Many parts of America's Great Plains have falling populations, facilitating PA creation and ecological restoration efforts in tall grass, mixed grass, and short grass prairies. One of the most ambitious is the American Prairie Reserve, which aims to purchase private lands and lease public lands to ensure a contiguous short grass steppe ecosystem of 3.2 million acres in central and eastern Montana (American Prairie Reserve, 2021). Human population densities are low in this area, although irrigation and cultivation have had a significant impact on the natural system (Nature Conservancy, 1999). The total population of Montana has increased steadily since statehood in 1889; however, most of the state's plains counties have experienced decreased population since the early 1900s (World Population Review, 2021a,b). The area covered by the rewilding project stretches along the Missouri River, containing much intact prairie and great plant and animal diversity. One of the project's focus species is the iconic American bison (*Bison bison*). In an area where the American Prairie Reserve organization reintroduced bison a decade ago, plant species richness and compositional heterogeneity of plant communities have increased (McMillan et al., 2019). Despite such benefits, the restoration of bison herds onto public lands is seen as a threat by some ranchers, generating opposition (Clark and Nyaupane, 2020). Proponents hope to resolve these conflicts and create an immense, fully functional short grass prairie ecosystem. Their efforts are especially important given that temperate grasslands are some of the most highly converted and least protected ecosystems globally (Hoekstra et al., 2005). While the endeavor faces challenges, it is aided by already low and declining human numbers in the region.

Increasingly many countries and regions are expecting smaller populations in coming decades (United Nations, 2019). This will present economic and social challenges, but also increase opportunities to create more vibrant and ecologically rich landscapes. Nations that embrace population decrease will see opportunities to expand rewilding efforts and transform marginal agricultural lands into more valuable national parks and protected areas (Navarro, 2014; Navarro and Pereira, 2015b; Cafaro and Götmark, 2019). In a world gravely damaged by biodiversity loss, population decreases provide valuable and inspiring opportunities for nature restoration, part of what one scholar has described as an environmental and social "depopulation dividend" (Matanle, 2017).

4. Research opportunities

The evidence summarized in Sections 2 and 3 shows the need for a research agenda that explores the connection between human numbers and biodiversity preservation more rigorously and systematically. First, research is needed into how important population growth and overpopulation are in driving biodiversity loss, particularly compared to other factors (Rust and Kehoe, 2017). While the research cited in section two confirms that increased population size and population density contribute to biodiversity loss, it is less clear how important they are compared to other factors, such as per capita consumption, or percentage of the landscape in protected areas. It is also unclear how these and other factors may act synergistically to drive biodiversity loss. This is an important deficiency, given the role of synergy in other environmental contexts, such as climate change vulnerability (Dodson et al., 2020). Historical studies relating population growth and associated factors to changes in threats against species and biological communities can help clarify the role of overpopulation in biodiversity loss.

Second, there is a need for research documenting how population decreases foster opportunities for protection of habitats and ecological restoration as described in Section 3. In particular, how important are population decreases for the success of future restoration? Managers of restoration projects often mention the importance of population decrease and land abandonment to their efforts, anecdotally. In the conservation biology literature, however, there is little documentation or rigorous analysis of the importance of population decrease (for some exceptions, see Pereira and Navarro, 2015; Götmark et al., 2018). Depending on policy decisions, France's population could decline from its current 67 million to 54 million by 2100, Germany's from 82 to 51 million, and Italy's from 61 to 30 million (Cafaro and Dérer, 2019). We know of no studies by biologists detailing the biodiversity benefits such declines might bring. In contrast, European economists have presented many papers on their potential fiscal harms. So it is not surprising that economic concerns dominate discussions about population policies (but see O'Sullivan, 2020), or that citizens are unaware that demographic choices matter in preserving biodiversity.

Most conservation biologists believe that greatly increasing the amount of land and seas protected in PAs is necessary to preserve Earth's remaining biodiversity (Dinerstein et al., 2019; Locke et al., 2019; IUCN, 2020). But the role of population reduction in achieving the goals of Half Earth or similar proposals remains largely unexplored (an important exception is Crist et al., 2021). So does the role of population increase in closing off conservation options, particularly at the national level where most substantial PA designations occur. How much of Germany or India, Mexico or New Zealand, would have to be set aside to preserve viable populations of their remaining native wildlife—and how large a human population would be compatible with this goal? How much of Africa's megafauna can remain if African populations triple by 2100, as forecasted in United Nations (2019) population projections—and how much more could be saved if African nations provided their citizens with universal access to modern contraception and family planning services? Many conservation biologists would agree with E.O. Wilson (2016) that our goal is to shepherd biodiversity through a high population bottleneck in the 21st century, preserving what we can for better times. But biologists' sense of how quickly and how much human numbers must decrease to sustain substantial biodiversity remains just that—a vague "sense." This astonishing lacuna is unacceptable. Every conservation biologist should know how many people her or his country can support while also supporting viable populations of all its native species.

Third, there is a need for quantitative models of how population and other key factors determine biodiversity loss. Creating, testing, and improving such models is essential to answering research questions. Conservation biologists might benefit by considering the approach used by climate scientists to calculate and predict changes in global CO_2 emissions (IPCC, 2014, 2022). According to the Kaya identity:

$$CO_2 \text{ emissions} = P \times GDP/\text{capita} \times \text{energy}/GDP \times CO2/\text{energy}$$

where P is population, GDP/capita measures per capita economic activity, and the third and fourth factors represent energy intensity and carbon intensity, respectively. This is an extension of Ehrlich and Holdren (1972) I = PAT formula with energy/GDP and CO2/energy specifying the technology factor (for further discussion, see York et al., 2003). Annual changes in overall emissions and the relative importance of their drivers can then be clearly expressed, as in the recent average annual percentage changes (in bold) from IPCC (2014):

$$\Delta \text{ CO2 emissions} = \Delta \text{ P} \times \Delta \text{ GDP/capita} \times \Delta \text{ energy/GDP} \times \Delta \text{ CO2/energy}$$

$$\mathbf{+2\%} \qquad \mathbf{+1.1\%} \qquad \mathbf{+2\%} \qquad \mathbf{-1.4\%} \qquad \mathbf{+0.3\%}$$

While the model captured in this equation does not provide an exhaustive causal analysis of the many drivers of climate change, it gives scientists, policymakers, and the public an accurate snapshot of the main factors driving CO_2 emissions. And while it did not prevent the IPCC's fifth and sixth *Assessment Reports* from neglecting climate policy options that address population growth, this framework makes it apparent to unbiased readers that human numbers play an important role in climate change.

Conservation biologists might find similar success by reformulating IPAT to quantify the causes of species and habitat loss, or habitat degradation. Population growth and economic growth are likely the primary causes of biodiversity loss, as they are of climate change and other global environmental problems (Ripple et al., 2020; Wiedmann et al., 2020). As IPBES (2019) notes: "Unsustainable use of the Earth's resources is underpinned by a set of demographic and economic indirect drivers that have increased" in recent decades. Along with the P and A factors, we may ask what ecological, technological, or institutional influences might be substantial enough to round out the _________ identity (ambitious young conservation biologist, insert your last name here). Possible candidates include landscape and seascape composition and change, acreage preserved in PAs (Krishnadas et al., 2018), and the effectiveness of existing legal protections for biodiversity. These and other factors should be quantified, and their roles assessed across the full range of geographical and national variation, for various taxa.

IPBES (2019) made a start toward such modeling by summarizing biodiversity's recent precipitous decline, with broad quantification of "direct drivers" to justify rough judgements regarding their importance. But no attempt was made to quantify the "indirect drivers" or fundamental causes of biodiversity loss, a serious weakness in our view. IPBES (2019) discusses numerous unquantified indirect drivers, turning the fundamental causes of biodiversity loss into a black box that impedes understanding (Fig. 2).

Besides a few statements that growth in human numbers and excessive economic activity are driving the biodiversity crisis, IPBES (2019) has many pages of convoluted, unquantified speculation about how "values," "institutions," "laws," "behaviors," "trends" and scores of

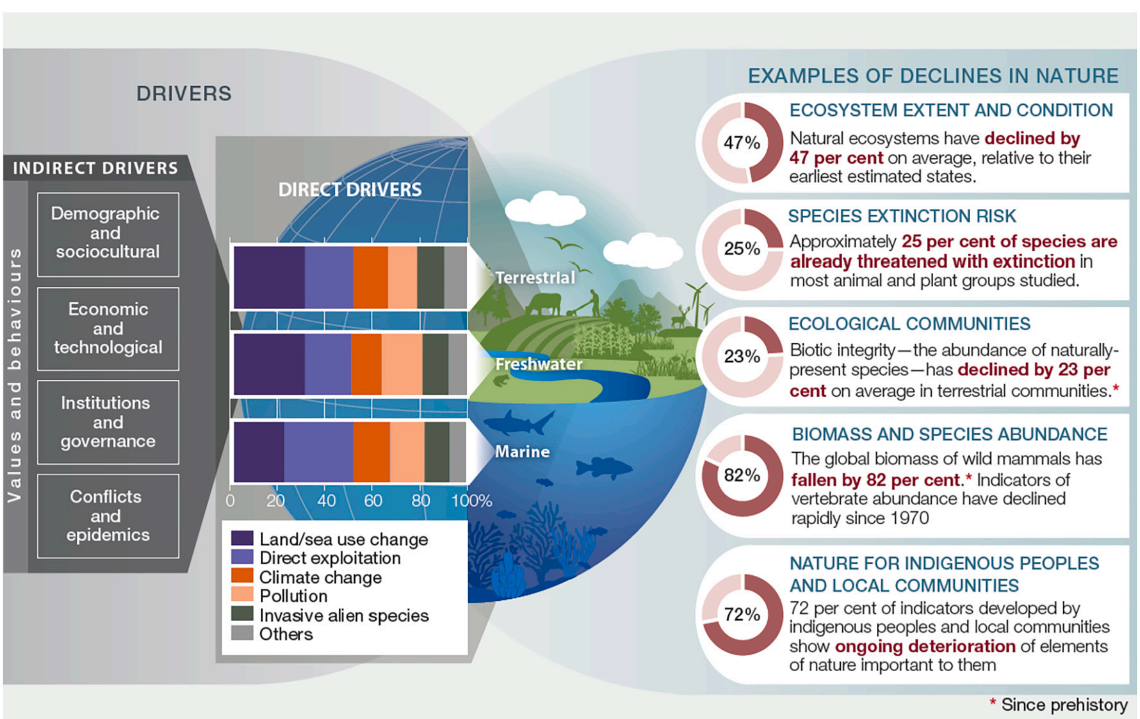

Fig. 2. Examples of global declines in nature, emphasizing declines in biodiversity, that have been and are being caused by direct and indirect drivers of change. Figure SPM2 from IPBES (2019). The original text for this figure states that "the underlying societal causes" of biodiversity loss "can be demographic (e.g., human population dynamics), sociocultural (e.g. consumption patterns), economic (e.g., trade), technological, or relating to institutions, governance, conflicts and epidemics." This suggests that "conflicts and epidemics" might be just as important in driving biodiversity loss as population growth or expanding economies, even though that is almost certainly not true. Note the lack of quantification, or even notions of more or less. "Human population dynamics" cause biodiversity loss, not "more people"; "trade" or "institutions" cause biodiversity loss, not "economic growth."

other factors might play a role in the problem. No clear picture is conveyed, and certainly not the message that if people want to preserve Earth's remaining biodiversity, they will have to limit their numbers and economic demands (Kolankiewicz, 2012; Diaz et al., 2019). Conservation biologists can do better, by testing clear quantitative models assessing the major causes of biodiversity loss, and seeing where theory and evidence lead us.

5. Advocacy needs

Overall, few papers in the conservation biology literature analyze the role overpopulation plays in biodiversity loss. But even those that do usually do not recommend policies to end or reverse population growth. Of the 30 studies cited in Section 2 that report a negative impact of excessive population on biodiversity, only three of them directly advocate stabilizing or reducing human numbers (Estrada, 2017; Crist et al., 2017; Qiu et al., 2018). Similarly, none of the papers and reports cited in Section 3, showing how population decline facilitates biodiversity restoration, propose measures to decrease human populations. Many conservation biology papers specify policy recommendations, but there seems to be an invisible fence preventing authors from addressing population policy. This is a missed opportunity to educate environmentalists and influence policy makers. It also gives the public the mistaken impression that human numbers have little to do with preserving other species or wild places.

Conservation biologists should advocate for smaller populations, because current human numbers are far beyond what could be compatible with the preservation of global biodiversity or long-term human wellbeing (O'Neill et al., 2018; Rees, 2020). Four recent studies suggest two to three billion people might be sustainable globally if societies made heroic environmental improvements in existing modes of consumption and production (Lianos and Pseiridis, 2016; Tucker, 2019; Dasgupta, 2019; Tamburino and Bravo, 2021). Continued overpopulation threatens massive suffering for billions of people and extinction for millions of species. These facts should convince conservation biologists to support just and realistic policies to reduce human numbers to sustainable levels. According to the most recent United Nations (2019) projections, reducing fertility rates half a child below the projected median (most likely) rate would reduce the global population in 2100 by more than three and a half billion people. The benefits to other species certainly would be substantial.

Most important, conservation biologists should advocate for universal access to modern, affordable contraception, a win/win for women's rights and the environment (Cottingham et al., 2012; Engelman and Johnson, 2019). In places where cultural norms celebrate high fertility, we should support those working to change those norms, by explaining that more people mean less wildlife (Attenborough, 2011; Kolankiewicz et al., 2022). Over the past fifty years, there have been many examples of well-executed, successful national family planning programs, from all parts of the world, including the Far East, South Asia, Latin America, Africa, and elsewhere (Robinson and Ross, 2007; Engelman, 2016). Providing free or affordable contraception and family planning services to everyone who wants it has rapidly reduced fertility rates in many nations, often down to or below replacement rate (May, 2012; Günther and Harttgen, 2016; Bongaarts and O'Neill, 2018). National programs that advertised the many health and economic benefits of small families have been particularly effective. Nations that failed to undertake such programs, due to patriarchal religious or cultural opposition (Yao and Wyman, 2017; Turner, 2021), or where they failed through conflicts, incompetence, or neglect, have continued to experience rapid population growth.

Because merely stabilizing current human populations does not appear sufficient to preserve existing biodiversity, conservation biologists should urge national governments to encourage one-child families (Foreman and Carroll, 2014). This can be done through tax policies, benefits policies, media outreach, and well-informed, compelling emotional appeals (Ryerson, 2012; Cafaro, 2021). Small family norms should be pursued in both less developed and more developed nations, including in countries with declining populations, which are still, for the most part, grossly overpopulated relative to what is sustainable (Cafaro and Götmark, 2019). Many environmentalists already limit themselves to one or two children, replacement rate, out of environmental concern (Mills, 2012). But most people are not serious environmentalists, and merely stabilizing current populations does not appear sufficient to avoid environmental degradation and mass species extinction. Human populations need to go much lower (Dasgupta, 2019; Cafaro, 2022); how much lower should be an urgent research question for conservation biologists and other sustainability scientists. Perhaps the best way forward would be for governments to secure the right of couples to choose their family size, while strongly encouraging them to choose small families (Conly, 2016; Coole, 2018). Coercion no, incentives yes. Forced sterilizations no, frank reminders that nations are overpopulated yes.

In the end, conservationists will only preserve biodiversity if we succeed in creating societies that protect rather than displace it (Crist, 2019; Johns, 2019). That depends on addressing the root causes of biodiversity loss, not saving a few remnants in the interstices of an ever-expanding humanity (Noss et al., 2012; Diaz et al., 2019). When conservation biologists shy away from discussing what needs to be done to achieve this in their professional publications, they encourage the idea that we can preserve Earth's remaining biodiversity while accepting continued overpopulation and economic expansion. While conservation biologists typically do not argue for this explicitly, since it makes no biological sense, social scientists with no commitment to preserving biodiversity do (see Fletcher et al., 2014; Napoletano and Clark, 2020).

In recent years, the conservation community seems to be waking up to the need to address population. Recent Scientists' Warnings to Humanity, signed by thousands of scientists, alert readers to the harmful role of continued population growth in driving global environmental problems (Ripple et al., 2017, 2020, 2021). They call for specific policies to “stabilize and gradually reduce the population,” including universal access to contraception. After three decades of silence on the topic, the International Union for the Conservation of Nature passed a motion in 2020 reaffirming the importance of addressing population. Titled “Importance for the conservation of nature of removing barriers to rights-based voluntary family planning,” it directs IUCN's member groups to reaffirm the importance of limiting human numbers to preserve wild nature (IUCN, 2020). As its supporters note in an explanatory memorandum, “Family planning is not a panacea for all environmental challenges, but there are many areas where population growth resulting from barriers to family planning is a major direct environmental issue.” Conversely, as seen in Section 3, there are regions where population declines create major conservation opportunities.

These synergies have led to the growth of Population-Health-Environment (PHE) programs, which strive to conserve biodiversity while simultaneously improving human health, livelihoods, and security (Lopez-Carr and Ervin, 2017). One of the organizations sponsoring the IUCN motion, the Cheetah Conservation Fund from Namibia, has long been a leader in developing PHE programs that combine provision of family planning services with wildlife conservation. As they note in an overview of their work:

> Human population dynamics, including population growth, are key issues when considering cheetah conservation. More than 90 % of Namibia's cheetahs, for instance, live outside protected areas, and are therefore even more susceptible to anthropogenic impacts such as human-wildlife conflict and habitat loss. These and other impacts intensify as human populations grow and land use becomes more intensive.
>
> (Cheetah Conservation Fund, 2018)

The Cheetah Conservation Fund sees these challenges as opportunities, since "PHE conservation programmes that incorporate voluntary and rights-based family planning actions, with conservation-focused sustainable livelihood interventions, have been demonstrated to achieve greater conservation, health and gender outcomes than single sector programmes" (Cheetah Conservation Fund, 2018).

Another successful PHE program is Blue Ventures, a marine conservation organization located in southwest Madagascar (Rocliffe and Harris, 2016). Through the integration of community-based reproductive health services and marine conservation initiatives, more than 800 unintended pregnancies were averted in the half dozen years after 2007, alternative livelihoods were developed, and a community-managed marine protected area was created (Robson and Rakotozafy, 2015). By identifying the role of overpopulation and incorporating effective methods to address it in a participatory social context, program outcomes reduced human pressures, allowing for the creation and effective management of a PA. With front-line conservation organizations like Blue Ventures and the Cheetah Conservation Fund stepping forward to address population growth and providing concrete examples of how to combine population and biodiversity advocacy fairly and effectively, conservation biologists' continued population timidity seems even less justified.

We do not argue that conservation biologists should focus exclusively on population or bring it up whenever biodiversity policy is under discussion. In many instances this would be beside the point, or counterproductive. But as we showed in Sections 2 and 3, the role of human population size generally needs to be kept in mind, simply because of its practical importance. Evidence-based conservation implies population-aware conservation. Even if conservation biologists are most comfortable warning about habitat loss or advocating for more PAs, *someone* still will have to address demographic and economic limits. Societies cannot create enough PAs or sustain sufficient wildlife habitat to preserve biodiversity, if human numbers and economic demands continue increasing. But who will advocate for responsible limits, if not those who care the most about biodiversity and know the most about the threats to it? Nothing in the science or the politics of the situation justifies our continued silence.

6. Conclusion

During the past hundred years, *Homo sapiens*' population increased from 2 billion to nearly 8 billion and the United Nations (2019) projects an increase of 3 billion more by 2100, unless steps are taken to reduce this population growth. Ignoring this projected increase means ignoring a major driver of the unfolding biodiversity crisis; accepting current bloated human numbers as an appropriate status quo means accepting a biologically impoverished planet. A scientific, evidence-based conservation biology needs to acknowledge the manifold ways overpopulation darkens the future for biodiversity. It should closely examine the impacts of increasing and decreasing populations on biodiversity and broadly share this information to enable informed decision making. In the political realm, conservationists should advocate for smaller families, universal availability of modern contraception, and smaller populations in their own countries and around the world. That is the way forward toward a just and sustainable future for all.

Declaration of competing interest

The authors hereby declare no conflict of interest involved in the writing or publication of this article. Philip Cafaro's work was supported by the endowment of the Philosophy Department, Colorado State University. Pernilla Hansson's work was supported by a grant from the GAIA Initiative for Earth - Human Balance.

References

Ahmed, S.E., et al., 2014. Road networks predict human influence on Amazonian bird communities. In: Proc.R.Soc.B Biol.Sci.. Proc. R. Soc. B Biol. Sci., 281. https://doi.org/10.1098/rspb.2014.1742.

Almeida, A.C., 2007. Rural abandonment and landscape evolution in the central region of Portugal. In: Jones, G., Leimgruber, W., Nel, E. (Eds.), Issues in Geographical Marginality: Papers Presented During the Commission Meetings 2001–2004: Demographic Problems. Rhodes University, Grahamstown, pp. 53–63.

American Prairie Reserve, 2021. Building the Prairie. Available at:. American Prairie, Bozeman, USA https://www.americanprairie.org/building-the-reserve.

Attenborough, David, 2011. Impact of population growth on the planet. In: Lecture to the Royal Society for the encouragement of Arts, Manufactures and Commerce, London.

Boitani, L., Linnell, J.D.C., 2015. Bringing large mammals back: large carnivores in Europe. In: Pereira, H., Navarro, L. (Eds.), Rewilding European Landscapes. Springer International Publishing, Cham, pp. 67–84.

Bongaarts, J., O'Neill, B., 2018. Global warming policy: is population left out in the cold? Science 361 (6403), 650–652.

Brinkhoff, T., 2021. Odessa: city population. Available at: https://citypopulation.de/en/ukraine/admin/51_od%C4%97sa_oblast/.

Cafaro, P., 2021. Just population policies for an overpopulated world. Ecol. Citizen 5 epub-046-1.

Cafaro, P., 2022. Reducing human numbers and the size of our economies is necessary to avoid a mass extinction and share Earth justly with other species. Philosophia 50. https://doi.org/10.1007/s11406-022-00497-w.

Cafaro, P., Dérer, P., 2019. Policy-based population projections for the European Union: a complementary approach. Comp. Popul. Stud. 44, 171–200.

Cafaro, P., Götmark, F., 2019. The potential environmental impacts of EU immigration policy: future population numbers, greenhouse gas emissions and biodiversity preservation. J. Popul. Sustain. 4, 71–101.

Catsadorakis, G., 2019. Establishment and growth of a new Dalmatian pelican Pelecanus crispus colony in central Greece. Acta Ornithol. 54, 125–132.

Chapron, G., et al., 2014. Recovery of large carnivores in Europe's modern human-dominated landscapes. Science 346, 1517–1519.

Cheetah Conservation Fund, 2018. The Importance of Human Reproductive Health and Rights for Cheetah Conservation. Margaret Pyke Trust, London.

Clark, C., Nyaupane, G.P., 2020. Connecting landscape-scale ecological restoration and tourism: stakeholder perspectives in the great plains of North America. J. Sustain. Tour. 1–19.

Colsaet, A., et al., 2018. What drives land take and urban land expansion? A systematic review. Land Use Policy 79, 339–349.

Conly, S., 2016. One Child: Do We Have a Right to More? Oxford University Press, Oxford, UK.

Coole, D., 2018. Should We Control World Population? Polity Press, Cambridge, UK.

Corlett, R.T., 2016. Restoration, reintroduction, and rewilding in a changing world. Trends Ecol. Evol. 31, 453–462.

Cottingham, J., Germain, A., Hunt, P., 2012. Use of human rights to meet the unmet need for family planning. Lancet 380, 172–180.

Crist, E., 2019. Abundant Earth: Toward an Ecological Civilization. University of Chicago Press.

Crist, E., et al., 2017. The interaction of human population, food production, and biodiversity protection. Science 356, 260–264.

Crist, E., et al., 2021. Protecting half the planet and transforming human systems are complementary goals. Front. Conserv. Sci. 2, 761292.

Crivelli, A.J., 1996. Action Plan for the Dalmatian Pelican Pelecanus crispus in Europe. Birdlife International, Cambridge.

D'Odorico, P., et al., 2018. The global food-energy-water nexus. Rev. Geophys. 56, 456–531.

Dasgupta, P., 2019. Time and the Generations: Population Ethics for a Diminishing Planet. Columbia University Press, New York.

Deinet, S., et al., 2013. Wildlife Comeback in Europe: The Recovery of Selected Mammal and Bird Species: Final Report to Rewilding Europe. Zoological Society of London.

Diaz, S., et al., 2019. Pervasive human-driven decline of life on earth points to the need for transformative change. Science 366, 1327.

Dinerstein, E., et al., 2017. An ecoregion-based approach to protecting half the terrestrial realm. Bioscience 67, 534–545.

Dinerstein, E., et al., 2019. A global deal for nature: guiding principles, milestones, and targets. Sci. Adv. 5, eaaw2869.

Dodson, J., Dérer, P., Cafaro, P., Götmark, F., 2020. Population growth and climate change: addressing the overlooked threat multiplier. Sci. Total Environ. 748, 141346.

Donald, P.F., Green, R.E., Heath, M.F., 2001. Agricultural intensification and the collapse of Europe's farmland bird populations. Proc. R. Soc. B 268, 25–29.

Driscoll, D., et al., 2018. A biodiversity-crisis hierarchy to evaluate and refine conservation indicators. Nat. Ecol. Evol. 2, 775–781.

Ehrlich, P., Holdren, J., 1972. One-dimensional ecology. Bull. At. Sci. 16–27.

Endangered Landscapes Programme, 2020a. Danube delta: endangered landscapes programme. Available at: https://www.endangeredlandscapes.org/project/danube-delta/.

Endangered Landscapes Programme, 2020b. Reintroduction efforts see long absent kulan return to the Danube delta. Available from: https://www.endangeredlandscapes.org/2020-05-28-reintroduction-efforts-see-long-absent-kulan-return-to-the-danube-delta/.

Engelman, R., 2016. Nine population strategies to stop short of 9 billion. In: Washington, H., Twomey, P. (Eds.), A Future beyond Growth: Toward a Steady State Economy. Routledge, London, pp. 32–42.

Engelman, R., Johnson, D., 2019. Removing Barriers to Family Planning, Empowering Sustainable Environmental Conservation: A Background Paper and Call for Action. Margaret Pyke Trust, London.

Estrada, A., 2017. Impending extinction crisis of the world's primates: why primates matter. Sci. Adv. 3, e1600946.

Eurostat, 2020. Population on 1 January by age group, sex and NUTS 3 region. Available at:. Eurostat, Luxembourg https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=demo_r_pjanaggr3&lang=en.

Fletcher, R., et al., 2014. Barbarian hordes: the overpopulation scapegoat in international development discourse. Third World Q. 35, 1198–1202.

Foreman, D., Carroll, L., 2014. Man Swarm: How Overpopulation Is Killing the Wild World. Live True Books.

Gagné, S., et al., 2016. The effect of human population size on the breeding bird diversity of urban regions. Biodivers. Conserv. 25, 653–671.

Goldewijk, K., Battjes, J.J., 1997. A Hundred Year Database for Integrated Environmental Assessments. National Institute of Public Health and the Environment, Bilthoven.

Götmark, F., Götmark, E., 2017. Management, scientific approach, and practice: a comment on Corlett. Trends Ecol. Evol. 32, 237–238.

Götmark, F., Cafaro, P., O'Sullivan, J., 2018. Aging human populations: good for us, good for the Earth. Trends Ecol. Evol. 33, 851–862.

Götmark, F., O'Sullivan, J., Cafaro, P., 2021. Discussing population concepts: overpopulation is a necessary word and an inconvenient truth. Int. J. Popul. Dev. 1, 51–60.

Günther, I., Harttgen, K., 2016. Desired fertility and number of children born across time and space. Demography 53, 55–83. https://doi.org/10.1007/s13524-015-0451-9.

Hoekstra, J.M., et al., 2005. Confronting the biome crisis: global disparities of habitat loss and protection. Ecol. Lett. 8, 23–29.

Hughes, A.C., 2017. Understanding the drivers of southeast asian biodiversity loss. Ecosphere 8, e01624. https://doi.org/10.1002/ecs2.162.

Iberian Lynx Ex situ Conservation Programme, 2021. Management of the Iberian Lynx breeding centers group. Available at: https://www.lynxexsitu.es/programa-en.php?sec=centro.

Intergovernmental Panel on Biodiversity and Ecosystem Services (IPBES), 2019. Summary for Policymakers. Global Assessment Report on Biodiversity and Ecosystem Services. IPBES Secretariat, Bonn, Germany.

Intergovernmental Panel on Climate Change (IPCC), 2014. Summary for Policymakers. Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.

Intergovernmental Panel on Climate Change (IPCC), 2019. Special Report on Climate Change and Land. Chapter 5, Food Security. Available at: https://www.ipcc.ch/srccl/chapter/chapter-5/.

Intergovernmental Panel on Climate Change (IPCC), 2022. Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Available at: https://www.ipcc.ch/report/sixth-assessment-report-working-group-3/.

International Union for the Conservation of Nature (IUCN), 2020. Importance for the conservation of nature of removing barriers to rights-based voluntary family planning. Motion at IUCN World Conservation Congress. Accessible at. https://www.iucncongress2020.org/motion/087/65540.

Johns, D., 2019. Conservation Politics: The Last Anti-colonial Battle. Cambridge University Press.

Keenleyside, C., Tucker, G., 2010. Farmland Abandonment in the EU: An Assessment of Trends and Prospects. World Wildlife Fund and Institute for European Environmental Policy, London.

Kolankiewicz, L., 2012. Overpopulation versus biodiversity: how a plethora of people produces a paucity of wildlife. In: Cafaro, P., Crist, E. (Eds.), Life on the Brink: Environmentalists Confront Overpopulation. University of Georgia Press, Athens.

Kolankiewicz, L., Beck, R., Ruark, E., 2021. Population Growth and the Diminishing Natural State of Arizona: Analysis of Natural Resources Inventory & U.S. Census Data on Development and Habitat Loss in a Thirsty Grand Canyon State. NumbersUSA, Arlington, VA.

Kolankiewicz, L., Beck, R., Ruark, E., 2022. From Sea to Sprawling Sea: Quantifying the Loss of Open Space in America. NumbersUSA, Arlington, VA.

Krishnadas, M., et al., 2018. Parks protect forest cover in a tropical biodiversity hotspot, but high human population densities can limit success. Biol. Conserv. 223, 147–155.

Leal Filho, W., et al., 2017. An assessment of the causes and consequences of agricultural land abandonment in Europe. Int J Sust Dev World 24, 554–560.

Lianos, T.P., Pseiridis, A., 2016. Sustainable welfare and optimum population size. Environ. Dev. Sustain. 18, 1679–1699. https://doi.org/10.1007/s10668-015-9711-5.

Locke, H., 2014. Nature needs half: a necessary and hopeful new agenda for protected areas in North America and around the world. George Wright Forum 31, 359–371.

Locke, H., et al., 2019. Three global conditions for biodiversity conservation and sustainable use: an implementation framework. Natl. Sci. Rev. 6, 1080–1082. https://doi.org/10.1093/nsr/nwz136.

Lopez-Carr, D., Ervin, D., 2017. Population-health-environment (PHE) synergies? Evidence from USAID-sponsored programs in African and Asian core conservation areas. Eur. J. Geogr. 8, 92–108.

Marques, A., et al., 2019. Increasing impacts of land use on biodiversity and carbon sequestration driven by population and economic growth. Nat. Ecol. Evol. 3, 628–637.

Matanle, P., 2017. Towards an Asia-Pacific depopulation dividend in the 21st century: regional growth and shrinkage in Japan and New Zealand. Accessible at Asia-Pac. J. Jpn. Focus 15, 5018.

May, J., 2012. World Population Policies: Their Origin, Evolution, and Impact. Springer Publishers.

McKinney, M., 2001. Effects of human population, area, and time on non-native plant and fish diversity in the United States. Biol. Conserv. 100, 243–252.

McMillan, N.A., Kunkel, K.E., Hagan, D.L., Jachowski, D.S., 2019. Plant community responses to bison reintroduction on the Northern Great Plains, United States: a test of the keystone species concept. Restor. Ecol. 27 (2), 379–388.

Mills, S., 2012. Nulliparity and a cruel hoax revisited. In: Cafaro, P., Crist, E. (Eds.), Life on the Brink: Environmentalists Confront Overpopulation. University of Georgia Press, Athens, GA.

Napoletano, B., Clark, B., 2020. An ecological-marxist response to the half-earth project. Conserv. Soc. 37–49.

Nature Conservancy, 1999. Ecoregional Planning in the Northern Great Plains Steppe. Available at:. Northern Great Plains Steppe Ecoregional Conservation Team https://www.conservationgateway.org/ConservationPlanning/SettingPriorities/EcoregionalReports/Documents/ngps_final_feb99.pdf.

Navarro, L.M., 2014. Rewilding Abandoned Landscapes in Europe: Biodiversity Impact and Contribution to Human Well-being. Doctoral thesis. University of Lisbon, Department of Animal Biology.

Navarro, L.M., Pereira, H.M., 2015a. Rewilding abandoned landscapes in Europe. In: Pereira, H., Navarro, L. (Eds.), Rewilding European Landscapes. Springer International Publishing, Cham, pp. 3–23.

Navarro, L.M., Pereira, H.M., 2015b. Towards a European policy for rewilding. In: Pereira, H., Navarro, L. (Eds.), Rewilding European Landscapes. Springer International Publishing, Cham, pp. 205–223.

Ng, L., et al., 2020. The scale of biodiversity impacts of the belt and road initiative in Southeast Asia. Biol. Conserv. 248 https://doi.org/10.1016/j.biocon.2020.108691.

Noss, R., 2020. The spectrum of wildness and rewilding: justice for all. In: Kopnina, H., Washington, H. (Eds.), Conservation: Integrating Social and Ecological Justice. Springer Nature, Switzerland.

Noss, R., et al., 2012. Bolder thinking for conservation. Conserv. Biol. 26, 1–4.

O'Neill, D.W., et al., 2018. A good life for all within planetary boundaries. Nat. Sustain. 1, 88–95.

OECD, 2020. Family Indicators. OECD Social and Welfare Statistics database. https://doi.org/10.1787/efd30a09-en.

O'Sullivan, J., 2020. The social and environmental influences of population growth rate and demographic pressure deserve greater attention in ecological economics. Ecol. Econ. 172, 106648.

Pereira, H., Navarro, L. (Eds.), 2015. Rewilding European Landscapes. Springer International Publishing, Cham.

Qiu, C., et al., 2018. Human pressures on natural reserves in Yunnan province and management implications. Sci. Rep. 8, 3260. https://doi.org/10.1038/s41598-018-21654-w.

Queiroz, C., et al., 2014. Farmland abandonment: threat or opportunity for biodiversity conservation? A global review. Front. Ecol. Environ. 12, 288–296.

Radeloff, V., et al., 2015. Housing growth in and near United States protected areas limits their conservation value. PNAS 107, 940–945.

Rees, W., 2020. Ecological economics for humanity's plague phase. Ecol. Econ. 169, 106519.

Rewilding Europe, 2021. Our rewilding areas. Available at:. Rewilding Europe, Nijmegen https://rewildingeurope.com/areas.

Rewilding Europe, 2021. Danube Delta. Available at:. Rewilding Europe, Nijmegen https://rewildingeurope.com/areas/danube-delta/.

Rewilding Europe, 2021. Western Iberia. Available at:. Nijmegen; Rewilding Europe, Nijmegen https://rewildingeurope.com/areas/western-iberia/.

Ripple, W.J., et al., 2017. World scientists'warning to humanity: a second notice. Bioscience 67, 1026–1028.

Ripple, W.J., et al., 2020. World scientists'warning of a climate emergency. Bioscience 70, 8–12.

Ripple, W.J., et al., 2021. World scientists'warning of a climate emergency 2021. Bioscience 71, 894–898.

Robinson, W.C., Ross, J.A. (Eds.), 2007. The Global Family Planning Revolution. The World Bank, Washington, D.C. https://doi.org/10.1596/978-0-8213-6951-7.

Robson, L., Rakotozafy, F., 2015. The freedom to choose: integrating community-based reproductive health services with locally led marine conservation initiatives in southwest Madagascar. Madagascar Conserv. Dev. 10.

Rocliffe, S., Harris, A., 2016. Experiences of Periodic Closures in Small-scale Invertebrate Fisheries. Blue Ventures, London.

Rust, N., Kehoe, L., 2017. A call for conservation scientists to empirically study the effects of human population policies on biodiversity loss. J. Popul. Sustain. 1, 53–66.

Ryerson, W., 2012. How do we solve the population problem? In: Cafaro, P., Crist, E. (Eds.), Life on the Brink: Environmentalists Confront Overpopulation. University of Georgia Press, Athens, GA.

Scharlemann, J., et al., 2005. The level of threat to restricted-range bird species can be predicted from mapped data on land use and human population. Biol. Conserv. 123, 317–326.

Schnitzler, A., 2014. Towards a new European wilderness: embracing unmanaged forest growth and the decolonisation of nature. Landsc. Urban Plan. 126, 74–80.

Seto, K.C., et al., 2011. A meta-analysis of global urban land expansion. PLoS One 6, e23777. https://doi.org/10.1371/journal.pone.0023777.

Shahabuddin, G., Rao, M., 2010. Do community-conserved areas effectively conserve biological diversity? Global insights and the Indian context. Biol. Conserv. 143, 2926–2936.

Shragg, K., 2015. Move Upstream: A Call to Solve Overpopulation. Freethought House.

Stanford, C., 2012. Planet Without Apes. Harvard University Press, Cambridge.

Sterling, E.J., Hurley, M.M., Minh, L.D., 2006. Vietnam: A Natural History. Yale University Press, New Haven.
Symes, W., et al., 2016. Why do we lose protected areas? Factors influencing protected area downgrading, downsizing and degazettement in the tropics and subtropics. Glob. Chang. Biol. 22, 656–665. https://doi.org/10.1111/gcb.13089.
Tamburino, L., Bravo, G., 2021. Reconciling a positive ecological balance with human development: a quantitative assessment. Ecol. Indic. 129, 107973.
Thompson, K., Jones, A., 1999. Human population density and prediction of local plant extinction in Britain. Conserv. Biol. 13, 185–189.
Tucker, C., 2019. A Planet of 3 Billion. Atlas Observatory Press.
Turner, N., 2021. Influence of Religion and Religiosity on Fertility and Contraceptive Use in Continental Sub-Saharan Africa: A Comprehensive review. Masters thesis. University of Gothenberg, Sweden. https://doi.org/10.31237/osf.io/sezdq.
Turvey, S., 2008. Witness to Extinction: How We Failed to Save the Yangtze River Dolphin. Oxford University Press.
United Nations, 2019. World Population Prospects. Available at:. UN Population Division https://population.un.org/wpp/.
Watson, J.E., et al., 2014. The performance and potential of protected areas. Nature 515, 67–73.
Weber, H., Sciubba, J.D., 2018. The effect of population growth on the environment: evidence from European regions. Eur. J. Popul. 35, 379–402. https://doi.org/10.1007/s10680-018-9486-0.
Wiedmann, T., Lenzen, M., Keyßer, L.T., Steinberger, J.K., 2020. Scientists'warning on affluence. Nat. Commun. 11, 3107.
Wilson, E.O., 2016. Half Earth: Our Planet's Fight for Life. Available at:. WW Norton & Company, New York, NY.
World Population Review, 2021. Montana Population 2021. Available at:. World Population Review, Walnut, USA https://worldpopulationreview.com/states/montana-population.
World Population Review, 2021b. Population of counties in Montana (2021). Available at. World Population Review, Walnut, USA. https://worldpopulationreview.com/us-counties/states/mt.
World Wildlife Fund, 2020a. Lower Danube green corridor agreement. Available at: http://danube.panda.org/wwf/web/search/details.jsp?pid=41.
World Wildlife Fund, 2020b. Bringing life to the lower Danube – a real success story for WWF in Ukraine. Available at: https://wwf.panda.org/?181581/BringinglifetothelowerDanube.
Yao, G., Wyman, R.J., 2017. Population. In: Jenkins, W., et al. (Eds.), Routledge Handbook of Religion and Ecology. Routledge, pp. 304–315.
York, R., Rosa, E., 2012. Choking on modernity: a human ecology of air pollution. Soc. Probl. 59, 282–300.
York, R., et al., 2003. STIRPAT, IPAT and ImPACT: analytic tools for unpacking the driving forces of environmental impacts. Ecol. Econ. 46, 351–365.