



*Synthesis*

# Revisiting the Environmental and Socioeconomic Effects of Population Growth: a Fundamental but Fading Issue in Modern Scientific, Public, and Political Circles

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**ABSTRACT.** Reversing ongoing declines in human welfare and biodiversity is at the core of human development. Although numerous institutions and avenues are in place to reverse such trends, there seems to be limited consideration of population growth as an ultimate driver. I review recent studies showing how the issue of population growth has been downplayed and trivialized among scientific fields, which may in part account for the reduced public interest in the issue and in turn the limited will for policy action. Different sources of evidence suggest that population growth could fundamentally affect society, nature, and the climate. Although tackling the issue of overpopulation will suffer from major impediments including scientific motivation, public scientific illiteracy, religion, and media attention, ongoing neglect of this issue will increase not only the extent of anthropogenic stressors but also the struggle associated with strategies to reverse biodiversity loss and improve human welfare.

**Key Words:** *biodiversity loss; climate change; debt; employment; population growth; public outreach*

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## INTRODUCTION

Two of the greatest concerns of our generation are to improve human welfare (Kollodge 2011) and to prevent the ongoing loss of biodiversity (Secretariat of the Convention on Biological Diversity 2006, Hails 2008). More than one billion people live in extreme poverty and hunger, and ecosystems are losing species at rates only seen in previous mass extinction events (Secretariat of the Convention on Biological Diversity 2006, Hails 2008, Barnosky et al. 2011, Mora et al. 2013a). Unfortunately, overcoming these problems remains difficult, and if anything, progress appears to be leaning in undesirable directions (Butchart et al. 2010, Kollodge 2011). Because of a plethora of human related-stressors (Mora and Sale 2011, Mora and Zapata 2013:239-257), which affect 83% of the world's land surface (Sanderson et al. 2002) and 100% of the world's oceans (Halpern et al. 2008), biodiversity remains in a downward trend, with an increasing number of species being threatened by extinction (Roberts and Hawkins 1999, Pimm and Raven 2000, Pitman and Jørgensen 2002, Gardner et al. 2003, Myers and Worm 2003, Pandolfi et al. 2003, Baillie et al. 2004, Stuart et al. 2004, Hails 2008, Mora and Sale 2011, Mora et al. 2013a). In turn, the world's human population has reached 7 billion and could grow to 9-12 billion before the year 2050, indicating that the effect of human stressors upon biodiversity will likely continue to increase and that in the coming half century we are likely to witness accelerated ecological changes (Sala et al. 2000) and the erosion of important biodiversity goods and services (Costanza et al. 1997, Daily 1997, Chapin et al. 2000). The sharp contrast between the declining supply of the Earth's services and the rising demand from a growing human population indicates that such services will increasingly fall short, thus exacerbating hunger and poverty (Wackernagel et al. 2002, Millennium Ecosystem Assessment 2005, Campbell et al. 2007, Kitzes et al. 2008, Ehrlich 2009).

Unfortunately, reversing ongoing deleterious trends in human welfare and biodiversity remains challenging despite

international initiatives such as the Millennium Development Goals and numerous international venues such as The World Conference on Human Rights, The Convention on Biological Diversity, Agenda 21, and the United Nations Framework Convention on Climate Change (which led to the Kyoto Protocol), among others. It has been already noted that part of the failure to reverse trends in human welfare and biodiversity loss stems from the paucity of international institutions that address the problems conjointly (Walker et al. 2009). The reasoning is that there are significant feedback loops between biodiversity loss and human welfare and several other issues such as climate change, overexploitation, habitat loss, violence, and so forth and that we lack institutions that can track all issues simultaneously, especially at transnational scales (Walker et al. 2009). I argue that another, and perhaps even more critical, reason for failure is the reluctance of many of these initiatives and institutions to call for specific actions on the issue of population growth. I reviewed recent literature (> 70% of the papers cited were from the last decade) to highlight the key role of overpopulation in several pressing social and environmental issues. This review of recent case studies suggest that the issue of overpopulation is being critically underplayed and fails to influence decisions in which millions of people and species could be negatively affected by a situation that might have been otherwise avoided.

## SCIENTIFIC, PUBLIC, AND POLITICAL CONSIDERATION OF POPULATION GROWTH

The issue of overpopulation is fading in importance throughout most endeavors and sectors of society. For example, overpopulation, despite being directly or indirectly linked to the deterioration of ecological systems (Mora and Sale 2011) and a key factor for the success of conserving species and ecosystems (Mora and Sale 2011), has been rarely considered and in fact "trivialized or ignored" by much of the conservation biology community (Meffe et al. 1993). For example, it is often argued that increasing greenhouse gas emissions are caused by a

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combination of excessive consumption and increasing population. In fact, projections on human population suggest that the net production of greenhouse gases could be equivalent between developed and developing countries due to the large consumption of the former and the large population growth of the latter (Bongaarts 1992). Yet the most authoritative report on climate change [i.e. the Intergovernmental Panel on Climate Change (Pachauri and Reisinger 2007)] makes little to no reference to the issue of population growth or family planning, or any related matter. Similarly, one could argue that food security will depend not only on our capability to produce more food but on how much food our population will continue to demand; yet some of the most seminal recent reports on food security lacked any reference to the role of or need to address population growth in ensuring current and future food security (Clay 2011, Foley et al. 2011). Finally, overpopulation is known to affect key aspects of human welfare (reviewed in *Window of opportunity for tackling overpopulation: Welfare*; APPGPDRH 2007, Campbell et al. 2007). However, the topics of overpopulation and family planning are rarely considered by leaders in different endeavors as mitigation solutions to improve the health of impoverished people (Poma et al. 2007), and population growth is “marginalized” in key recent reports about improving human welfare (Cleland et al. 2006).

It is very likely that population growth as a missing scientific agenda accounts in part for the reduced public knowledge and interest in this issue. Meffe (1994) introduced the concept of “missing awareness” to explain a current lack of understanding of the magnitude of our population even among portions of our society with higher education. In the United States, public opinion on population growth as a pressing problem declined from 68% in 1992 to 8% in 2000 (Schindlmayr 2001) and does not appear in recent opinion polls (PollingReport.com, <http://www.pollingreport.com/prioriti.htm>). Despite the significance of the recent milestone that our global population reached seven billion people, the press coverage faded quickly, particularly when compared to more trivial news at the time (e.g., the possible love affairs of Herman Cain, which lasted for weeks). Unfortunately, the limited public consideration of the issue translates into limited policy action. As an example, the share of international funding on family planning has dropped to ~5% in 2007 from ~55% in 1995 (Bongaarts and Sinding 2009). This collision between lack of interest in the topic of population growth (by scientists and the public) and the declining support for family planning programs and addressing population growth among developed countries (Myrskylä et al. 2009) generates a worrisome situation for the spontaneous stabilization of the world’s human population. Although the relevance of population growth can vary by country, especially among developed and developing countries (Lee 2011), interest in the topic should be a global concern as even developed countries appear to be reversing their negative population birth rates (Myrskylä et al. 2009) and because interest in the topic among developed countries greatly determines the success of education and family planning programs in developing nations (Schindlmayr 2001).

However, this is not to say that overpopulation is solely restricted to developing countries. As an example, former presidential candidate Mitt Romney, age 66, recently released a family photograph of him with 20 of his 22 grandchildren ([http://www.](http://www.politico.com/story/2013/09/mitt-romney-grandchildren-97151.html)

[politico.com/story/2013/09/mitt-romney-grandchildren-97151.html](http://www.politico.com/story/2013/09/mitt-romney-grandchildren-97151.html)). If every child choose to have the same number of children their parents and grandparents did, by the time that Mitt Romney is in his 90s, he could potentially be taking a photograph with ~97 great-grandchildren, which added to the 22 grandchildren and the 5 children adds to ~124 people from two parents. Several other candidates in the last U.S. election have 5 to 7 children. This indicates that the problem is hardly restricted to developing countries and that the underlying reason for overcrowding is not restricted to poor and uneducated people and thus should be a serious issue to consider across the board.

### WHY THE DECLINING INTEREST IN POPULATION GROWTH?

The limited engagement of scientists in public discussion about environmental issues has been discussed before and is related to limited rewards and discouragement by institutions, limited skills and avenues for communication, the loss of personal time, possible lack of support or approval from colleagues, possible attacks by interest groups, the possibility that such efforts may fail, and even the potential loss of one’s job (Chan et al. 2005, Batts et al. 2008, Pace et al. 2010). One also has to consider the mismatch in the frequency in which information is delivered in scientific fields and the frequency needed to gain and maintain the public’s attention. Let me expand on this: in science a given idea is published once, and although some spin-offs can still be published, the reality is that given lack of novelty it will become increasingly harder to publish papers related to that former idea. Scientific publications are the main opportunities used by scientists to communicate their results to the general public, often in the form of press releases; in my experience press coverage of scientific findings lasts only a handful of days. However, as noted by the massive expending in publicity campaigns, information has to be repeated over and over again to ensure peoples’ attention. Between the limited opportunities for science outreach and the needed constant reminder to people, public attention on environmental issues can fade out very quickly. These conditions are likely aggravated when dealing with overpopulation given the contentious nature of the issue.

Increasing public understanding and awareness about the issue of overpopulation is fundamental to its solution. Public consciousness can influence not only people’s choices in favor of having smaller families (Lee 2011), but should also stimulate political will (Nisbet and Mooney 2007) and drive public and private funding (Schindlmayr 2001). As noted earlier, however, public interest on the issue of overpopulation is declining and although the lack of scientific engagement could be responsible in part, there are other elements.

A key factor, for instance, is the large rate of scientific illiteracy of the public in general. In countries like the United States, Canada, Japan, and others in Europe, the proportion of scientifically literate adults is below 17% (Gross 2006), and one would expect lower numbers for developing nations. Scientific literacy is at the core of better appreciating the link between individual actions and environmental conditions (Blumstein and Saylan 2007); how human activities aggregate to affect the health of the biosphere (Perry 1993); and in the case of overpopulation, real comprehension of what the overpopulation numbers mean (Meffe 1994). In a survey of university students, Meffe (1994)

found, for instance, that responses to the question of how many people there are in the world and how fast the population is growing yielded several-fold overestimated answers including population estimates of one to three trillion and annual increases of hundreds of billions, highlighting the abstractness of the problem or a more serious education problem about differentiating the meaning of “million, billion, and trillion” (Meffe 1994).

Scientific literacy also plays an important role as “... a conceptual tool kit ... to ... ask questions, identify assumptions, and make well-reasoned decisions ;... without it ... a population ... is particularly ... ripe for exploitation by less-than-honest industries and politicians” (Blumstein and Saylan 2007:975, see also van Eijck and Roth 2007). This limitation of the general public regarding scientific literacy is particularly critical in regards to overpopulation, due to its conflict with religious beliefs. The role of religion in the number of childbearing and other family factors (Thornton 1985, Studer and Thornton 1987, Goldscheider and Mosher 1991) as well as donor support in family planning programs (van Dalen and Reuser 2006) is well established. Religion can also feed into the politicization of science, which by promoting or demeaning specific knowledge reduces scientific legitimacy and public awareness (Gauchat 2012). Gauchat (2012:179) argued, for instance, that in the United States religion has been “a chief factor contributing to conservatives’ distrust of science” by showing how public trust in science declined significantly since the 1970s, more so among conservatives, especially those who attended church frequently and were well educated; that well-educated conservatives are becoming less confident in science was explained by the fact that they are aware of more information and will choose only that information that supports their ideology; the so-called confirmation bias (Gauchat 2012). In short, conveying the need to regulate population growth would require convincing not only policy makers and the general public but, perhaps more importantly, priests. Public assimilation of scientific knowledge in the face of religious and political beliefs is without a doubt the toughest challenge for tackling overpopulation; yet this is not impossible, because religions do also adapt to the needs of modern society (Thornton 1985). A reviewer of this paper also suggested that other sentiments about reducing population growth that contribute to the resistance of nations to adoption of policies that deal with population may include fears over the shrinkage of a nation’s military or industrial capacity, a misguided concern over social welfare costs, or just a sense that diminishment in numbers means failure.

Conveying the issue of population growth to the general public is further troubled by skepticism from historical flip-flops about the significance of overpopulation (Lee 2009), environmental generational amnesia or the process through which declining baselines over generations reduce levels of concern (Miller 2005, Knowlton and Jackson 2008), declining interest over environmental issues in the face of far more imminent concerns such as jobs and wealth (Revkin 2009), the overload of information and avoidance of information perceived as irrelevant (Nisbet and Mooney 2007), psychological biases toward short-term versus long-term gains (Laibson 1997), and a common attention cycle driven by the sound-bite nature of news media and the short-term focus of many politicians (Downs 1972). Although tackling the issue of overpopulation will suffer from major

impediments ranging from scientific motivation to public scientific illiteracy to religion to media attention, the matter of fact is that failing to address overpopulation will increase not only the extent of anthropogenic stressors but also the struggle associated with strategies to reverse biodiversity loss (Mora and Sale 2011) and to improve human welfare (APPGDRH 2007, Campbell et al. 2007).

## **WINDOW OF OPPORTUNITY FOR TACKLING OVERPOPULATION**

Despite historical skepticism over the issue of population growth, numerous lines of evidence highlight the key role of overpopulation as an ultimate factor in multiple social, economic, and environmental issues. These issues are attracting considerable public, political, and media attention in countries throughout the world, which provides a unique window of opportunity to bring up overpopulation to the forefront of peoples’ attention.

### **Employment**

A top pressing concern for governments worldwide is the need to supply jobs. Because jobs are the main mechanism through which individuals gain earnings that allow spending and healthy economies, high levels of unemployment can cause economic and social turmoil. At the core of this struggle for constant job generation is the growing size of the work force resulting from a simple growth in population. According to the World Bank database (<http://data.worldbank.org/indicator>), the world’s labor force has grown indeed; from 1.9 to 3.2 billion people between 1980 and 2009. According to the U.S. Census Bureau database (<https://www.census.gov/#>), in the world there are 560 million people aged 55 to 64 and 1.2 billion aged 5 to 14; considering retirement age at 64 and assuming that the jobs of retirees are fully occupied by the young, then for the next decade simple demographics imply a deficit of 640 million jobs worldwide. Failure to offset this growing need for jobs could exacerbate unemployment, although some governments have adjusted it by reducing relative wages. For instance, it is curious that even though labor productivity has increased by 70% since the 1970s, average wages, adjusted for inflation, have remained constant and have actually declined by ~20% among unskilled workers in the United States according to data from the U.S. Bureau of Labor Statistics (<http://www.bls.gov/>). Absorbing the new labor supply will remain a major challenge everywhere because widespread availability of advanced technology will tend to reduce demand for human labor; because of labor shortages resulting from declining natural resources, especially land for agriculture, which is the main sector of employment; and for developed countries, because of job outsourcing due to globalization. Whether it is through unemployment or through wage reduction, the challenge of absorbing the labor supply will only be aggravated with further additions to our population.

### **Public debt**

Another major political concern for governments worldwide is their increasing budget deficits. Corruption aside, the conflict between providing basic social security for the young and the elderly without creating a tax burden on the work force is ultimately leading to increasing debt. Public budgets are constantly burdened by both ends of the population age pyramid. On one end, it is the youths and the necessity for their

support, both financial and medical, and investment in human capital, i.e., providing the conditions for the generation of knowledge and training in skills necessary for technological innovation and competitiveness in a globalized world, and to avoid future economic downfalls due to lower levels of taxes paid by individuals who, as adults, may be deprived of the better earnings of skilled workers. In the United States, the public cost of unintended pregnancies, i.e., ~50% of all pregnancies, medical care during gestation and the first infant year is calculated to be \$11 billion a year (Sonfield et al. 2011). Some fraction of unintended pregnancies are likely to be unwanted, and in those cases children are known to be more likely to drop out of school and are prone to greater levels of criminal activity (Hay and Evans 2006), which further adds to the public cost of unintended pregnancies, costs of externalities related to criminal justice, lower and/or unskilled labor-force participation, and loss of tax revenue. On the other end, it is the elderly and the necessity to provide basic services for their welfare after retirement. Mostly because people are living longer, i.e., on average, life expectancy increased from 46 to 69 years between 1950 and 2011 (Bloom 2011), there is a growing elderly population, which is raising the cost of the pension system and welfare services. For the United States, various simulations under various assumptions suggest that public debt could increase from ~55% of the gross domestic product in 2009 to 128%-321% by 2050 mainly because of mandatory spending on programs related to Social Security and Medicare/Medicaid (Congressional Budget Office 2009). Recommended but unpopular measures to balance increasing debt include increasing retirement age, increasing taxes, or reducing the extent of welfare services. Other solutions include encouraging higher fertility (e.g., increasing the period for maternity leave, government child support, tax credits) and immigration (Turner 2009, Bloom 2011); these policies are expected to increase the ratio of working to nonworking age but if children are also included in the nonworking population, the ratio may show little change (Carr 2010); these policies also fail to consider the initial cost of youth dependency, how to ensure fairly waged jobs for the surplus of working age people, and that eventually these same people will retire and will require social security. Overall economic growth will remain a key objective of governments worldwide to finance their increasing costs; however, appreciating the public cost of overpopulation may allow wiser distinctions between overall economic growth through adding more people to the production line or investing in human capital; one would expect that the latter should increase per capita productivity, allow access to better wages, and generate more wealth equity while increasing tax revenues.

The relationship between population and economic growth has been highly debated between two mainstreams: (1) those who view overpopulation as a driving economic force and an avenue for inventiveness and ingenuity capable of enhancing Earth's capacity to support our species indefinitely at a high standard of living and capable of overcoming environmental externalities through technology (Simon 1996); and (2) those who see overpopulation as an economic impediment, retarding capital accumulation and improvements in standard of living (Campbell et al. 2007, Turner 2009) and as a deterrent to environmental and biological capital (Cohen 1995, 1996, Harte 2007). Unfortunately, empirical

evidence has been highly contentious. The 1986 U.S. National Academy of Sciences Report on Population Growth and Economic Development suggested that although correlations were intriguing, little insight existed into the causality of such correlation (National Research Council 1986). In contrast to early assessments, recent reports have found that rapid population growth can exercise a quantitatively important negative impact on the pace of economic growth in developing countries and that a rapid fertility decline can reduce the incidence and severity of poverty (Birdsall et al. 2001). Even among developed countries, increasing population growth would demand increased expenditures on basic infrastructure, leading to unproductive capital widening at the expense of capital deepening (Birrell 2009, O'Sullivan 2013). Kelley and Schmidt (1996) have argued that past positive relationships between population and economic growth may not be used as an argument to favor population growth today. Some of the reasons include lower saving rates resulting from the rapid population growth in the 1980s, return to existing technologies in agriculture may have diminished, and environmental degradation may have reduced the quality of some agricultural land.

#### **Welfare**

Overpopulation could also have a considerable effect on different issues related to quality of life and health (Cleland et al. 2006, APPGPDRH 2007, Campbell et al. 2007, Rollins 2007, Birrell 2009). For instance, it has been broadly discussed that achieving the Millennium Development Goals is and will be considerably undermined by ongoing population growth (Cleland et al. 2006, APPGPDRH 2007, Campbell et al. 2007). Rapid population growth, for instance, is increasing the proportion of the world's poorest people and impairing their economic growth, making the objective of eradicating poverty and hunger increasingly unattainable (Eastwood and Lipton 1999, APPGPDRH 2007, Campbell et al. 2007). It will reduce the availability of recourses for education, especially for girls; thus, it will feed a pernicious cycle of gender inequity (aggravated by the burden of excessive childbearing [Cleland et al. 2006]) and high fertility (because uneducated girls marry early and tend to have more unintended pregnancies [Upchurch et al. 2002]). High fertility also reduces the share of maternity health services (APPGPDRH 2007, Campbell et al. 2007), thus increasing deaths among mothers (Collumbien et al. 2004) and newborns (Rutstein 2005, APPGPDRH 2007, Campbell et al. 2007), especially those born close together (Rutstein 2005). Regarding overall health, population growth adds to the inability of governments to scale up health care systems and facilities for prevention and treatment of HIV/AIDS, malaria, and other diseases (APPGPDRH 2007, Campbell et al. 2007). Population growth can exacerbate the transmission of HIV/AIDS by forcing unsafe behaviors among poor and hungry individuals, i.e., forcing individuals into prostitution and/or unprotected sexual activities resulting from lack of access to contraception and methods to prevent sexually transmitted disease" (Rollins 2007); by increasing urbanization and subsequent increase in sex workers, migrant laborers, and overcrowding (APPGPDRH 2007); and by increasing mother-to-child transmissions (Reynolds et al. 2005). Harte (2007) further emphasizes that a society facing a high and/or increasing population is less capable of achieving social and economic equity,

let alone providing appropriate health care and education. Raising the welfare standards of people, especially among the world's poorest, is clearly troubled by a growing population.

### Climate change

The recent temperature record shows that our climate has warmed and that weather extremes are becoming more frequent and catastrophic, leading to costly damage of infrastructure and loss of human life (IPCC 2007). If one accepts the overwhelming body of evidence linking ongoing climate change to burning fossil fuels and agricultural practices, then one can safely argue that climate change is a by-product of supplying human demands; thus, overpopulation is a key component of projections in carbon emissions (Birrell 2009, O'Neill et al. 2010). It is often argued that climate change could be alleviated by reducing our carbon footprint through less consumption and better technology (IPCC 2007). However, the unsustainability of ongoing growth in human population can overwhelm those efforts; thus, definitive solutions will require not only smaller footprints, but fewer feet (Bongaarts 1992, Birrell 2009). For instance, if a given individual were to implement an extensive list of actions known to reduce greenhouse gas emissions, that reduction would still be about 40 times smaller than the emissions generated if this person were to have two children (Murtaugh and Schlax 2009). In the United States, each child adds about 9441 metric tons of carbon dioxide to the carbon legacy of an average parent, which is 5.7 times his/her lifetime emissions (Murtaugh and Schlax 2009). Achieving a reduction of greenhouse gases will become increasingly difficult even under modest population growth rates given expected improvements in human welfare and expected increases in energy consumption (Birrell 2009).

Framing overpopulation on the issue of climate change, however, reveals the possibility of economic silver bullets. For instance, simulation models indicate that the reduction in fertility rate resulting from providing available contraceptives to women who want them will result in an absolute reduction of CO<sub>2</sub> emissions similar to that resulting from implementing available technologies but at a cost that will be almost five times lower (Wire 2009). (According to the United Nations Population Fund, ~215 million women lack but want access to family planning, which in turn leads to ~76 million unwanted pregnancies worldwide annually; averting such births would reduce population growth by ~20% [Cleland et al. 2006].) Failure to act on overpopulation could lead to dire economic consequences related to climate change. It has been calculated, for instance, that if governments invest in strategies to stabilize CO<sub>2</sub> emissions, any additional birth will impose externalities on society through extra emission reduction costs and extra climate damage costs, valued between \$3000 and \$20,000 per birth in developed countries and \$1000 to \$13,000 in developing countries (O'Neill and Wexler 2000). These costs are considerably higher than the costs of averting additional natality, which could be only \$220 per birth through family planning and \$175 through sex education (Birdsall 1992).

### Demands for food and water and ecological costs

Aside from the social and climatic framing of overpopulation, recent statistics reinforce its traditional framing on resource shortcoming and environmental impacts (Harte 2007, Mora and Sale 2011). Today, one billion people live in severely diminished or depleted areas and thus constantly face hunger (FAO 2010)

and another billion live in water scarce areas (FAO 2011). By 2050, in part because of population growth, food demand is forecast to increase between 70% and 100% (Godfray et al. 2010), whereas the percentage of the world's population living in water-stressed countries will increase by anywhere from threefold to fivefold (Gardner-Outlaw and Engelman 1997). Meeting food and water demands for a growing human population will be challenging for a mixture of reasons: (1) the supply of nature's freshwater is fixed (Vöösmary et al. 2000, FAO 2011); (2) more than 65% of the world's continental water discharges are now threatened by human factors (Vöösmary et al. 2010); (3) agriculture uses 70% of the world's water withdrawals; (4) there are limited possibilities for agriculture expansion, i.e., ~70% of the Earth's suitable area for food production is already in use or cannot be used (Foley et al. 2011); (5) there is ongoing shifting of farmland to the production of more lucrative biofuels; and (6) climate change has potential deterring effects on food production, e.g. through changes in temperature, precipitation, drought, and fire (IPCC 2007, Mora et al. 2013*b,c*). Supplying water demands to growing populations will be challenging even among developed countries because of a combination of limited infrastructure and more frequent and intense drought events expected from climate change (Birrell 2009). Ruttan (2002) argues that raising the ceiling of agricultural production has become increasingly difficult and concludes that in the absence of increases in quality and quantity of agricultural land and renewed investment in agricultural research and technologies, it is doubtful whether sustained growth in agricultural production will be sufficient to meet the increasing demand for food as a result of population growth and increased income. This situation may be common to other nonrenewable resources such as metals, fuels, and minerals, of which ~88% are now considered scarce because their supply is failing to keep pace with increasing global demand (Clugston 2010).

Concern over future food and water demands are further aggravated by the massive environmental and climatic impacts of supplying those services so far. Current estimates suggest that agricultural expansion accounts for the annual deforestation of 5-10 million hectares of forest, whereas inappropriate practices have caused the erosion of ~30% of the world's cropland at a rate of 10 million hectares per year (FAO 2011). This is not to say that all regions are facing land clearing, as some regions have seen forest growth resulting from reforestation of timber, palm oil, and other plant products (FAO 2011). Habitat loss is the leading factor in wildlife extinction (Sala et al. 2000), while also releasing captured CO<sub>2</sub> and tampering with the functionality of forests to store CO<sub>2</sub> (IPCC 2007). Similarly, more than 2.5 million metric tons of pesticides and 142 million tons of fertilizers are used in agricultural practices each year according to the Food and Agriculture Organization of the United Nations (2011). They significantly contribute to greenhouse gases due to methane emissions from livestock and nitrous oxide from soil fertilizers (IPCC 2007, Good and Beatty 2011) and are a leading cause of biodiversity change because of their runoff (Sala et al. 2000, Good and Beatty 2011).

Population growth also poses additional challenges to keep food supplied through agricultural expansion, which may in turn trigger conflicts over the land necessary for biodiversity conservation. Harte (2007) refers to this situation as the "low-hanging fruit gets picked first," to suggest that it is very likely that

we have used or are already using the most fertile soils and cleanest water; thus, as we increase our population and expand its distribution, we will see fewer and fewer such suitable areas for agriculture. Meeting food demands through agricultural expansion could also generate conflicts between the use of land for agriculture and the land needed for biodiversity protection. For instance, by 2050 about 26% of the world's land could see conflicting uses between what is needed to supply human food demands through agriculture and what is needed to effectively protect biodiversity from human threats (Musters et al. 2000, Mora and Sale 2011). Today, the broad coverage of multiple human stressors on land (Sanderson et al. 2002) and ocean (Halpern et al. 2008) complicate considerably the location of protected areas in which biodiversity can remain viable (Mora and Sale 2011).

### CONCLUDING REMARKS

"History may be a comforting guide, but it cannot guarantee our future" (Bloom 2011:568). Evidence is now mounting that population growth can be a deciding force between desirable and undesirable scenarios for society and nature and that overpopulation is a common denominator to many environmental and socioeconomic issues (see above). Thus, as a single tractable factor, tackling population growth could deliver not only beneficial but also long-term resolutions to a wide range of pressing issues. Simple solutions such as empowering women (Cohen and Richards 1994), sex education (Turner 2009), providing affordable family planning (Bongaarts and Sinding 2011, Lee 2011), revisiting subsidies that promote natality (Myrskylä et al. 2009), and highlighting the economic cost and necessary investment for children's future success (Hay and Evans 2006, Sonfield et al. 2011) could considerably avert population growth. However, the magnitude of the task is considerable; even for developed countries, where the growth rate is just below replacement level, there could be positive net gains in their populations because of demographic momentum, i.e., a storage effect resulting from increasing life expectancy, and current incentives for encouraging natality, e.g., tax breaks and government subsidies as a solution to increase the working force to offset the economic effects of demographic ageing (Myrskylä et al. 2009).

It is often suggested that the target for population stabilization is 2.1 children per women (one child to replace the mother, the other to replace the father and the 0.1 to account for child mortality), because that will replace the generation in consideration. However, such a target should be considered with caution because increasing life expectancy and early reproduction could create the overlap of generations, increasing population size even if growth rate is kept at replacement levels of 2.1 children per woman. In reality, population stabilization is achieved when the natality rate is equal to the mortality rate, which by today's demographics would be equivalent to one child per women (Mora and Sale 2011). It is unlikely and undesirable to achieve such targets through intrusive and coercive government policies (Mueggler 2008), whereas the alternative will require reaching a global consciousness and change in behavior on the issue of population growth (Sale 2011). This will entail increasing public awareness on the issue; and for this, we need greater courage from scientists to take a public stand on the issue of population growth and on the family, state, and natural costs of childbearing. In a planet with limited resources and a sensitive climate, with most of its

natural resources being overexploited and its economic systems overstressed, meeting the additional demands of a growing human population without destroying the Earth and our social systems will be one of the greatest tests to humanity in the years to come (Ehrlich and Ehrlich 2013). The bulk of statistics help us to appreciate not only the magnitude of the problem but also the effective solutions we already have at hand. Therefore, one can only hope that the issue of population growth rises from obscurity to the forefront of national and international concerns.

*Responses to this article can be read online at:*

<http://www.ecologyandsociety.org/issues/responses.php/6320>

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### Acknowledgments:

*I thank two reviewers and several colleagues for constructive feedback on the paper.*

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