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News and Views

Reawakening Malthus: Empirical Support for the Smail Scenario

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Editor's Note:
In the November issue of the Journal, Kenneth Smail presented the third and final part of his series on Malthus and human population growth. Here, Jeffrey McKee offers additional thoughts on population and its impact on biodiversity and extinction history. Am J Phys Anthropol 122: 371–374, 2003.

Through the animal and vegetable kingdoms Nature has scattered the seeds of life abroad with the most profuse and liberal hand; but has been comparatively sparing in the room and the nourishment necessary to rear them.
— Malthus (1798)

Malthus not only inspired Darwin and others by his keen insights on the limits to growth in Nature, but his work is still relevant to a new generation of neo-Malthusians. Principles that Malthus envisioned long ago apply urgently today, as our human population soars well beyond the six billion it reached in 1999—a year past the 200th anniversary of the first publication of Malthus's *Essay on the Principle of Population*. Now the lessons of Malthus are being taught with a vengeance throughout the animal and plant kingdoms.

Physical anthropologists can play a unique role in dissecting out the effects of human numbers and human enterprises on Earth's biodiversity. We have the long-term data on humans, prehumans, and their environments. This helps us to garner long-term trends in human demography and health, and resource use and abuse. Whereas much of our work seems arcane, every data point is part of the larger picture, and is relevant to understanding the trajectories of Earth's ecosystems over the next century.

In a recent series of *News and Views* essays, Smail (2002, 2003a,b) broached the dilemmas faced by humanity as our population continues to grow by over 200,000 people per day. It can be shown that our burgeoning population also poses a dilemma, and indeed a severe threat, for numerous other species of plants and animals that get pushed aside in the wake of ever more humans. Therein lies empirical support for three of Smail's assertions: 1) that our current population size of 6.4 billion is not sustainable; 2) that Earth's optimal carrying capacity, at a moderate to comfortable standard of living, may be in the range of 2–3 billion people; and 3) that other ecological issues are subordinate to the demographic threat.

SPECIES EXTINCTIONS: THE POPULATION CONNECTION

Population growth among humans and their predecessors can be tied directly and indirectly to mammalian species extinctions since the origins of *Homo erectus*. Behrensmeyer et al. (1997) and McKee (2001) independently demonstrated a decline in mammalian biodiversity of Africa subsequent to 1.8 mya, that is, following the origin and spread of *Homo erectus*. Whereas there is no direct evidence to attribute the Pleistocene extinctions to *H. erectus*, let alone to the population growth of the species, Klein (2000) documented a pattern of extinct genera associated with hominin evolution and entry into four geographical regions. Alroy (2001) attributed the overkill of North American megafauna in the end-Pleistocene in part to human population growth. The patterns of biodiversity loss led McKee (2003) to attribute many past extinctions worldwide to the effects of the growth and spread of human and prehuman populations.

With the origins of agriculture, the impact of human population growth accelerated (Redman, 1999; McKee, 2003). Our effects on the viability of other species were still strong, but mediated in a different way. Rather than killing off species directly through hunting or interspecific competition for natural food resources, wholesale displacement of other species came from utilizing expanses of land for agriculture and herding. These converted lands became less diverse and less productive in biomass, while at the same time becoming more productive in supplying foods specifically for human consumption.

Despite the human health decline that accompanied the origins and spread of agriculture (Larsen, 1995), human populations flourished. Building upon an established base of human "capital," the exponential nature of population growth (even at a slow growth rate) ensured that our numbers expanded (McKee, 2003). Meanwhile, large mammal extinc-

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tions hit an all-time high. For example, in South Africa, 16 mammal species have gone extinct in the past 10,000 years, including nine in historic times. This is in contrast to a Plio-Pleistocene pattern of about four large mammal species going extinct every 100,000 years (McKee, 1995). The ineluctable conclusion is that the growth of our population and the extinction of other species have long been closely related.

Today, the pattern continues in an alarming manner. McKee et al. (2004) found that human population size is strongly correlated with the number of threatened species of mammals and birds on the IUCN Red List. Using a multiple regression analysis, we determined a mathematical model that explains 88% of the variability in current threats to mammal and bird species per country on the basis of just two variables: human population density and species richness (or number of species per unit area). In other words, more people in areas of more species appear to be on a collision course, with other species losing ground.

It is a well-supported assumption that a sustainable human population will require functioning ecosystems around the globe to provide essential environmental services (Daily, 1997). Thus it can be argued that not only does our current population size pose a significant threat to the global biodiversity on which we rely, but it also does not appear to be sustainable as we continually lose other species.

Continued growth most likely will make matters worse. Using this model to forecast future species threats based upon demographic projections per country, it was found that we can expect a 7% increase in the global number of threatened species of mammals and birds by 2020, and a 14% increase by 2050, based on growth in human numbers alone (McKee et al., 2004). If these forecasts hold weight, and if the biodiversity data for mammals and birds are reflective of other life forms (Ceballos and Ehrlich, 2002), then we face the potential for severe losses of species that will in turn disrupt ecosystem functioning, thereby threatening our own life-support system and planetary sustainability. It is Malthusian principles writ large.

OPTIMAL POPULATION SIZE

As the quip goes, it is difficult to make predictions, especially about the future. But upon reading Smail's *News and Views* essays, it occurred to me that the data we compiled and analyzed regarding biodiversity threats could be used to empirically gauge Smail's admittedly intuitive assertion that the "optimal" (i.e., sustainable) human population size should fall in the range of two to three billion. We had noted in our original research that *mathematically* those nations for which population declines were expected should expect a decrease in the number of threatened species. Theoretically, one could use the formula to calculate an optimal human population size that would reduce the number of threatened species globally, or at least diminish the threat posed by continued population expansion.

A word of caution before I follow through with the mathematics. Forecasting complex ecological phenomena, like forecasting the weather, holds many more assumptions and nuances than appear on the surface. Thus, this is merely a mental exercise with which to provide rough estimates to provoke thought and action, not a solid prediction.

My initial test used our mathematical formula to find the maximum number of human beings allowable for which there would be absolutely no threat to other species. I proceeded by systematically reducing the population size data for each nation, and recalculated the predicted number of threatened species. As the numbers dwindled, it became clear, mathematically speaking, that the number would have to be zero. Whereas this is in part a nuance of extrapolations based on much larger numbers, it also makes a modicum of sense. I have already noted that a case can be built that *Homo erectus* could have impacted species diversity in Africa after 1.8 mya. Indeed, any species, especially large-bodied omnivores in growing numbers, become part of the ecosystem and necessarily must have some impact on those species with which they interact, eat, or compete. It is thus unreasonable to expect the human population to pose absolutely no threat to other species.

Our question must then shift to something more reasonable and perhaps attainable without annihilating the single species that gives anthropologists their careers. How much of a reduction in human population would it take before every country in our data base demonstrated a reduction in threats to at least one or more species of mammals or birds? The answer is that a reduction to 57% of the global population in 2000 (i.e., to approximately 3.4 billion) would accomplish this goal (see Table 1). In other words, just to begin to globally reduce our threat to other species, we would have to come close to Smail's upper estimate of an optimal population size of three billion people.

Table 1 also includes estimates of reduced threats to other species of mammals and birds at Smail's proposed population levels of three billion and two billion *Homo sapiens*. None of these estimates eliminates our impact on other species, but with proper conservation measures we could at least ensure that much more of Earth's biodiversity is sustainably preserved. How far we go in reducing population numbers then would depend on measuring progress and adjusting the estimates accordingly. Cohen (1995), in his book *How Many People Can the Earth Support?*, came to the conclusion that the number in answer to his question depends on how those people want to live. A similar conclusion comes in answering the question about how many the Earth can support with sustainable ecosystems: we will have to ascertain the number at which we are confident that ecosystem collapses are not imminent.

TABLE 1. Effects of population size reduction from that of year 2000, upon threatened species of mammals and birds per nation, based on empirically derived formula: log threatened species per 10^6 km^2 = −1.534 + 0.691 × log species richness + 0.259 × human population density (McKee et al., 2004)

Reduction of human population size	N of nations tested	Mean reduction in number of species threatened/nation	Balance of threatened species/nation
57% (~3.4 billion)	114	−3.85	26.40
50% (~3 billion)	114	−4.66	25.58
33% (~2 billion)	114	−7.08	23.16

SUBORDINATE EFFECTS

Sustainability does not come without responsibility, even at reduced numbers. At two to three billion people, we are only back to where we were between 1930 and 1960. Back then there was not the level of environmental consciousness and hard data to acknowledge what many ecologists now refer to as the "ecological footprint," the effect each individual or group has in terms of resource consumption (Wackernagel and Rees, 1996; Chambers et al., 2000). This is manifested in many ways: fuel consumption, deforestation, fresh water usage, or even the household dynamics of urban sprawl (Liu et al., 2003).

Smail (2003a) fleshed out the footprint notion with the I = PCT formula of Holdren and Ehrlich (1974): Impact = Population × Consumption × Technological Efficiency. Yet he emphatically stated that "*Population stabilization and subsequent reduction is undoubtedly the primary issue facing humanity; all other matters are subordinate*" (Smail, 2003b; italics his). Are consumption and efficiency indeed subordinate?

There is no doubt that the "ecological footprint" is important in terms of both renewable and nonrenewable resources. However, when Chambers et al. (2000, p. 59) exclaim, "Don't count the heads—measure the size of their feet," they overstate their case. Indeed, they acknowledge the I = PCT formula in its "IPAT" version of Ehrlich and Holdren (1971), in which "consumption" is replaced by affluence. One measure of affluence is per capita gross national product (GNP). Whereas there is a strong correlation between species threats and human density, the threat has virtually no correlation with per capita GNP. Figure 1 shows the relationship between currency adjusted per capita GNP (Purchasing Power Parity, www.unesco.org) and the number of species threats for mammals and birds among 101 nations (for which all data were available). The effects of affluence on threatened species are overshadowed by our sheer numbers.

It was somewhat surprising to find virtually no correlation. Kerr and Currie (1995) found a correlation between threatened mammal species and per capita GNP with a different global data set and different methods (N = 82 nations), but this was not borne out by our data (which, unlike their study, excluded small and island nations, perhaps accounting for some of the differences). The reasons behind this counterintuitive lack of correlation, or the *negative* correlation found by Kerr and Currie (1995), no doubt are complex. But it is clear that the effects of our large population are mediated through a variety of means, just as in the past, when the hunting effect was supplanted by the agricultural effect. Kerr and Currie (1995) *did*, like us, find a strong population effect on threatened bird species, and other independent tests have also highlighted the effects of human population numbers (Kirkland and Ostfeld, 1999; Thompson and Jones, 1999). Large numbers of people in nations rich and poor invariably put pressures on other species who rely on the same resources.

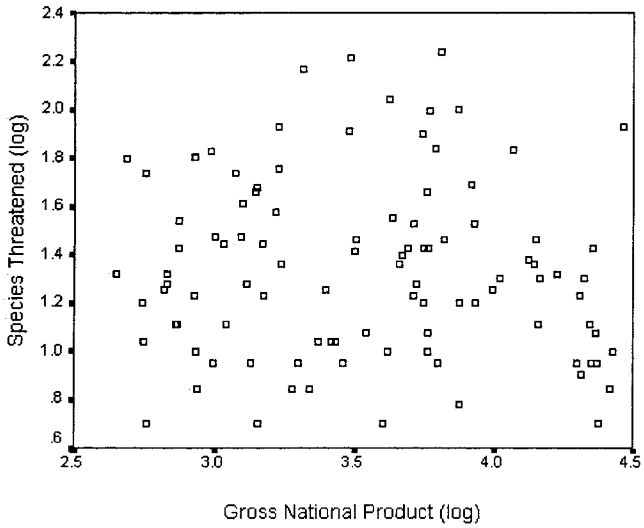

Fig. 1. Log-linear correlation of per capita gross national product (adjusted for purchasing power parity) with density of threatened mammal and bird species per nation. N = 101, r = 0.003, P = 0.974.

Whether it be the poor hunting for bushmeat, or the rich wastefully consuming the sparing amount nature has bestowed upon the earth, numbers matter. I do not wish to imply that we can absolve ourselves of responsibilities for reduced and more efficient patterns of consumption. Indeed, we need the strongest conservation ethic possible in order to manage Earth's biodiversity, for the subordinate effects are logically (if not mathematically) of great importance. In other words, *because* we have already overpopulated the earth beyond sustainability, sustainable and novel conservation must become key priorities and primary objectives. For example, reconciliation ecology (Rosenzweig, 2003), in which we "modify and diversify anthropogenic habitats so that they harbor a wide variety of species" (Rosenzweig, 2001, p. 5404), recognizes that we are already past a position in which biodiversity can survive in nature preserves alone. But at best it is a way to buy time and abate the tide of extinctions. Thus, I still believe the data suggest that without reducing human population density worldwide, even our best efforts at conservation will be for naught.

REAWAKENING MALTHUS

Humans, like other species, have always exerted pressures on the ecosystems in which we have lived. In his thoughtful series of *News and Views* pieces, Ken Smail has alerted us to at least one aspect of how our data, largely grounded in the past, are relevant to our future. Malthusian principles, although much maligned for two centuries due to the successes of the human enterprise, have sneaked up behind us as the biodiversity on which we rely has continued to quietly dwindle to dangerous levels of vulnerability. Smail (2003b) has outlined a series of actions that can and must be taken with regards to the juggernaut of human population growth. It is up to us who hold the data to alert those who hold the power of implementation.

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