The Impact of Agricultural Biotechnology on Biodiversity: Myths and Facts

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I will discuss biodiversity and I will discuss agriculture, but I cannot avoid going into social matters, into cultural matters. Let me begin with a brief background to the great debate. All participants in this conference are participants also in the discussion of world-food problems and we should feel privileged to be involved in this historic debate. A technology boost is coming to biology, and, in turn, biology will be the source of the biggest technology advancement that humankind has ever gone through. Hence biology has lost its innocence, and we need to understand the background.

GENETIC SYMPHONY

Many still have no idea where we should be headed. William Reese gave us a brilliant example of rethinking knowledge-based agriculture. The complexity of genomics research is recognized. Although the interrelationships among chromosomes are known to be complex, even with *Arabidopsis*—one of the best-characterized genomes—we are far from understanding what is going on at the gene level. We are all painfully aware of the rapid growth in knowledge; it is accumulating at such a speed that it is likely that no one in this room would claim to be able to stay abreast of developments even in her/his own field.

Each genome is extremely complex. Genes should not be viewed singly, in isolation, but rather as a concept, working together in a fantastic symphony. By understanding how genes interrelate, the possibilities for progress will be immeasurable; we will move beyond the current phase of single-gene-altered crops—paleogenetics, as I call it—with insect-resistance and herbicide tolerance.

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Risk Perspective

We live in a risk-averse society; although human longevity is increasing, paradoxically many people believe they live under increasing risk. We should view this aspect from a historical perspective. The introduction of coffee in London met with stiff resistance. Women's petitions attempted abolishment of coffee shops on the grounds that it caused impotence in their spouses. Pope Clement VIII (1593–1605) took a different tack: "Why this Satan's drink is so delicious…it would be a pity for the [sinners] to have exclusive use of it. We shall fool Satan by baptizing it and making it a truly Christian beverage." Thus, ideology was brought to bear. During the great coffee debate the notion of systemic or substantial equivalence was fielded. There was much discussion in that regard, and we now know that coffee contains at least sixteen carcinogens. It would have no chance of being approved as a new beverage today, which illustrates a modern-day schizophrenia about risk. The Greens demand a ban on the release of genetically engineered organisms, because they maintain there is no proof that they are safe, yet they promote the use of cannabis. Joking aside, there is a serious problem here. It is not unreasonable to be concerned over the genetic engineering of plants. Those without anxiety are the fools in my eyes.

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Precautionary Approach/Principle

Part of the complexity of the debate results from the use of the precautionary approach in legislation. Precautionary "principle" is inappropriate terminology resulting from poor translation within the European Union. Consultation of the original text reveals that it is an "approach."

Linear planning processes are insufficient in this debate. A systems approach is needed. We also need to take a step back to gain perspective in this debate. One of

the foremost principles I would make clear is the symmetry of ignorance. As stated already in this conference, as long as scientists try to explain the world with scientific facts alone, we will encounter more and more difficulties; it's a clash between post-modernism and modernism. I have insufficient time to go into the elements of the systems approach, but we know that this is not functioning today. Look at US corporate entities: they cannot understand why Europeans refuse their soybeans. Scientists working at the bench often feel little social responsibility for what they do and feel no obligation to debate the issues with the public.

Everyone fond of Italian food has eaten spaghetti produced by gamma-irradiation of the whole genome of wheat.

Manipulation of Evolution

Let us go to the heart of the matter: with respect to biodiversity, we should address the argument of the manipulation of evolution rationally and realistically. It does not seem to be generally understood that pollen drift did not begin with the engineering of transgenes. But, because non-containment of transgenes is now an issue, it is likely that the next generation of transgenic plants will not result from complex manipulations for drought resistance, for example—which will take 5 to 10 years—but with non-alien genes. Useful traits will be taken from progenitor landraces and restored to modern cultivars of the same species. If you think that genes are being transferred for the first time across hybridization barriers, you would be wrong; it has been done for years with protoplast technologies. And if you think that we did not manipulate genomes artificially before genetic engineering you would also be dead wrong. Everyone fond of Italian food has eaten spaghetti produced by gamma-irradiation of the whole genome of wheat. This is "Frankenstein"—if you ask me—but it is not genetic engineering. It has been used hundreds of times to produce superior cultivars. The FAO Web-site shows a list of over 500 cultivars produced by gamma irradiation. Yet, although we don't know what we have done to these genomes, we eat the products without reservation. In fact, not even a red nose has resulted.

There is a common misperception that Golden Rice™ is uniquely artificial; in fact, the parent cultivars of Golden Rice™ were already artificial. Figure 1 was provided by Ingo Potrykus; each "@" sign indicates a breeding event in the pedigree, the result of each of which is totally unpredictable. If safety rules for transgenic crops were applicable, a hundred years of probation and safety tests would be needed. Although the normal process of breeding and selection involves many unpredictable steps, fortunately, pragmatism has prevailed.

One-sided views are inappropriate in this great debate.

One-sided views are inappropriate in this great debate. For instance, when Charles Benbrook claimed that more pesticides are used with transgenic crops he mad two mistakes. First he followed the rule that you should believe only the statistics you have falsified yourself; it has been shown that his figures are 20% too high. The bases of all statistics should be examined carefully. Second, he failed to take toxicity as the critical parameter. Toxicity is reduced in conjunction with Roundup Ready® cultivars. Even if it's from Monsanto it is less toxic, I'm sorry.

In the monarch butterfly case it was shown that no differences exist between *Bt* and non-*Bt* maize fields. If I were a non-target insect, I would prefer to visit a *Bt* field because there would less likelihood of being showered with pesticide. But, to be honest, I would most prefer to vacation with an organic farmer.

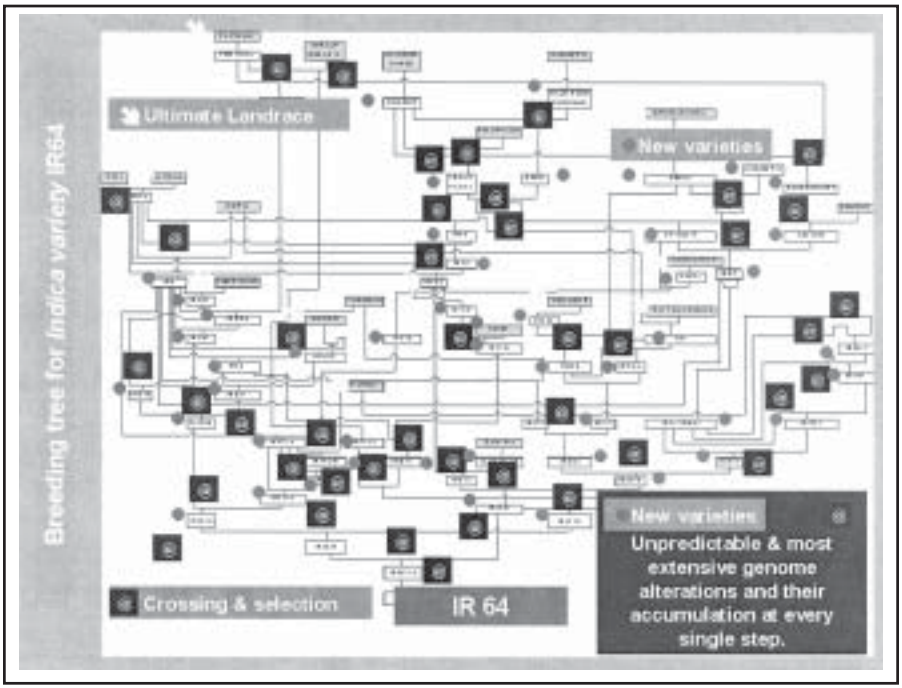

Figure 1. The pedigree of rice cultivar IR 64.

That *Bt* is toxic to certain classic non-target insects is a myth. In a 2004 publication Romeis *et al.* came to the conclusion that the classic studies of Hilbeck *et al.* (1998) were done with the wrong insects (half dead), with the wrong concentrations and with the wrong statistics. We should be careful in interpreting the scientific literature.

Mutually contradictory data have been published in peer-reviewed journals from a number of studies on maize pollen deposition on leaves. This is not to suggest that such experiments on pollen deposition have been done with the wrong methods, but the data have demonstrated regional and seasonal differences; sometimes firm conclusions are impossible from so-called exact scientific results. Care in interpretation is needed. Dr. Reese made that very clear in his discussion of ecosystems.

Gene flow is not new; it's an important component of evolution.

We found no problem with barley, wheat, rye, potato, clover, maize, but we did identify problems with alfalfa and its wild relatives and the grasses of course; and I would like to put lettuce and carrot behind bars!

Gene Flow

Gene flow is not new; it's an important component of evolution. Careful attempts to measure pollen drift have yielded highly variable data from cultivar to cultivar and from year to year. In Switzerland we have developed, together with Dutch groups, a method of deriving data from hybrids in herbaria, which is a curious approach for bench workers. We used a statistical approach—I won't dwell on the morphometrics and numerical taxonomy—to quantify gene flow to wild relatives of nineteen crops in Switzerland: we found no problem with barley, wheat, rye, potato, clover, maize, but we did identify problems with alfalfa and its wild relatives and the grasses of course; and I would like to put lettuce and carrot behind bars! These data, accumulated over many decades, show that seed-producing hybrids are possible. This is agriculturally relevant and more important than producing hybrids by embryo rescue. These findings will soon be reflected in Swiss law.

Apomixis—development of seeds without pollination—offers the most effective means of precluding gene flow. Although some 10% of the wild flora have this capability, its reliable induction in crop plants is proving to be difficult.

Need for Vision

We need knowledge-based agriculture and you at the University of Guelph are making significant contributions in this regard, and I am glad to have been invited

here. I am impressed by your publications record and all the things you are doing here. But we also need vision. As already stated, we need to seriously consider organic farming strategies. A 21-year trial in Switzerland—comparing organic and conventional farming systems—revealed 30% to 40% more earthworm biomass and 50% to 80% higher earthworm density in the former. Clearly, positive effects of organic strategies on soil fertility merit attention. Organic farming should not be the brunt of jokes. (On the other hand, insect-resistant potato would be a wonderful thing to have.)

People in other countries must be free to decide which technologies they wish to adopt and adapt. Progress is not always defined in terms of new technologies. Local traditions are important and we should refrain from corporate and eco-imperialism. Neither should we joke about the precautionary principle: we should develop it as a systems approach, a discursive approach, an open-minded approach. I have debated Buddhists, Zen Buddhists, abbots of Catholic monasteries and Amish farmers, and, in my experience, spirituality goes hand-in-hand with open-mindedness and genuine curiosity. After a 2-hour discussion with Amish farmers, they agreed to plant transgenic crops; Monsanto happily supplied the seed. They tried them out and have adopted them. My best such encounter was with a noble and dignified teacher of the Dalai Lama when he was *en route* to Hollywood for the premier of *Seven Years in Tibet*; we had a wonderful discussion. Three world views need to be taken into account:

- through the eye of the flesh—the level at which scientists generate data;
- through the eye of the intellect—the more intelligent scientists view their work in context and ask themselves, "What am I doing here?";
- through the eye of the spirit—which cannot be intellectualized, but must be felt and practiced.

I believe that a "lacuna" exists in our society, illustrated by the fact that organo-transgenic crops—combining the potential of precision-biotechnology with organic approaches—should be our target. Data generated for length of time of quail chicks to satisfy daily nutritional requirements showed that they foraged for 4.2 hours under no-till herbicide-tolerant soybean whereas they had to forage for 22 hours per day in conventionally tilled soybean fields. Clearly, ecology and herbicide tolerance can be positively correlated.

References

Hilbeck A *et al.* (1998). Effects of transgenic *Bacillus thuringiensis* corn-fed prey on mortality and development time of immature *Chysoperla carnea* (Neuroptera: Chrysopidae). Environmental Entomology 27 480–487.

Romeis J *et al.* (2004) *Bacillus thuringiensis* toxin (Cry1AB) has no direct effect on larvae of the green lacewing *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae). Journal of Insect Physiology 50 175–183.

KLAUS AMMANN has served as director of the Botanical Garden at the University of Berne, Switzerland, since 1996. As an honorary professor at the university, he teaches plant systematics and evolution, and biogeography. He also teaches air-pollution biomonitoring at the Federal Institute of Technology, Zurich.

Dr. Ammann's research interests encompass the chemotaxonomy of macro-lichens, calibrated biomonitoring of air pollution with lichens, molecular systematics of lichens, ethnobotany in Jamaica, and ecological monitoring in Bulgaria. He is involved also in ecological risk assessment of vertical geneflow in Switzerland, and in measuring gene flow of the *Brassicaceae* in Europe as the Swiss coordinator. In collaboration with the United Nations Industrial Development Organization (UNIDO) he is assembling a Compendium on Risk Assessment Research and is a participant in the Global Initiative on Education in Biotechnology.

Ammann contributed to reports on The Impact of Agricultural Biotechnology on Biodiversity and on Systems Approaches to Biosafety.

His committee work includes chairing the European Group of Plant Specialists, serving as a member of the coordination group of the European Science Foundation on risk assessment of transgenic crops, and membership of the Biosafety Committee of the Government of Switzerland.

Reducing the Agricultural Eco-Footprint: Reflections of a Neo-Darwinian Ecologist

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We humans live on a finite planet. Yet, our numbers have been increasing exponentially for thousands of years and continue to do so. At the turn of the century we numbered over 6 billion (United Nations, 1999). During the early 1980s, the human ecological footprint (Wackernagel and Rees, 1996) surpassed Earth's capacity to maintain our current lifestyles and, by the end of the twentieth century, it was estimated that it had exceeded the bio-capacity of the planet by some 20% (Rees, 2002; WWF, 2002; Wackernagel *et al.*, 1999; 2002a, b). In short, we now require more than 1.2 planet Earths to support present conditions. By 2050, the United Nations predicts that the human population will have increased to about 9 billion (United Nations, 2003).

The problems facing the planet—or, more precisely, the human species—are well documented and have been discussed in previous National Agricultural Biotechnology Council (NABC) Reports (*e.g.* Kirschenmann, 2003). As the global human population grows, resources (especially non-renewable) continue to be depleted and the environment becomes increasingly degraded (*e.g.* Meadows *et al.*, 2004). Our unsustainable practices include the clearing of forests (Pimm, 2001), the loss of productive soils (Chesworth, 2004; Jackson, 2004), and the overexploitation of fisheries (FAO, 2002a; Pauly *et al.*, 2002), all of which contribute to the on-going loss of biodiversity that some have characterized as the "sixth extinction" (Leakey and Lewin, 1996; Eldredge, 2001; Ward, 2004). In addition, we are interfering with fundamental evolutionary processes through the exploitation of natural resources (e.g. selective hunting, such as trophy hunting, fishing, and forestry), the introduction of exotic, alien, or non-native species, and, most recently, through the production and release of genetically modified (GM) organisms into the environment (S.J. Holt, pers. comm.). We are also depleting reserves of oil and natural gas (P. Roberts, 2004), increasing greenhouse-gas emissions and contributing to global climate change (IPCC, 2001). Superimposed

on all these realities is the growing social inequity and economic disparity between the North and South, the so-called developed and developing worlds, respectively (*e.g.* Elliott, 2001). Of particular relevance is the fact that millions of people (some say billions), most of whom live in the developing world, are going hungry and suffer from malnutrition (*e.g.* Mittal, 2000; Pimentel, 2004).

In this symposium, we have been asked to consider the prospects for reducing the agricultural eco-footprint. In order to attempt that, I will first try to place agriculture into a broader global ecological context. I will then consider the "problem" of feeding the world's hungry, including possible roles for agricultural biotechnology. Finally, I will examine the prospects for reducing the agricultural eco-footprint, given our evolutionary legacy as Darwinian animals. I will end on a note of optimism: that humans really can change the current situation, if there is the collective will to do so.

Agriculture and the First "Law" of Ecology

If there are "laws" in ecology, one would be that "everything is connected to everything else" (Commoner, 1971). Agriculture is a case in point (Figure 1). Human

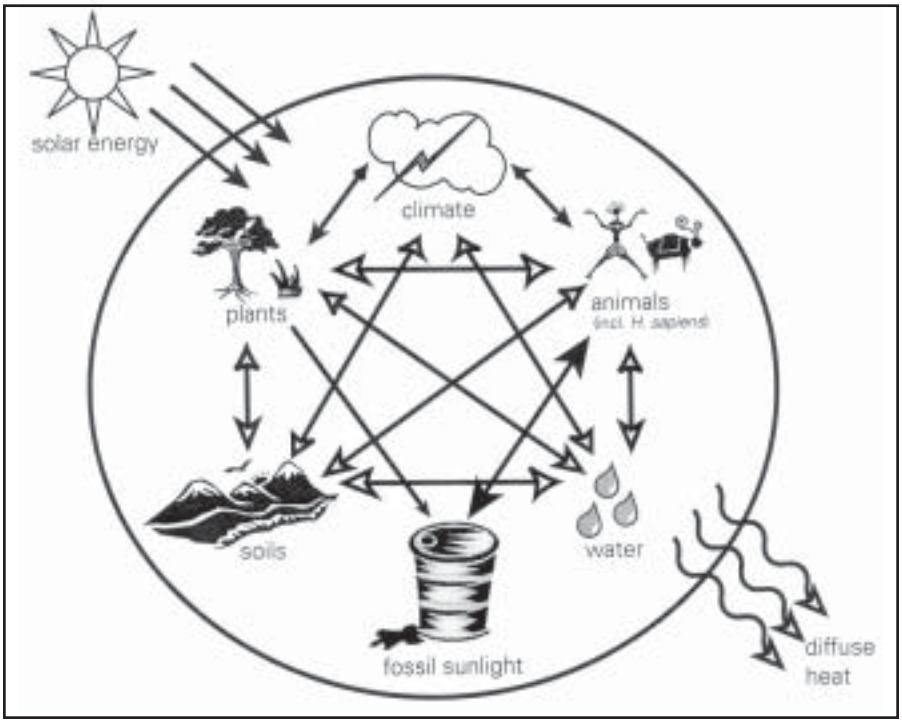

Figure 1. Commoner's first law of ecology: "Everything is connected to everything else" (Commoner, 1971).

animals have practiced it for some 10,000 years; it obviously has effects on both non-human animals and plants that collectively constitute what these days we call biodiversity. Agriculture also affects the quality and quantity of soil and the quality and availability of water (Pearce, 2004) and, in recent decades, it has used increasing amounts of "fossil sunlight," including oil and natural gas, to maintain soil fertility and to increase food production. The latter results in the release of increasing amounts of carbon dioxide to the atmosphere, adding to the accumulation of greenhouse gases, which are thought to be contributing to climate change on a global scale.

We can accept that there are problems and look for potential solutions.

Given the problems associated with the human condition outlined in the introduction and reiterated in relation to agriculture in the preceding paragraph, we have at least two options. We can deny that there are problems, following the examples of the late Julian Simon (*e.g.* 1992) and his modern disciple, Bjorn Lomborg (2001; EAI, 2002). Alternatively, we can accept that there are problems and look for potential solutions. I will deal only with the latter alternative.

One Putative Solution

One suggested "solution," widely embraced and promoted since 1987, is the concept of "sustainable development." Formally introduced in the 1980 World Conservation Strategy produced by the International Union for Conservation of Nature and Natural Resources (IUCN), in conjunction with the United Nations Environment Programme (UNEP) and the World Wildlife Fund (WWF), it was brought to the public consciousness by the 1987 report of The World Commission on Environment and Development (WCED), entitled Our Common Future. (This widely cited and influential document is commonly referred to as the Brundtland Report after its chair, Dr. Gro Harlem Brundtland, the former prime minister of Norway.) The WCED report was followed by a second—almost forgotten—world conservation strategy, Caring for the Earth (IUCN, 1991), which attempted to insert the ideas of sustainable development back into a conservation agenda (Robinson and Redford, 2004). But what Caring for the Earth really did was to subsume "conservation under the development agenda and [confuse] the distinct goals of conservation and development" (Robinson and Redford, 2004; Robinson, 1993).

The WCED (1987) defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (p. 8). This definition has been criticized not only because it is circular (development defined in terms of development), but also because

it does not specify precisely what it is that needs to be sustained (*e.g.* Lavigne, 2002). Some commentators, like Robinson (2002), regard the lack of a precise definition as a virtue, termed "constructive ambiguity." Being vague and ambiguous allows so-called "stakeholders" with very different values and objectives to sit at the same table and come to some "agreement" about "sustainable development." The fact that each participant interprets the words quite differently and has quite different—and, often, diametrically opposed—views on what needs to be done really doesn't seem to matter.

Among many others, I take quite a different view, agreeing with those, like Chesworth *et al.* (2001), who characterize sustainable development as the oxymoron of the latter twentieth and early twenty-first centuries (Lavigne, 2002). Unlike Robinson (2002), I do not see the ambiguity implicit in the term sustainable development to be constructive in any redeeming way. Rather, I argue that the vagueness of the term actually facilitates something called "deceptive ambiguity" (Lavigne, 2002). To my mind, sustainable development is actually part of a "conspiracy"—in the words of my colleague Sidney Holt—"devised to maintain capitalism as the only and permanent economic system," and to allow the developed world to maintain and increase the size of its ecological footprint at the continuing expense of the developing world (Lavigne, 2002). Viewed in this light, sustainable development really is "a new world deception," something that Willers (1994) recognized and described rather early in the game (for a detailed critique of the concept, see Beder, 1996).

If such a view seems overly harsh, consider what has happened in the world, post-Brundtland. We have managed largely to sustain economic growth in the developing world. Meanwhile, according to the World Bank, the gap between rich and poor nations has widened to the point that 20% of the world's population now controls 80% of the wealth (Elliott, 2001). Furthermore, somewhere between 800 million (Mittal, 2000; http://www.monsantoafrica.com) and 3 billion (Pimentel, 2004) people remain hungry and malnourished. After the 2002 United Nations conference on environment and development in Johannesburg, one observer went as far as to suggest that "sustainable development is dead" (Bruno 2002). Nonetheless, many world leaders, among others, continue to promote it as the solution to the world's ills (Lavigne, 2002).

With this as background, let's move on to the topic at hand: agriculture's contribution to the current state of the human condition, and how we might reduce the size of the agricultural eco-footprint.

The Nature of Agriculture

Non-agricultural scientists often view agriculture quite differently from many who work in the field. Niles Eldredge (2001)—an evolutionary biologist, best known perhaps for his work with Stephen J. Gould on punctuated equilibria (Eldredge and Gould, 1972)—suggested, for example, that "agriculture represents the single most profound ecological change in the entire 3.5 billion-year history of life."

While Eldredge's claim may be open to debate (but, see Ward, 2004), Wes Jackson's (2004) more modest claim that "our farming has never been sustainable" is difficult to refute. Jackson, a geneticist by training, argues that our agriculture, based as it is on annual crops, is an historical accident that replaces natural ecosystems with monocultures, contributes to the on-going loss of biodiversity, reduces soil fertility, leads to soil erosion, and promotes environmental contamination through the application of human-made pesticides, fungicides, and herbicides. According to Jackson, some 38% of the world's agricultural soils are now degraded. The logical extension of his argument appears in a commentary by Ward Chesworth (2002), a geochemist: "The fact that we have not yet invented a truly sustainable agricultural system means that we have not yet achieved a truly sustainable civilization."

The solutions to the problems described above are not trivial, but they do seem quite obvious. We must limit our numbers or nature will impose its limits on our quality of life, our numbers, or our very existence as a species. We must also reduce our consumption of the biosphere (especially those of us in the developed world) and thereby reduce the size of the human ecological footprint, including, of course, the agricultural eco-footprint.

A dilemma (noted previously) is that the human population continues to grow, especially in the developing world. So, can we even contemplate feeding the world's hungry without increasing further the size of the agricultural eco-footprint?

The "food shortage" problem is actually one of distribution and affordability

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Feeding the World's Hungry

Not being a specialist in agriculture, I did some research on the Internet to see what ideas had been put forward for solving the problem of feeding the world's hungry. According to the non-governmental organization, the FoodFirst Institute for Food and Development Policy, food production is actually not the problem *per se*; we already produce enough food to feed the world's 6 billion inhabitants (Mittal, 2000). In fact, 78% of countries reporting child malnutrition actually export food. The "food shortage" problem is actually one of distribution and affordability[1].

Mittal's claims were substantiated in a report from the Food and Agriculture Organization of the United Nations (FAO, 2002b): there is not only enough food for the present, but for the future as well. And, of particular relevance to an NABC

[1]On a visit to Ireland following NABC 16, I learned that such occurrences are nothing new. During the Irish potato famine of the mid-1800s—when millions starved to death or were forced to emigrate—Ireland exported food (O'Grada, 1993; Woodham-Smith, 1991).

symposium, there is enough food without GM crops. (Indeed, GM crops, livestock, and fish were omitted from the FAO analysis due to ambiguities over long-term promise, safety and consumer acceptance.) According to the FAO, poverty and poor food distribution will continue to limit access to food in some countries for the foreseeable future (also see Union of Concerned Scientists, 2000).

Contrary views are also to be found. According to Hassan Adamu—at the time, the Nigerian Minister of Agricultural and Rural Development—agricultural biotechnology holds great promise for areas of the world like Africa where poverty and poor growing conditions make farming difficult: "GM food could almost literally weed out poverty" in Africa and "without the help of biotechnology, many people will not live" (Adamu, 2000).

And, according to Monsanto (http:// www.monsantoafrica.com), agricultural biotechnology can increase crop yields, provide more nutritious foods, and reduce costs to farmers, in an environmentally sustainable manner. The corporation goes on to say that the biotechnology revolution must not bypass Africa (as did the Green Revolution of the 1960s and 1970s; Manning, 2004a). In light of my earlier comments, it was interesting to note that "Monsanto welcomes the opportunity to be a partner for progress, working toward the *sustainable development* of farmers in Africa and across the world" (emphasis added).

Biotechnology holds great promise for agriculture in developing countries. Poor farmers can benefit only from the products of biotechnology if they have access to them on profitable terms.

A more recent report from FAO (2004) seems to reveal a change in perspective from that offered in 2000. By 2004, FAO was of the view that biotechnology holds great promise for agriculture in developing countries. But its newly found enthusiasm for GM crops was tempered with several caveats. Poor farmers, FAO noted, can benefit only from the products of biotechnology if they "have access to them on profitable terms." (Again, we have an example of the distribution and affordability problems mentioned earlier.) These conditions, the report continues, are being met only in a handful of developing countries. The report also notes that the basic cash crops of the poor—cassava, potato, rice and wheat—actually receive little attention from practitioners of agricultural biotechnology in the developed world. This is, of course, entirely consistent with the assessment of sustainable development above.

The differing opinions outlined above notwithstanding, the fact is that we continue to look to increasing agricultural production as the means for reducing both hunger and poverty around the globe (*e.g.* ADM, 2004; Watson and Mcintyre,

2004), and for accommodating the expected increase in the size of the human population over the coming decades. As in the past (Donald, 2004; P. Roberts, 2004), increases in agricultural production can be achieved in two ways: we can increase the area of land planted (*e.g.* Meadows *et al.*, 2004) or we can—in theory at least—increase the yield achieved per unit area (*e.g.* Donald, 2004; Meadows *et al.*, 2004).

If we take the first approach, we must clear more forests, especially in the developing world, thereby exacerbating the depletion of wildlife (as in the on-going bushmeat crisis in Africa and Latin America; Robinson and Bennett, 2000). By 2050, Tilman *et al.* (2001) estimate that 10^9 ha of land may be cleared for cultivation in the developing world, particularly Latin America and sub-Saharan Africa. This is an area approximately equal to that of all of the remaining tropical forests (Mayaux *et al.* 1998). In addition to the concomitant loss of biodiversity—tropical forests are characterized by high species diversity (Donald, 2004)—forest clearance by burning already accounts for about 25% of the total CO_2 emissions, making it a major contributor to global climate change (Newmark, 1998).

The second approach, continuing to intensify production—to the extent that further increases are even possible (Meadows *et al.*, 2004)—will require ever-increasing inputs of energy. Remember the second law of thermodynamics (Rees 2004) and Barry Commoner's (1971) reminder, reiterated by Garrett Hardin (1977): "there is no such thing as a free lunch." For every calorie of food produced by intensive agriculture, we already invest ten or more calories of energy (Jones, 2003), much of it in the form of fossil fuels (Manning, 2004a, b). And we are rapidly running out of fossil fuels (P. Roberts, 2004).

Further, if GM plants and animals continue to be part of the equation, then any increases in the productivity of intensive agricultural systems will be accompanied by the introduction of truly alien species into the environment. Noting that "naturally occurring" introduced, non-native species already represent one of the major threats to endemic species (*e.g.* Groombridge, 1992; Simberloff, 2000), one can only begin to speculate on the potential impacts of GM organisms on natural biodiversity in the years to come.

Regardless of any anticipated benefits from biotechnology, such as the reduced use of fertilizers and environmentally contaminating chemicals, increasing production in an agriculture based on annual crops (whether assisted by biotechnology or not) seems destined to increase, rather than decrease, the size of the agricultural eco-footprint (Jackson, 2004). That may even be the not-so-hidden objective, if we may take literally the promotional materials of one prominent agricultural biotechnology company (ADM, 2004). In the center of one page, there is a globe, oriented—tellingly—to feature the United States. Superimposed over the planet in white lettering are the words, "What if we looked at the world as one giant farm field?" Now that really is increasing the size of the agricultural eco-footprint. At the bottom of the advertisement are the alarming (to an ecologist, at least) words: "The Nature of What's to Come."

Reducing the Size of the Agricultural Eco-Footprint

The promotional material referred to in the preceding paragraph also tells us, "Nature has answers" and asks the question, "Is anyone listening?" It is Wes Jackson's (2004) view, in fact, that nature does have some answers. But the answers he is referring to are quite different from those implied in the ADM materials. I suspect, however, that he too would ask whether anyone is really listening.

Wes Jackson argues that we can make agriculture sustainable only by applying ecological principles. We must reverse the accident of history and develop an agriculture based on perennials and dependent solely on contemporary sunlight (as opposed to fossil fuels). It might even use agricultural biotechnology to hasten its realization. Such an agriculture would reduce soil degradation and loss through erosion, and would be ecologically sustainable.

Jackson (2004) argues that we can make agriculture sustainable only by applying ecological principles. We must, he says, reverse the accident of history and develop an agriculture based on perennials and dependent solely on contemporary sunlight (as opposed to fossil fuels). It might even use agricultural biotechnology to hasten its realization. Such an agriculture would reduce soil degradation and loss through erosion, and would, in his view, be ecologically sustainable.

In theory, Jackson's proposal sounds convincing. In practice, it may be difficult to achieve. He estimates, for example, that it would take about 50 years to complete the transition from an agriculture based on annuals to one based on perennials. And, if we were successful, such a transition might buy *Homo sapiens* another 10,000 years ("maybe"), and result in a carrying capacity of about 2 billion people (one-third of the 2004 world population and two-ninths of the population anticipated within fifty years (Jackson, 2004; Lavigne, 2004a).

In my opinion, Jackson's vision will be difficult to sell. It will be opposed by traditional agriculture, including seed suppliers, and fertilizer and pesticide producers; organic farmers; the producers of annual GM crops; and their existing (and well established) lobbies. It will also be resisted by politicians with their short time horizons (4 to 5 years in western democracies) (Lavigne, 2004a).

A Way Forward

There is, however, a way forward. First and foremost, we need to identify the real problems. In the case of feeding the world's hungry, we must decide whether the real problem is a food shortage or a distribution/affordability issue. Once the real problem has been identified, we must then work toward developing solutions that actually deal with it. For example, we currently have a global over-fishing problem. One question today is whether we need to cull marine mammals (including whales) because they are draining the oceans of fish (Tamura and Ohsumi, 1999; Lavigne, 2003) or do we work to make fishing an ecologically sustainable activity?

We also have problems with overexploited wildlife populations and an increasing number of endangered species. Do we provide increased protection for endangered species with a view to halting their decline and promoting their recovery, or do we promote their commercial consumptive use and free trade in order to "save" them (Child and Child, 1990; Baskin, 1994; SASUSG, 1996; Lavigne, 2004b; Lavigne *et al.*, 1999)?

In the case of the human food crisis, do we work to solve the distribution problems, or do we recommend the development of GM foods, recognizing—among other things—that the delivery of GM technology is plagued by the same distribution and affordability issues as the delivery of food. Similarly, where we have problems of economic disparity and social inequity, do we consider implementing real debt-reduction schemes, or do we simply maintain the *status quo*?

We must recognize that humans are part of nature, not outside of it. Generally, we must increasingly incorporate ethics into science and technology.

If society wants to find solutions to real problems, the answers to the above questions should be self-evident. But more can be done if we really want to change the unsustainable practices of the last 10,000 years. One suggestion that has been made frequently over the past 50 years is the need for a new conservation ethic. This idea was central to Aldo Leopold's (1949) Land Ethic, in which he argued that we must adopt a more ecological and eco-centric approach to our dealings with the rest of nature. In other words, we must recognize that humans are part of nature, not outside of it. Generally, we must increasingly incorporate ethics into science and technology (*e.g.* Lynn, 2004). We must also recognize and accept that nature has intrinsic and other values and, to paraphrase Eugene Odum (1971), that money is not the common currency of ecosystems (Lavigne, 2004b). In addition, we must reduce (rather than promote) human population growth; get treatment for our addiction to consumerism (*e.g.* Gore, 1992); and adopt truly precautionary approaches to conservation (Lavigne, 2004b).

We should also abandon the idea of sustainable development, including the simple-minded, three-legged stool model that depicts sustainability as being perched on legs of environment, economy and social equity (for a discussion, see Dawe and Ryan, 2003). In such a model, economic considerations always take priority over environmental (and, indeed, social) concerns. Yet, the reality is that we cannot have a healthy economy or ever hope to enhance social equity unless we have—first and foremost—a sustainable environment (Dawe and Ryan, 2003).

Conservation in the twenty-first century must also recognize that different regions of the world have different values, objectives and needs (Menon and Lavigne, 2004). Conservation, therefore, must become "a more elastic concept, stretching to meet the distinct social contexts, cultural matrices, and political environments in which it must function" (Miller, 2001). The latter, of course, is the antithesis of globalization, the path down which the world community currently gallops.

And, in keeping with the theme of NABC 16, Finding Common International Goals, we must, as Gifford Pinchot—arguably the father of the modern conservation movement—said over 50 years ago, "see to it that the rights of people to govern themselves shall not be controlled by great monopolies through their power over natural resources" (Pinchot, 1945, cited in Miller, 2001).

Reasons for Pessimism

While there does seem to be a way forward, the fact remains that there are a number of reasons for doubting that much progress will be made in finding solutions to our global problems and, in particular, in reducing the size of the agricultural eco-footprint. These reasons relate to our evolutionary legacy: the nature of individual human animals, and—not unrelated—our group behavior in social situations.

Our Evolutionary Legacy as Darwinian Animals

The first reason for doubt lies in our evolutionary legacy. We are good Darwinian animals concerned primarily with selfish, self-interest. Altruistic behavior required to solve many of our global problems does not come easily to Darwinian animals (Lavigne 2002).

In addition, all life forms seem to practice deception in one form or another. In the case of human beings, however, we appear to have elevated the art to include self-deception. Indeed, we seem to have evolved what some academics call "Machiavellian intelligence" (Whiten and Byrne, 1997). One of the unfortunate consequences of Machiavellian intelligence, especially in the present context, is that we have "considerable capacity for self-delusion when the truth is unpalatable" (Gaskin, 1982).

Let me give one example where self-delusion plays a role in the current situation. As a species, we have difficulty coming to grips with our individual mortality. Rather than confront our limited life spans, most human societies have developed as myths to get around the issue. These myths take a variety of forms, but almost

invariably involve a "life-after-death." How can a species in which individuals deny their own mortality even begin to contemplate the death (*i.e.*, extinction) of our entire species (Orr, 2002)? Personally, I don't think we can. But even if we could, it is unlikely that we will. The possibility of our extinction—well, actually, its inevitability—is simply too far down the road, *i.e.* beyond our own lifetimes and those of our children and grandchildren, to disturb us very deeply or keep our attention for very long.

The Behavior of Humans in Groups

According to Whiten and Byrne (1997), "The evolution of [human] intellect [including Machiavellian intelligence] was primarily driven by selection for manipulative, social expertise within groups, where the most challenging problem faced by individuals was dealing with their companions." It is not surprising, therefore, that further evidence of deception and self-deception becomes evident when one examines even superficially the behavior of humans in groups. I discuss two examples below: the behavior of governments and corporations, the two most powerful institutions in the modern world.

Let's begin with governments and examine the practice of politics. Politics is "bloodless conflict among individuals, groups, and nations…among alternative values, or…competing visions of what is 'good' " (Donovan *et al.*, 1981). Politics is also "the father of lies. In political arenas…the participants will distort the advantages of their positions and the disadvantages of their opponents." Fair enough, but "they will [also] shade the truth—first for their audiences; then in many cases, for themselves" (Donovan *et al.*, 1981). As noted previously (Lavigne 2002), shading the truth for their audiences is deception; Byrne and Whiten (1997) would call it "tactical deception." Shading the truth "for themselves" requires self-deception.

Of course, this sort of behavior is to be expected. Machiavelli (1469–1527) long ago described the need for such deceptive behavior among political leaders in his classic work The Prince (see Bull, 1961). But what perhaps is less well understood are the consequences that often emerge from such group behavior.

The late historian, Barbara Tuchman (1984), for example, described a "phenomenon… noticeable throughout history: the pursuit by governments of policies contrary to…the self-interest of the constituency or state involved." She termed this phenomenon "wooden-headedness," which, she wrote, "plays a large role in government…acting according to wish while not allowing oneself to be deflected by facts." I expect that the pursuit of continued economic growth, sustainable development, and an unsustainable agriculture in a finite world, will one day be recognized as examples of twenty-first century wooden-headedness.

Now let's turn to modern corporations. Like governments, corporations are made up of human beings and so provide another opportunity to examine human group behavior (Achbar *et al.*, 2003; Bakan, 2004). Corporations, like individuals, are characterized primarily by selfish self-interest. They are concerned, first

and foremost with their shareholders and with profit-maximization. The bottom line is more important than the public interest. Generally, they exhibit no moral conscience (as a number of high profile recent events attest). Indeed, if corporations were people, their behavior would be seen to exhibit all the traits of a prototypical "psychopath" (Achbar *et al.*, 2003; Anon., 2004; Bakan, 2004). The analogy is not as stretched as it might seem at first glance. Through an accident of history, corporations—in the United States at least—have the same rights and legal standing as individual citizens (Bakan, 2004). In a remarkably constructive review of the Achbar *et al.* film, The Economist's parting shot was that the "infinitely more powerful…modern state has the capacity to behave…as a more dangerous psychopath than any corporation can ever hope to become" (Anon., 2004).

Maybe so, but either way, when you put a number of selfish, self-interested individual Darwinian human beings into a group (*e.g.*, have them form a government, or work together in a bureaucracy or a corporation) something that appears quite un-Darwinian typically emerges: decisions that ultimately act against (rather than promote) the collective self-interest of the group.

When Will Things Change?

It seems unlikely that we humans will overcome our self-delusional tendencies and come to grips with the reality that our ecological footprint (including our agricultural eco-footprint) exceeds the capacity of the planet to support us.

The world's dominant institutions—governments and multi- and trans-national corporations—continue their blind pursuit of increasing economic growth and increased profits. Today, it is difficult to imagine how individuals and nongovernmental organizations who recognize the folly in such policies can really do anything to change the course of history. But, as several authors have noted recently, they probably can, if only they have the will to do so. While governments and corporations may represent the two most powerful institutions in the world today, there is a third potential power broker: people.

Indeed, modern society can be viewed as having three realms: the economic, the political and the cultural (Perlas, 2000). On the world stage, the economic realm is the purview of international corporations and three major international organizations concerned with development: the International Monetary Fund, the World Bank—both established by the West following World War II—and the World Trade Organization, which emerged out of the General Agreement on Tariffs and Trade (GATT) in the mid-1990s (Parrish 1999). Governments, of course, dominate in the political realm. That leaves the cultural realm and it is occupied—in Perlas's scheme—by civil society, which comprises individual human beings [for independent but apparently complementary views on this topic, also see Dowie's (1995) discussion of the "fourth wave" of the environmental movement—grassroots activists—and Chomsky's (2003) comments about public opinion, which he terms the "second superpower"].

While it is obvious that corporations and governments currently have the power and are in control of the world situation, individual human beings also have power, should they choose (or be allowed) to exercise it. In democratic societies, at least, they have power in the political realm because they cast the votes that elect the politicians. Governments (not to mention political parties and individual politicians) really have only one overriding goal and that is to be elected (or re-elected). Consequently, they are reactive—as opposed to being proactive—which explains why they spend so much of the people's money monitoring public opinion. Al Gore put it as succinctly as anyone, before he became the Vice President of the United States. "When enough people insist upon change to embolden the politicians to break away from the short-term perspective," Gore predicted that "the political system will fall over itself to respond to this just demand that we save the environment for future generations" (cited in Lavigne, 1992).

Corporations are just as vulnerable as governments to public pressure, but in the economic realm consumer behavior in the marketplace counts rather than votes. If no one buys their products, they lose their market-share, their profits drop and their shareholders get anxious. Eventually, they respond in predictable and understandable ways and bow to public pressure.

A recent and relevant example of how this works may be seen in Monsanto's decision to delay further development of Roundup Ready® wheat (Monsanto, 2004). News stories, columns and op-ed pieces (*e.g.* McCallum, 2004; O. Roberts, 2004; Scoffield, 2004) tell us that it was a "calculated business decision" influenced by "public opinion." In this particular instance, public opinion was shaped—in large part—by the Canadian Wheat Board, grower and consumer resistance, and by international political pressure from places like Europe and Japan. At the end of the day, the decision was made because of poor market conditions now and in the foreseeable future.

There are increasing numbers of examples where the power of global civil society (or public opinion) has shaped events on local, regional and global scales.

There are increasing numbers of examples where the power of global civil society (or public opinion) has shaped events on local, regional and global scales. Examples include the civil rights and women's movements of the 1960s (Chomsky 2003), and the environmental movement during its heyday of the 1960s to 1980s (Dowie, 1995). A more recent example was the derailment of the Multilateral Agreement on Investment (MAI), perhaps one of the first examples where the power of the people was mounted using the Internet (*e.g.* Shah, 2000, 2003).

Noam Chomsky recently wrote, "One can discern two trajectories in current history: one aiming toward hegemony [*i.e.* power], acting rationally within a lunatic doctrinal framework as it threatens survival; the other dedicated to the belief that 'another world is possible'" (Chomsky, 2003). My parting question is whether society will remain uninvolved, complacent and silent [remember Richard Nixon's (1969)"silent majority"?], and accept the "lunatic doctrinal framework" that currently threatens human survival. Or will it say enough is enough, and demand change, in the belief that "another world" really is still "possible"?

Either way, it will provide another test of Suroweicki's (2004) hypothesis about the "Wisdom of Crowds." He argues that "large groups of people (and here, I'm thinking of Perlas's civil society) are smarter than an elite few (governments and corporations)—no matter how brilliant—better at solving problems, fostering innovation, coming to wise decisions, even predicting the future." My earlier observations about the emergent behavior of humans in groups notwithstanding, we can only hope he is right.

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References

Achbar MJ *et al*. (2003) The Corporation. Big Picture Media Corporation MMIII. http://www.thecorporation.com.

Adamu H (2000) We'll feed our people as we see fit. Washington Post, 11 September, p. A23. http://www.foodfirst.org/media/opeds/2000/9-enough.html.

Anon. (2004) The lunatic you work for. The Economist, 6 May. http://www.economist.com.

Archer Daniels Midland Company (ADM) (2004) The nature of what's to come. http://www.admworld.com.

Bakan J (2004) The Corporation: The Pathological Pursuit of Profit and Power. Toronto: Viking Canada.

Baskin Y (1994) There's a new wildlife policy in Kenya: Use it or lose it. Science 265 733–744.
Beder S (1996) The Nature of Sustainable Development, Second Edition. Newham, Australia: Scribe Publications.
Bruno K (2002) Sustainable development: R.I.P. Corpwatch, 4 September. http://www.corpwatch.org/print_article.php?&id=3831.
Bull G (1961) Niccolò Machiavelli. The Prince. Translation, with an Introduction. Reprinted 1995. London, New York: Penguin Books.
Byrne RW Whiten A (1997) Machiavellian intelligence. In: Machiavellian Intelligence II. Extensions and Evaluations (Whiten A Byrne RW, Eds). Cambridge, U.K.: Cambridge University Press, 1–23.
Chesworth W (2002) Sustainability and the end of history. Geotimes, October. http://www.agiweb.org/geotimes/oct02/comment.html.
Chesworth W (2004) The evolution of soil. In: From the Ground Up. The Importance of Soil in Sustaining Civilization. Symposium, AAAS Annual Meeting. Seattle, WA, 12–16 February. (abstract)
Chesworth W *et al*. (2001) Malthus and sustainability: A codicil. In: Malthus and the Third Millenium. The Kenneth Hammond Lectures on Environment, Energy and Resources. 2000 Series (Chesworth W *et al*.). Faculty of Environmental Sciences, University of Guelph, Guelph, Canada, 163–167.
Child G Child B (1990) An historical perspective of sustainable wildlife utilization. Paper prepared for Workshop 7, 18th IUCN General Assembly, Perth, Australia.
Chomsky N (2003) Hegemony or Survival: America's Quest for Global Dominance. New York: Metropolitan Books, Henry Holt and Company.
Commoner B (1971) The closing circle: nature, man, and technology. In: Thinking About The Environment (Cahn MA O'Brien R Eds). Armonk, NY: M.E. Sharpe, Inc. 161–166.
Dawe NK Ryan KL (2003) The faulty three-legged-stool model of sustainable development. Conservation Biology 17 1458–1460.
Donald PF (2004) Biodiversity impacts of some agricultural commodity production systems. Conservation Biology 18 17–37.
Donovan JC *et al*. (1981) People, Power & Politics. An Introduction to Political Science. Reading: Addison-Wesley Publishing Company.
Dowie M. (1995) Losing Ground. American Environmentalism at the Close of the Twentieth Century. Cambridge, MA: The MIT Press.
Eldredge N (2001) The Sixth Extinction. American Institute of Biological Sciences. http://www.actionbioscience.org/new frontiers/eldredge2.html.
Eldredge N Gould SJ (1972) Punctuated equilibria: An alternative to phyletic gradualism. In: Models In Paleobiology (Schopf TJM Ed). San Francisco: Freeman, Cooper & Co., 82–115.
Elliot J (2001) The West knows now there is no wall to hide behind. The Guardian. 13 November 2001. http://www.guardian.co.uk/business/story / 0,,592418,00. html.

Environmental Assessment Institute (EAI) (2002) Assessing the ecological footprint. A look at the WWF's Living Planet Report 2002. Institut for Maljøvurdering, Kobenhavn, Dk. http://www.imv.dk.

Food and Agriculture Organization of the United Nations (FAO) (2002a) The State of World Fisheries and Agriculture. Rome: FAO. http://www.fao.org /sof/sofia/index_en.htm .

Food and Agriculture Organization of the United Nations (FAO) (2002b) The State of Food and Agriculture 2000. Rome: FAO. http://www.fao.org/docrep/x4400e/x4400e00.htm.

Food and Agriculture Organization of the United Nations (FAO) (2004) The State of Food and Agriculture 2003–2004. Agricultural Biotechnology. Meeting the Needs of the Poor. Rome: FAO. http://www.fao.org/ docrep/006/y5160E/Y5160E00.htm.

Gaskin DE (1982) The Ecology of Whales and Dolphins. London: Heinemann Educational Books Ltd.

Gore A (1992) Earth in the Balance: Ecology and the Human Spirit. Boston: Houghton Mifflin Company.

Groombridge B (Ed) (1992) Global Biodiversity. Status of the Earth's Living Resources. London: Chapman Hall.

Hardin G (1977) Rewards of Pejoristic Thinking. Stalking the Wild Taboo. http://www.lrainc.com/swtaboo/stalkers/gh_vpoj.html.

Intergovernmental Panel on Climate Change (IPCC) (2001) Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change (Houghton JT *et al*. Eds). Cambridge UK and New York: Cambridge University Press.

International Union for Conservation of Nature and Natural Resources (IUCN) (1980) World Conservation Strategy: Living Resource Conservation for Sustainable Development. Gland, Switzerland: International Union for Conservation of Nature and Natural Resources.

International Union for Conservation of Nature and Natural Resources (IUCN) (1991) Caring for the Earth. A Strategy for Sustainable Living. Gland Switzerland: IUCN—The World Conservation Union, United Nations Environment Programme, and World Wildlife Fund.

Jackson W (2004) Agriculture: The primary environmental challenge of the 21st century. In: The Human Ecological Footprint. The Kenneth Hammond Lectures on Environment, Energy and Resources 2002 Series. (Chesworth W *et al*. Eds). Guelph: Faculty of Environmental Sciences, 85–99.

Jones A (2003) Eating Oil. Resurgence 216. http://www.resurgence.gn.apc.org/issues/jones216.htm.

Kirschenmann F (2003) Technologies for a sustainable future: Therapeutic intervention versus restructuring the system. In: Biotechnology: Science and Society at a Crossroad. Ithaca: National Agricultural Biotechnology Council, 73–85.

Lavigne, D.M. (1992) Republicans vs owls. BBC Wildlife, November 1992. Bristol: Origin Publishing, 74.

Lavigne DM (2002) Ecological footprints, doublespeak, and the evolution of the Machiavellian mind. In: Sustainable Development: Mandate or Mantra. The Kenneth Hammond Lectures on Environment, Energy and Resources 2001 Series (Chesworth W *et al*. Eds.). Guelph: Faculty of Environmental Sciences, 61–91.

Lavigne DM (2003) Marine mammals and fisheries: The role of science in the culling debate. In: Marine Mammals: Fisheries, Tourism and Management Issues (Gales N *et al*. Eds). Collingwood, VIC, Australia: CSIRO Pusblishing, 31–47.

Lavigne D (2004a) The human ecological footprint: a commentary. In: The Human Ecological Footprint. The Kenneth Hammond Lectures on Environment, Energy and Resources 2002 Series (Chesworth W *et al*. Eds). Guelph: Faculty of Environmental Sciences, 169–190.

Lavigne D (2004b) The Return of Big Brother. BBC Wildlife, May 2004. Bristol: BBC Worldwide Publishing, 66–68.

Lavigne DM *et al*. (1999) The evolution of North American attitudes toward marine mammals. In: Conservation and Management of Marine Mammals (Twiss JR Reeves RR Eds). Washington: Smithsonian Institution Press, 10–47.

Leakey R Lewin R (1996) The Sixth Extinction: Patterns of Life and the Future of Humankind. New York: Anchor Books.

Leopold A (1949) A Sand County Almanac, and Sketches Here and There. New York: Oxford University Press, Inc.

Lomborg B (2001) The Skeptical Environmentalist. Cambridge, U.K.: Cambridge University Press.

Lynn W (2004) From sound science to sound ethics: What science and the scientific method can and cannot contribute to conservation and sustainability. Paper presented at the IFAW Forum 2004, Wildlife Conservation: In: Pursuit of Ecological Sustainability. 16–19 June, Limerick. http://www.ifaw.org/ifaw/general/default.aspx?oid=87328 (abstract).

Manning R (2004a) The oil we eat: Following the food chain back to Iraq. Harper's Magazine 308 37–45.

Manning R (2004b) Against the Grain: How Agriculture has Hijacked Civilization. New York: North Point Press.

Mayaux P *et al*. (1998) Global tropical forest area measurements derived from coarse resolution satellite imagery: a comparison with other approaches. Environmental Conservation 25 37–52.

McCallum C (2004) Separating wheat from GM chaff. Guelph Mercury, 18 May, A9.

Menon V Lavigne DM (2004) Attitudes, values, and objectives. The real basis of conservation. Paper presented at the IFAW Forum 2004, Wildlife Conservation: In Pursuit of Ecological Sustainability. 16-19 June. Limerick http://www.ifaw.org/ifaw/general/default.aspx?oid=87327 (abstract).

Meadows D *et al*. (2004) Limits to Growth. The 30-Year Update. White River Junction, VT: Chelsea Green Publishing Company.

Miller C (2001) Gifford Pinchot and the Making of Modern Environmentalism. Washington: Island Press.
Mittal A (2000) Enough food for the whole world. Washington Post, Friday, 15 September, A26. http://www.foodfirst.org/media/opeds/2000/9-enough.html.
Monsanto (2004) Monsanto to realign research portfolio, development of roundup ready wheat deferred. Decision follows portfolio review, consultation with growers. News Release, 10 May. http://www.monsanto.com/monsanto/layout/ media/04/05-10-04.asp.
Newmark TE (1998) Carbon sequestration and cocoa production: financing sustainable development by trading carbon emission credits. Proceedings of the Smithsonian Migratory Bird Center Cacao Conference. http://www.nationalzoo.si.edu/ConservationAndScience/MigratoryBirds /Research/Cacao/newmark.cfm .
Nixon RM (1969) Speech. 3 November. www.cnn.com/SPECIALS/ cold.war/episodes/11/documents/nixon.speech.
O'Grada C (1993) Ireland Before and After the Famine: Explorations in Economic History. New York: Manchester University Press.
Odum E (1971) Fundamentals of Ecology, Third Edition. Philadelphia: W.B. Saunders Company.
Orr D (2002) Four challenges of sustainability. Conservation Biology 16 1457–1460.
Parrish D (1999) Who rules the world?—the International Monetary Fund, the World Bank and the World Trade Organization. New Statesman, 2 April. http://www.findarticles.com/p/articles/mi_m0FQP/is_4430_129/ai_54682688.
Pauly D *et al*. (2002) Toward sustainability in world fisheries. Nature 418 689–695.
Pearce F (2004) Asian farmers sucking the continent dry. New Scientist, 28 August. http://www.newscientist.com/news/print.jsp?id=ns99996321.
Perlas N (2000) Shaping Globalization: Civil Society, Cultural Power and Threefolding. Quezon City, Philippines: Center for Alternative Development Initiatives. http://www.cadi.com.
Pimentel D (2004) Food production and modern agriculture. In: From the Ground Up. The Importance of Soil in Sustaining Civilization. Symposium. AAAS Annual Meeting. Seattle, WA. 12–16 February (abstract).
Pimm SL (2001) The World According to Pimm. A Scientist Audits the Earth. New York: McGraw-Hill.
Rees WE (2002) Footprint: Our impact on Earth is getting heavier. Nature 420 267–268.
Rees WE (2004) Growing humanity, dissipating the ecosphere: Using SOHO theory and eco-footprint analysis to ynterpret humanity's dependence on soil. In: From the Ground Up. The Importance of Soil in Sustaining Civilization. Symposium. AAAS Annual Meeting. Seattle, WA. 12–16 February (abstract).

Roberts O (2004) Genetically modified wheat did not die with Monsanto move. Guelph Mercury, 17 May.
Roberts P (2004) The End of Soil. On the Edge of a Perilous New World. Boston: Houghton Mifflin Company.
Robinson J (2002) Squaring the circle? On the very idea of sustainable development. In: Sustainable Development: Mandate or Mantra. The Kenneth Hammond Lectures on Environment, Energy and Resources, 2001 Series (Chesworth W *et al*. Eds). Guelph: Faculty of Environmental Sciences, 1–34.
Robinson, J.G. (1993) The limits of caring: Sustainable living and the loss of biodiversity. Conservation Biology 7 20-28.
Robinson JG Bennett EL (2000) Carrying Capacity Limits to Sustainable Hunting in Tropical Forests. In: Hunting for Sustainability in Tropical Forests (Robinson JG Bennett EL, Eds). New York: Columbia University Press. 13–30.
Robinson JG Redford KH (2004) Jack of all trades, master of none: Inherent contradictions among ICD approaches. In: Getting Biodiversity Projects to Work: Towards More Effective Conservation and Development (McShane TO Wells MP). New York: Columbia University Press. 10–34.
Scoffield H (2004) Biotech giant backs off on wheat. Genetically modified product won't be sold. 11 May. http://www.globeandmail.com.
Shah A (2000) Free Trade and Globalization: Multilateral Agreement on Investment. http://www.globalissues.org/TradeRelated/MAI.asp.
Shah A (2003) Free Trade and Globalization: Public Protests Around the World. http://www.globalissues.org/TradeRelated/FreeTrade/Protests.asp.
Simberloff D (2000) Introduced species: The threat to biodiversity and what can be done. An actionBioscience.org original article. December.http://www.actionbioscience.org/biodiversity/simberloff.html.
Simon J (1992) Scientific establishment now agrees: Population growth is not bad for humanity. In: Rational Readings on Environmental Concerns (Lehr JH Ed). New York: Van Norstrand Reinhold, 557–578.
Southern Africa Sustainable Use Group (1996) Sustainable Use Issues and Principles. Gland, Switzerland: Southern Africa Sustainable Use Group, IUCN Species Survival Commission.
Suroweicki J (2004) The Wisdom of Crowds. New York: Doubleday.
Tamura T Ohsumi S (1999) Estimation of Total Food Consumption by Cetaceans in the World's Oceans. Tokyo: Institute of Cetacean Research.
Tilman D *et al*. (2001) Forecasting agriculturally driven global environmental change. Science 292 281–284.
Tuchman BW (1984) March of Folly from Troy to Vietnam. New York: Alfred A. Knopf.
Union of Concerned Scientists (2000) Backgrounder. FAO Report: Enough Food in the Future—Without Genetically Engineered Crops. http://www.ucsua.org/food_and_environment/biotechnology/page.cfm? pageID=331.

United Nations (1999) The World at Six Billion. Population Division Department of Economic and Social Affairs United Nations Secretariat. ESA/P/WP.154. 12 October 1999. http://www.un.org/esa/population/publications/sixbillion/sixbilcover.pdf.

United Nations (2003) World Population Totals for 1980—2050, According to the United Nations Revisions of World Population Estimates and Projections. New York: United Nations Department of Economic and Social Affairs, Population Division. http://www.un.org/esa/population/publications/longrange2.htm.

Wackernagel M Rees W (1996) Our Ecological Footprint. Reducing Human Impact on the Earth. Gabriola Island, BC: New Society Publishers.

Wackernagel M *et al*. (1999) National natural capital accounting with the ecological footprint concept. Ecological Economics 29 375–390.

Wackernagel M *et al*. (2002a) Tracking the ecological overshoot of the human economy. Proceedings of the National Academy of Sciences, USA 99 9266–9271. http://www.pnas.org/cgi/doi/10.1073/pnas.142033699.

Wackernagel M *et al*. (2002b) Ecological fooprints of nations. November 2002 Update. How much nature do they use? How much nature do they have? Redefining Progress for People, Nature, and the Economy. Oakland, CA: Sustainability Issue Brief. http://www.RedefiningProgress.org.

Ward P (2004) The father of all mass extinctions. Conservation In Practice 5 12–19.

Watson R Mcintyre B (2004) Thought for food. New Scientist 7 August 17.

Whiten A Byrne RW Eds. (1997) Machiavellian Intelligence II. Extensions and Evaluations. Cambridge, UK: Cambridge University Press.

Willers B (1994) Sustainable development: A new world deception. Conservation Biology 8 1146–1148.

Woodham-Smith C (1991) The Great Hunger: Ireland 1845–1849. London: Penguin Books.

World Commission on Environment and Development (WCED) (1987) Our Common Future. Oxford: Oxford University Press.

World Wide Fund for Nature (WWF) (2002) Living Planet Report 2002. Gland, Switzerland: WWF International, Gland. http://www.panda.org.