Global Population Growth and the Demise of Nature

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ABSTRACT: Global human population expansion is rooted in a remarkably successful evolutionary innovation. The neolithic transformation of the natural world gave rise to a symbiosis between humans and their domesticated plant and animal partners that will expand from a current 20 per cent to 60 percent of terrestrial biomass by the middle of the coming century. Such an increase must necessarily be accompanied by a concomitant decrease in wildlife biomass.

We suggest that current trends in population growth are unlikely to abate for three reasons: first, there are intrinsic biological pressures to reproduce regardless of social engineering; second, the character of the domestic alliance makes it a formidable competitor to wildlife; and third, the timeframe before population doubling is, from a biological perspective, virtually instantaneous. This paper draws from a wide body of research in the biological and social sciences. We neither condone nor endorse this picture of inexorable population increase. Rather, we appeal for a change in the nature of the discussion of population among environmentalists, to focus on the question of how best to manage what wildlife will be left on the margins of a domesticated world.

KEYWORDS: Domestication, evolution, nature, population, wildlife

INTRODUCTION

As the millennium ends, observers of the human condition – scientists and non-scientists alike – have argued that the direst Malthusian predictions of overpopulation and social catastrophe persist in validity, with new form and urgency. In this view, unchecked population growth is exceeding the carrying capacity of the earth – its ability to sustain human and other life – and will ultimately mean an intensified struggle to control food and resources, with the spectre of widespread malnutrition and hunger. Concomitantly, abundant evidence is at hand of profound environmental degradation and the prospect of ecological catastrophe. Without drastic countermeasures, it is argued, a population growing out of

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control threatens our ability to live in some degree of harmony within a recognisable natural world, and severely diminishes the essential quality of human life.

Our purpose here is not to add another voice to the call to save the planet, nature and wilderness before it is too late, but rather to attempt to refocus the discussion, and the menu of options that follows. We take up the plea that concludes Westing (1990), that 'we must develop a true sense of our place in Nature'. We argue that the trajectory of human population growth, our collective inability to limit reproduction, and the disappearance of 'wild' nature, are not simply the unhappy results of human failure – not merely a consequence of human error and shortsightedness that can be resolved by determined policy-makers. Rather, they are the predictable outcomes of a successful evolutionary strategy that has shaped human life and behaviour since the onset of the Neolithic era. Dealing realistically with the social, political and ethical implications of the present situation requires that we have a clear and unsentimentalised understanding of the biological pressures and mechanisms that have led us to it.

THREE PERSPECTIVES ON WORLD POPULATION AND GROWTH

Natural scientists, social scientists and public policy makers alike, in confronting the challenge of population growth, initially divided into two camps that later begat a third. The first – the 'cassandras' as they are called in Westing (1990) – maintain that the earth has an intrinsically limited carrying capacity, and interpret the population explosion and environmental degradation as an intractable catastrophe that will come to pass unless draconian limitations are imposed on reproduction. Failure to adopt stringent birth control methods, say the cassandras (also represented by Hardin, 1968; Daily & Ehrlich, 1992; and others, predominantly natural scientists), will ineluctably lead to the destruction of the global ecosystem and the loss of the 'natural' world. The last vestiges of pristine wilderness (e.g., rain forests, coral reefs, Arctic tundra) will succumb.

The 'cornucopians' (Meyer & Turner, 1992), by contrast, have portrayed global carrying capacity as (perhaps limitlessly) expandable by technological innovation that leads to the development of new sources of energy, new foods grown without soil, new urban 'villages' – all paralleled by a decline in the general importance of physical goods and resources for a rising standard of living. The cornucopians underscore the continuing acceleration in the rate of new discovery, and hold to ridicule the track record of past doomsayers. Yet they are quick to note that, by definition, the unknown is yet to be discovered – so do not inquire into particular solutions for apparent dilemmas. Rather, they maintain that the process of discovery and invention is driven by the very impending scarcities that are feared, reinforced by a framework of prices, markets, rational self-interest and the systematic management of scientific inquiry itself. A characteristic example-by-metaphor is the observation that 25 grams of silica in

a fibre-optic communication system will now transmit the same number of messages that once required one ton of copper. The misdirection of the scientific/technological community toward guns over butter, they hold, only underscores the latent potential for human advancement. And lastly, corncuopians do not argue that environmental concerns are trivial, but rather that they are solvable. Indeed, according to Meyer and Turner (1992), cornucopians hold that 'population increases stimulate technological and social advances that improve the conditions of life: greater numbers can transform the environment for the better'.

The polar character of the debate between the cassandras and the cornucopians has produced a search for a 'third way' – a search led by a group we call 'navigators'. Seeking to chart a course that mediates between continued growth and preservation of the world ecosystem, the navigators offer a cautious optimism under the flag of 'sustainable development'. They seek to shed the ideological baggage of the old capitalism-vs.-socialism debate within a new global humanism. The world clock may be at the eleventh hour, the navigators argue, but it is not too late to arrest global warming, preserve the rain forests, protect endangered species, and make cities habitable. The discourse of the navigators is conducted in a language of stewardship over exploitation, of soft energy paths over hard, and of international farsightedness over the myopia of short-term 'discounting' solutions. From the 1972 United Nations Conference on the Human Environment to the 1987 World Commission on Environment and Development (leading to the Brundtland Report [*Our Common Future*] in 1987) and on to the Rio Earth Summit in 1992, sustainable development has emerged as the central organising principle for linking the quest for expanded development and growth for the world's poor with the equally strong plea that we not destroy the world in the process. A new North/South Passage is to be mapped that does not, to use the words of the World Bank (1992), create a false dichotomy between development and the environment.

There is much that is beguiling in the agenda for sustainable development, in part because it embraces all things ethical and just, and in part, as Adams (1990, p.3) observes, because 'sustainable development thinking very often proves to have no coherent theoretical core'. The intent here is not to argue against sustainability as a cornerstone principle in refocusing development strategies nor to ignore or minimise the inequality and poverty that confront over half the world's people.

But a significant blindspot in some writing on sustainable development is the failure to address seriously the issue of population growth as an acknowledged variable in the search for balance across development, the environment, and the quality of human life. For some, to raise the issue is to adopt a privileged, even punitive, position – one associated with harsh population control regimes that target third world nations in a discriminatory fashion, sometimes with genocidal overtones. Others correctly note that much human suffering in the world is associated with great inequality, both within nations and across nations. But even if the political framework for large scale redistribution were found, this still

would not absolve us from inquiring into the implications of an precipitously-expanding world population. The Brundtland Report (1987) characterises sustainable development as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs'. However, if twice or threefold as many people lay claim in the next two generations, then meeting such needs becomes an arduous, compounding challenge.

All three of these views, we believe, are misleading, and do not adequately take account of – or perhaps they misunderstand – the biological nature of the current situation. The cassandran strategy of population control ignores the character of human reproductive behaviour. Cornucopian assumptions about the nature of carrying capacity and food production are flawed. And the navigators seek a reconciliation of economic growth and environmental preservation that omits population as a significant consideration. Cornucopians, cassandras and navigators alike believe it is possible – if difficult – to 'restore' the natural world. We will argue that population control, however desirable, is an exceedingly difficult goal; that developing sustainable food production for expanding human populations requires a radically different understanding of 'sustainability' and appropriate agricultural technique; and most centrally, that the dream of returning human beings to their proper, balanced, and limited 'place in nature' – indeed, the very notion of 'nature' as we have come (recently) to cherish it – is beyond our reach, because the very nature of Nature has been altered by evolution.

HUMAN REPRODUCTIVE BEHAVIOUR AND THE FAILURE OF POPULATION CONTROL

The cassandran call for radical population control arises – ironically – from a recognition of the near-intractability of the problem. Westing (1990) acknowledges that Malthusian alarmists, for all the success of their predictions, have had little impact on the rate of population growth. Early observers like Pitkin (1947) were already writing that 'reckless breeding has become strangely like social cancer... the surplus of humans eats away at all of us. Is there still time to diagnose this social evil and to save us patients? Or have we done too little and come too late?' That same year, Burch and Pendell (1947) noted that 'Even if the birth rate was cut 25 per cent, the world would have around 3,000,000,000 people within the scant 55-year period remaining between today and the next millennium'.

In 1968, Paul Ehrlich published *The Population Bomb*, a ringing call for control. By 1990 – with the human population exceeding 5 billion and already far exceeding the prognostication of Burch and Pendell –the bomb had gone off; Paul and Anne Ehrlich published a sequel entitled *The Population Explosion.* The current annual global growth rate is estimated at 1.7 per cent – a yearly

increase of over 90 million, with a doubling time of about 40 years. In third world countries like India, average family size is now close to four children; Daily and Ehrlich (1992) observe that even with a 50 per cent fertility drop, the Indian population alone will increase from 870 million to one billion within the decade eventually replacing China as the world's most populous nation. Even in the 'developed' world, where birth control is perhaps more socially sanctioned and technologically feasible than in other parts of the world, a growth rate of .5 per cent presents a doubling time of less than 140 years. Why haven't the alarms been heeded?

To begin with, there is, quite simply, disagreement among intelligent people as to the nature of the problem (cf. Shrivastava, 1992, for example) – and those differences tend to be associated with differences in political influence. As we noted, the optimistic cornucopian view requires little or no intervention on the population front. Indeed, as Meyer and Turner suggested, the strongest cornucopian assumption is that both growth and scarcity will generate their own technological (or social) solutions. European Marxists – though in a period of perhaps terminal decline as a global political force – hold a position quite close to this view. So do the propounders of many variants of liberal capitalist ideology. So did the fascist ideologies of the first half of the century (which characteristically propagandised in favour of rapid population growth, at least for some favoured national groups). That is to say, contemporary political and social policy makers – of whatever stripe – have generally been cornucopians. The cassandras have tended, overwhelmingly, to be members of the scientific community – lacking direct political clout, and often suspected to be out of touch with real social and human needs.

Secondly, the intellectual character of the population problem is especially difficult to grasp on the individual level at which reproductive activity actually takes place. As Hardin (1993) notes, 'It is a mistake to think that we can control the breeding of mankind [sic] in the long run with an appeal to conscience.' Yet overwhelmingly the population problem has been cast as a matter of conscience, even by natural scientists – that we have a responsibility to preserve the Good for our descendants; that we have a special moral responsibility as stewards of nature. While such transcendent moral arguments may make for good politics and an appearance of sensible social policy, they probably have little effect on human behaviour. As Daily and Ehrlich (1992) observe, there is seemingly 'a natural human tendency to discount costs that appear remote, either in time or space'. This is, of course a general and well-known problem in human life. We do not 'THINK AHEAd' very well (to recall the old bumper sticker); we are driven, we sometimes admit, by 'immediate gratification' even when the ultimate consequences are potentially severe.

Humans often engage in reproductive activity, in particular, with little regard for (or even an understanding of) future consequences – pregnancy and offspring that may be a social or economic burden, or sexually transmitted disease that may

be lethal. Whether this kind of reduction in value of delayed outcomes ('discounting', as the economists term it) is a learned, cultural characteristic or a fundamental consequence of (biologically-based) human cognitive architecture is irrelevant. There is good reason to think that natural selection favours the present over more distant outcomes (cf. Heinen & Low, 1992). In the short term, evolution necessarily rewards successful reproduction. It is difficult to select against fecundity, and impossible to select for sterility, and ultimately negative population growth. Hardin (1993) discusses the thesis that, given a varying human population with conscience-driven 'contraceptors' and conscienceless 'reproducers', the reproducers will – all things being equal – always outreproduce the contraceptors. It is true, of course, that ecological circumstances (e.g., resource scarcity) could over the longer haul create selective pressures for reduced reproduction. But such pressures, we suspect, must operate on a relatively long biological time-scale. There is no reason to think that, when human populations were still at an entirely viable level a mere ten generations ago, there could have been sufficient selective time to generate a species inclination toward 'conscience' for a reduced reproductive rate. Furthermore, the success of 'conscience' would also require a mechanism that enabled the individual or the reproductive unit to assess and evaluate the carrying capacity of its niche – which in the case of contemporary human populations is the entire world.

Homo sapiens is now dispersed worldwide, and is virtually a niche-independent organism. While there are species which appear to have evolved special feedback mechanisms for assessing and responding to carrying-capacity changes by alterations in reproductive strategy, there is no evidence for such mechanisms in human beings. Questions about the quality of life aside, increases in population density appear not to reduce reproduction rates in humans, and under certain conditions, may even increase them. Indeed, some of the highest reproductive rates appear to occur in large cities where population density is highest, and the quality of life – certainly the closeness of everyday life to 'nature' – is at its lowest.

The explanation for the absence of such control mechanisms is, we think, to be found in the fundamental character of our sexual behaviour. Human beings – unlike most mammals, indeed, unlike all the primates except for the bonobo, or 'pygmy chimpanzee' whose social behaviour and biological character are remarkably close to *Homo sapiens* (see, e.g., de Waal, 1982; 1989) – are continuously sexually receptive. There are no seasonal signals that constrain the timing or the behavioural nature of copulation in humans. Indeed, we think there is good reason to believe that the primary motivation of human copulatory behaviour is not simply to procreate; rather, it serves as a means of cementing pair-bonds, sustaining family units, and mitigating aggression and conflict. In short, as de Waal suggests for bonobos, it is a mechanism for maintaining human social cohesiveness.

But that said, the result of copulation ultimately is a high probability of reproduction, with a dozen reproductive opportunities a year. And there is good reason to think that sexual behaviour is governed in part by complex physiological and psychological factors of which neither partner is consciously aware – factors that are reproductively adaptive in the Darwinian sense (see, for example, the discussion of human sperm competition in Baker and Bellis, 1993a,b).

If there are neither species-specific biological pressures nor individual cognitive predispositions to constrain population growth, is it possible that other forces – perhaps socially constructed – can halt the precipitous increase in the number of humans? Despite the more than tripling of world population in this century, a dominant line of analysis contends that the end of growth is in sight. The World Bank predicts, in what it labels the most likely base case, that – after doubling yet one more time by the year 2050 – world population will eventually level off at 12.5 billion people. This forecast requires that countries with high fertility rates experience a substantial fertility decline – often by more than half – over the next forty years, as the World Bank report (1992, p.26) suggests. If fertility declines do occur, but are delayed and rates are slower, the World Bank then estimates the earth's population will more than quadruple, to over 22 billion in the next 150 years. And even this scenario requires some mechanism or feedback loop that causes world population growth to be self-limiting. In nature, it is starvation and intragroup aggression that serves to reduce fecundity and raise mortality levels.

WILL POPULATION GROWTH BECOME SELF-LIMITING?

Three lines of argument have been advanced to suggest the possibility of an eventual halt to world population growth without such dire social consequences.

The first is the improved ability to dissociate sexual activity from reproduction, through better methods of contraception and through the continuing legitimation of abortion, as essential elements of modernity and the 'sexual revolution'. But these socio-technological options are quite obviously embedded in a complex social matrix that varies across and within nations. Particularly salient are matters of religion, patriarchy and class. (See, for example, Hartmann, 1987.) However, the call for birth control and its enhanced availability leaves unanswered the question of preferred family size, and is not necessarily predicated on the goal of bringing the net world reproduction rate down to one.

A second possibility is the intervention of the state to shape the terms on which individual 'choices' are made. Measures may range from the draconian to the gentle, from forced sterilisation and failure to prosecute infanticide to sex education in the schools. Tax penalties and incentives, social welfare programmes, public health practices, housing policies – all can play a role in configuring family size. At what point does individual choice yield to the

coercive authority of the state? China, with one in every five of the world's people, dramatically slowed its population growth in less than one generation, despite very low income levels and a high percentage of rural people (cf. Conly & Camp, 1992; Tien et al., 1992).

However, some argue forcefully that poverty and hunger in the third world should not simply be attributed to high birth rates, nor should they be used to justify making population control a foundation for state intervention or international policy making. Instead, to understand the political economy of impeded development, one must look to such matters as corporate cash crop agricultural systems, unequal terms of international trade, the social dynamics of class and patriarchy, and similar constraining forces. We agree. Population growth is not the single autonomous variable that drives the rest of the world system: the number of people who live in poverty is not simply a function of the number of people. But neither is the earth's total population irrelevant to any thoughtful effort to enhance the human condition in generations to come. Indeed, it is irrevocably linked to such efforts, and certainly to a scientific understanding of the underlying difficulties.

The third possibility is that improved living standards – achieved through economic growth, rising per capita income levels, and increasing degrees of education, especially among women – will lead families to prefer fewer children, as children shift from functioning as household producers and are seen, instead, as expensive long-term investments in human capital. The strongest evidence for this position is cross-sectional data: countries with higher per capita income levels tend to have lower population growth rates (World Bank, 1992, Tables 1, 26, 27). Because this argument is, we believe, the principal source of optimism for those predicting a halt to world population growth, it warrants more careful scrutiny.

One initial effect of economic growth and development is a dramatic decline in infant mortality. A surge in population ensues – and the young, as a proportion of the total, expand. As this cohort reaches reproductive age, population will surge again, even if the birth rate (or average family size) begins to decline.

It is also crucial to understand that the feedback mechanism is not economic growth per se, but sufficient growth to produce rising per capita output – i.e., income per person. Thus an economic growth trap is possible in which population and output rise simultaneously, pressing the limits of carrying capacity (locally and globally) without reaching the per capita income feedback threshold. Examples include Argentina, Bangladesh, Chile, Haiti, Nigeria, Peru, Venezuela and Zaire (cf. World Bank Report, 1992, Tables 1, 16). Other difficulties suggest we should be cautious in predicting that world economic growth will arrest the expansion of population. The nation-state is a useful frame of reference only if the internal distribution of income is relatively equal (so that significant numbers of the reproducing population have roughly the same per capita income). In those countries where economic growth is disproportionately

experienced by urban professional élites – while large numbers of wage earners or agricultural households live in poverty – declines in national fertility may be very slow. Furthermore, it is not sufficiently known whether the per capita income feedback constraint on population growth is a function of relative well-being or absolute income levels. If world incomes rise, but regional patterns are uneven, it becomes even less certain whether the escape from poverty can be defined as an absolute threshold. Lastly, given the high absolute level of population already reached by the world, there may not be sufficient time (in generational terms) for per capita income to reach the threshold levels that trigger slower reproduction before world carrying capacity limits begin to constrain economic growth itself.

Will population growth become self-limiting? The three possibilities of increased contraception, state intervention and rising per capita incomes are themselves time-driven processes that differ substantially across nations. While it is appealing and appropriate to delineate the contributing forces of inequality, patriarchy, ignorance and impulse, the roots of these conditions run deep, and the problems they raise are not particularly tractable through transnational intervention and control. Within the lifetime of most of us, world population assuredly will double again. Is there a point after which – in generational time – a reformation of living standards and social arrangements will bring global population into a steady state equilibrium? And at what point will the issue itself be acknowledged widely as critical?

THE RISE OF THE DOMESTIC ALLIANCE

Our first purpose in this paper has been to understand the biological and ecological mechanisms which make the problem of population increase so resistant to easy social or technological resolution. We now turn to the interrelationship of population expansion with the natural world. We do not see population increase as a consequence of human social shortedsightedness or defective information-gathering and assessment – nor as a failure of adaptation in the course of our species' peculiar evolutionary history. Rather, our view is that the dramatic increase in human population and concomitant decrease in overall biodiversity (the 'shrinking' of the natural world) are predictable – and probably (if regrettably) irreversible – characteristics of the evolutionary trajectory of *Homo sapiens* and the domestic animals and plants that have become critical elements in human survival.

To make sense of this viewpoint, we must rehearse some elementary biology and ecology. The behaviour of an animal species must satisfy three essential requirements: foraging, hazard avoidance, and reproduction. The first two categories of behaviour must be practised on a continuous basis; reproduction is seasonally periodic. Seasonal periodicity is, as a rule, selectively advantageous,

providing a measure of accommodation to inevitable fluctuations in resource availability. Reproduction is energetically expensive (offspring must be grown, and there are more mouths to feed), and in a periodic reproducer, reproduction can be timed to coincide with seasonal flushes in resources. Finally, since individual members of a species are competitive for resources within their common niche, increases in resource production generally tend to coincide with population growth.

As far as we know, human beings practised the typical mammalian feeding pattern – 'search and feed' within a given ecological niche – until the end of the Mesolithic era (up to c. 10,000 years B.P.). Humans had tools that facilitated hunting (as well as, we may speculate, hazard-avoidance activities such as shelter construction) but they were essentially omnivorous hunters, scavengers and searchers for food. But by the beginning of the Neolithic period (about 10,000 yrs. B.P.) human foraging behaviour had begun to change. With the onset of (limited) agriculture and the advent of permanent settlements, the need for energetically-expensive searching, foraging and hazard-avoidance behaviours began to abate.

We cannot overstress the importance of the traits which distinguish Neolithic human agriculturalists from other mammals. (1) Where most mammals forage as individuals or small family groups – with the cost of foraging undertaken separately by all (mature) individuals – neolithic humans developed a division of labour, wherein the biotic production of food did not demand the attention of every individual. (2) Food came to be stored, in living as well as preserved form. (3) Resources were distributed to group members, and shared among members. (4) The eventual emergence of the state and organised religions increased opportunities for collective hazard avoidance, with tithing and taxing for the common good (though, we must note, church and state also arrange for wars, ethnic holocausts, crusades and inquisitions which may play some role in reducing population). We will return to these issues shortly.

It is true that agriculture is generally not as biologically efficient as natural production (Colinvaux, 1986). But that lesser efficiency holds only in terms of 'primary' production (i.e., the level at which food, naturally produced, is directly utilised by an organism). As we see it, primitive agriculture – say, settlements strategically located near some natural crop on a seasonally permanent basis – quickly gave rise to a secondary level of production, and a new ecological arrangement that has governed human behaviour, and shaped the natural world, ever since.

That new arrangement was domestication. In our view, domestication did not arise as a conscious, intentional manipulation of nature by inventive humans. Rather, we think, early neolithic settlements near natural crops produced quantities of waste products that in effect provided plants and animals with the opportunity to 'volunteer' for domestication. Plants which benefited from nitrogen-rich wastes flourished; mammals which could support closer contact with humans were able to reap the benefits of easy foraging and scavenging at

the dump. At the same time, humans were able to cultivate new, opportunistic crops, and had relatively cost-free access to meat animals. A 'domestic alliance' arose (Coppinger & Smith, 1983).

In the course of the ensuing 10,000 years, the alliance's membership – humans, domestic crops and domestic animals – mutually benefited from a continuous reduction in predation and competition that led to a dramatic increase in reproductive survivorship. By modern times, the alliance represents over 20 per cent of terrestrial biomass, according to estimates by Westing (1981). In 30 years, Westing estimates, humans and our domestic partners will constitute 40 per cent of biomass, and by the middle of the next century, 60 per cent. Clearly we are crowding out other species. The domestic alliance is a remarkably effective evolutionary innovation that, on balance, is significantly more successful than the strategies for survival and reproduction that have evolved among other megafauna. While the rest of the animal world continued to search for food on a daily basis, risking predation and environmental hazards, the membership of the domestic alliance was able to utilise food contained within the alliance itself. Humans had to do little more than protect the domesticants from non-human foragers (predators) – an arrangement that increased the overall reproductive success of the domesticants, and provided humans with abundant, storable food sources which resolved the constraint of seasonal scarcity.

But 'wild' nature, as a consequence, became the enemy. The domestic alliance is a system that outcompetes the rest of nature so effectively that at least some aspects of environmental degradation – the disappearance of primordial wilderness, and the dwindling or extinction of large wild carnivore predators and other marginal wild megafauna, as well as animal and plant pests (weeds) – become inevitable. By the same token, the 'population explosion', among humans as well as our domestic partners, can be viewed as the predictable outcome of a generally adaptive evolutionary strategy. Unless we abandon the domestic alliance – a move that would have cataclysmic repercussions for the quality of human life as we know it, given current population size and the limits to significant reproductive control – the demise of the rest of nature is, we fear, inevitable.

CARRYING CAPACITY, SUSTAINABILITY AND THE END OF NATURE

The problem essentially reduces to the question of carrying capacity and sustainability. Carrying capacity (K) is defined as the maximum population that can be indefinitely supported within a niche without depleting its own base; sustainability is a state of resource production that is required to keep a population at or below K for the indefinite future. Daily and Ehrlich (1992) also distinguish between biophysical and social carrying capacities, where social K is constrained by behavioural and ideological as well as biological and physical

variables. As we noted earlier, the cassandran view is essentially that K has already been exceeded – the only possible remedy is to reduce population by any means necessary. The cornucopians envision a technology and a social organisation that will increase K by extending resource production well beyond minimal or current sustainability. The navigators make sustainability a hallmark of their position, but only in the sense of a self-renewing resource base, never as a defining limit to K or to world population.

We believe that each of these views fails to appreciate the real nature of carrying capacity and the biological character of sustainability. To understand this, we turn first to a brief discussion of human agriculture, and then to the broader issue of carrying capacity, paying particular attention to the ways in which human foraging behaviour differs from that of other animals.

First, a major feature of human agricultural production is the use of annual plants which are started each year from seed . The reliance on annuals provides for relatively reliable and predictable resource availability, and frees humans from the energetically-expensive behaviour of searching for food sources. But it is far from problem-free. The need for spacing between plants (to reduce competition) means that production will vary considerably in different ecosystems (Colinvaux, 1986, p.405). This constrains (though does not necessarily limit) the range of new niches into which humans can move – and reduces total primary productivity. Moreover, the exposure and re-exposure of soil results in land degradation because of evaporation, salinisation, lowering of water tables, nutrient dumping and most importantly soil erosion. Effective irrigation often becomes an expensive necessity. And because annuals tend to be short-rooted, they produce leaching of organic materials from top soil, and fertilisation becomes an additional (and expensive) requirement. Annuals are not examples of ecological balance. They are, in important respects, dramatic disturbances.

But Neolithic agricultural innovations also solved some problems. Since many forms of seed store well in dry form, they can be transported and replanted in new regions, at least temporarily addressing problems of drought and meteorological damage. And more importantly, domestic animals (especially herbivores that store fat) provide a 'walking larder' (Clutton-Brock, 1989) in times of scarcity. They are not only a means of storage, but also utilise (and store) wastes undigestible by humans, that can be recycled into human food. It should be noted, however, that agriculturalists sometimes will grow animal feed as annuals – increasing overall disturbance of the land. And stored food (whether in granaries or on the hoof) requires considerable amounts of energy to be spent in the form of protection – from insect pests, climatic damage, competitive wildlife – and other humans.

The advent of efficient agriculture also encouraged a division of labour that ultimately requires distribution and sharing of stored food – a strategy that has become a cornerstone of human foraging behaviour (though it is important to underscore that by 'sharing' we mean a system of distribution, exchange and

trade rather than an individually altruistic behaviour). Dominance and power in the current human social structure also are operative in sharing behaviour. As population grows, smaller social units (such as villages) tend to enlarge and aggregate so they can combine resource bases, storage, distribution, and sharing mechanisms. But this also tends to lengthen the distance between producers and consumers, increasing overall nutrient transfer costs, and placing significant energy demands on non-producers. And, perhaps more significantly, it creates massive population sinks in which the negative social impacts of growth – problems in health, education, housing sanitation, and so on – tend to be aggravated. The necessity of sharing, in other words, carries with it an intrinsic social burden, as well as considerable economic cost.

The centrality of sharing has suggested to many that the potential for food crisis is a matter of distribution rather than production. Certainly the boundaries of what we call nation states have not been constructed to optimise the relationship of food to population. The Food and Agriculture Organisation of the United Nations projects that if agricultural technologies are applied as they are today – and if populations continue to grow at current rates – 64 countries (29 in Africa) will still be unable to meet the nutritional needs of their populations by the turn of the century. As a consequence, if we are to add another 5 to 10 billion people in two or three generations and meet their food requirements, rather heroic assumptions are necessary about growth-financed trade or direct economic aid across international borders. The United States, an affluent nation with the world's largest food surplus, devotes far more political energy to sheltering endangered species than to designing a framework for sharing food internationally. Change in the world arena is not inconceivable, but one wishes for greater signs of its possibility.

Others have sought a way out through the 'greening' of agricultural technologies, not only reversing trends of salinisation, soil erosion, and desertification, but opening the cornucopia in its literal sense of an increasing sustainable flow of food – achieved by changing what we grow and how we grow it (cf. Collins & Lappe, 1977 or Smith & Yamamori, 1992). Edward O. Wilson notes that for reasons of historical happenstance we domesticated the wrong species. Instead of goats, pigs, sheep, and cattle, we would be better served, in protein per hectare, by raising Amazon river turtles, capybara (a large rodent), or green iguanas, and planting the fields to maca, amaranth or the winged bean of New Guinea (Wilson, 1992).

These visions of improved international sharing and the greening of the domestic alliance mutually suggest that the concern should not be with the number of people, per se, but with the reorganisation and rationalisation of the planet to serve the needs of more people. Is there no limit?

Normally, assumptions about carrying capacity are cast in niche-particular terms. That is, the limits of sustainability are presumed to be constrained within a particular species' share of the biosphere. But the niche of human beings – more

properly, the niche of humans and our partners in the domestic alliance – is essentially the entire world eco-system. If we discount the metabolic needs of wild competitors within that global niche (rain forests, tigers, bald eagles, snail darters, etc.) it seems reasonable to us to assume, in principle, that the only effective limit on carrying capacity is sunlight. That is, in a world completely dominated by the domestic alliance, it will – in principle– be possible to achieve some sort of sustainability even at very high population levels.

But sustainability in this sense would not necessarily entail a 'quality of life' that all of us would find comfortable. Nor is it likely to be socially or politically acceptable to everyone. In a recent paper Coppinger, Clemence, & Coppinger (1991) argued the ecological soundness of eating only food that has passed through an animal first. Real sustainability, in the face of the explosive growth of the domestic alliance, is in fact possible only at those high trophic levels. To achieve it, we must eat our partners which eat domestic plants. Critics of this view note that: first, diet at a high trophic level is 'unhealthy', i.e., it tends to decrease human longevity; and second, moving up a trophic level is still not likely to provide enough food to feed all the people all the time at nutritional levels that are optimal for human activity. Sadly, we concur. Maximal population size will either mean even less food per person equally distributed, or even more unequal distribution.

Furthermore, we conclude that the requisite maximisation of global carrying capacity – even given the almost boundless limits of photosynthesis – will still mean the acceleration of the mechanisms by which the Neolithic domestic alliance has succeeded. We will have to continue, by whatever technological means are available, to expand the availability of food. And such an acceleration – with all of its attendant ethical dilemmas – will have to occur at the expense of other biota.

CONCLUSION

The remarkable success of human beings since the onset of the Neolithic era is rooted in a domestic alliance with certain plants and animals. As the alliance moves toward 60 per cent or more of the earth's total biomass in the next two or three generations, its very success shapes our deepest concerns.

A first intent of this essay has been to reintroduce the issue of world population growth to the table. After it is agreed that inequality and the maldistribution of world resources should not be masked; after it is acknowledged that population control can, all too easily, be an agenda of the first world for the 'good' of the third; after a full understanding of cultural differences or the dynamics of patriarchy has been achieved: is it then not appropriate to ask about the relationship of the earth to its carrying capacity for humans? Of course many more can be accommodated – and fortunately so since a doubling and likely

tripling is at least in store. To feed, clothe and house, to repair and maintain the collective and largely unintended consequences of the presence of each five or ten billion cohort is a challenge of mounting difficulty. But to accommodate that population implies – no, requires – the continuing success of the domestic alliance in its competition with the wild.

If there is any argument in favour of the view that population growth could be self-limiting, it is the claim that rising standards of living encourage smaller families. That 'economic development' – used here as a general proxy for better health, more education, greater access to birth control methods, more self-determination and choice among women – may bring population growth to an end, through individually taken decisions and without coercive state intervention. Set aside, for the moment, the enormous social and political constraints arrayed against such a universal lifting of living standards. This equilibrium-through-growth scenario requires an acceleration in world output which only intensifies the process by which the planet's resources must be drawn upon and brought under strict regimes of environmental management – regimes that likely will challenge our customary sense of the 'natural'.

Care must be taken not to misconstrue our efforts to reshape the terms of discourse as indifferent or antithetical to environmental and conservationist movements. Remarkable gains have been achieved within a few decades in mitigating the social costs of consumption, improving the environmental efficiency of production processes, recycling waste, and preserving some species. In many respects the task has barely begun. But 'the task' is a management task. It entails the full panoply of administrative, scientific, informational, and organisational structures that have attended the domestic alliance. The husbandry ethic of this system seeks to unify the (ever-spreading) private sphere of capitalism with a social sphere of organisational accounting – one that produces environmental impact statements, social impact statements, and determines who shall bear the cost of 'managing the commons'. We note in passing the somewhat desperate turn to 'deep ecology' to discover an environmental ethic not linked to the primacy or survival of humans. (See, for example, Devall & Sessions, 1985 or Tobias, 1985; and the critique in Merchant, 1992.) For other species, environmental context is the independent variable that sets the terms for evolutionary success or failure. For humans, nature has become increasingly a dependent variable, ever since the Neolithic domestic alliance with plants and animals was launched. Thus the very nature of Nature has changed. However, in a McLuhanesque world of rear view mirrors, restoration theology seeks to hold to 'wildness' in its remaining niches. If these efforts succeed, they can best be described by the oxymoron of 'managed wilderness'.

Thus a second intent of this essay has been to challenge the very vocabulary of contemporary discourse around nature, wilderness, the environment, and sustainability. We speak, in particular, against a perspective of 'restoration ecology', a perspective that currently shapes and colours the discussion of the

relation of humans to the natural world. Restoration ecology offers the hope that things can be put back the way they were – that humans and their activities, and nature and its activities, can be spoken of as separably identifiable spheres that can live 'in balance' with each other.

We anticipate that in the coming 'climax' phase of the Neolithic era, wilderness will become preserve, preserve will become park, and in time park will become exhibit. Managers and caretakers will preserve 'natural' places as artefactual, with human visitation and viewing controlled to prevent not only cumulative damage, but contamination by mere presence. Wild nature – as once understood to mean a surrounding contextual environment with which 'man' forges a pact of harmony, peace, balance, and respect – will recede into museum-like enclaves. 'Eco-tourism', offered as a new age alternative to the rape of the landscape, will be increasingly unavailable to the growing bulk of humanity. How many people per year can visit the Bridal Falls of Yosemite, in Disneyland fashion, or stop by the Antarctic to look at penguins? As eco-tourism continues its heritage as an élite good, the zoo, the theme park, and the technology of virtual reality may be the only venues available in which the old conception of nature can be 'captured' and experienced by the population at large.

In short, as we enter the climax period of the Neolithic, it is becoming increasingly inadequate to speak of 'our place in nature'. The imperative to manage the global village in order to save it is leading not to the discovery of a new place for humans in wild nature, but to a radically different understanding of the character of Nature in a domesticated world.

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