Biotechnology and Transgenics in Agriculture and Aquaculture: the Perspective from Ecosystem Integrity

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ABSTRACT: New agricultural technologies are often justified morally in terms of their expected benefits, e.g., feeding the world's hungry. Such justifications stand or fall, not only on whether such benefits are indeed forthcoming, but on whether or not they are outweighed by attendant dangers. The practical details of easch case are, therefore, all-important. In this paper agriculture and aquaculture are examined from the perspective of ecosystem integrity, and with further reference to the uncertain effects of anthropogenic changes in the earth's atmosphere. The principle of integrity provides a strong justification for a cautious approach to new technologies, and particularly so in the case of transgenics.

KEYWORDS: Agriculture, aquaculture, biotechnology, ecosystem health, integrity,

INTRODUCTION

When we are faced with questions about the commercial uses of biotechnology and transgenics, we need to ask ourselves two important questions, *before* (not after) consenting to, or tacitly approving their use: 1) 'Are these technologies *morally* right?' and 2) 'Can these technologies *in practice* realise their intended aims?'. Most of those who recognise the legitimacy of one of these questions, tend to ignore that of the other. As I have argued in my paper 'A Transgenic Dinner?' (Westra, 1993), the multinational corporations that push to develop, patent and market technologically altered organisms, do so for profit. At the same time, however, they claim that their products are environmentally sound; and, in fact, that they provide the only solution to hunger in the Third World, in the face of ever-increasing populations whose hunger we cannot possibly satisfy, we are told, with present techniques. The implicit claim is that the 'good' of feeding the hungry is surely warrant enough to eliminate any further need for ethical inquiry.

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Accidents such as the one at Bhopal, and episodes such as the ALAR scare contribute to public fear and distrust, as well as to growing anger at the efforts of these companies to marginalise and trivialise the so-called 'ignorance' and 'irrationality' displayed by people attempting to voice their concerns. What could be better, then, than to represent the same chemical companies in a new guise, now bearing 'gifts' of non-chemical, genetically engineered 'solutions' to the agricultural problems that (to some extent) they themselves created? For it is the 'high tech' approach to agriculture – developed in northwestern countries and introduced to less developed countries as the 'better way' – that has contributed significantly to soil erosion, increased use of pesticides (and thus encouraged pesticide resistant insects), and contaminated food.

However, the benign 'new' version of the same corporate bodies, when closely analysed, also reveals a host of problems. The revamped 'green' look of these companies does not represent an effective change: the mild sheep reveal themselves as nothing but the same hungry wolves, albeit in (green) sheep's clothing. Thus their final products consist in 'new' engineered plants or domestic animals: for example, a plant may have been bred with a virus so that the new creation is both 'animal' and 'vegetal' (an 'aniplant' perhaps?), and possesses traits the previous plant did not possess. These traits may be desirable from the standpoint of economics and production: on the plus side, they increase yield, hence they promise to feed more people more efficiently; but on the minus side, the new plant has now an inbred resistance to a specific herbicide. The result is that the bioengineered species – heralded as a step forward for environmental safety, and a step away from chemicals – represents instead a permanent, inescapable link to chemicals. Hence, the corporation gains twice: first, when it sells the biotechnology, and second, when it ensures thereby 'permanent addiction' to its own patented herbicide. In contrast, the people and the environment, correspondingly, lose twice: first, because the proposed 'safe' product ultimately is not what it seems, and second, when other possibly safer, organic and sustainable choices are pre-empted instead.

The producers' strategy entails appealing to shared principles of the good for the majority, in order to defend their aggressive pursuit of these novel technologies and their intensive marketing. But these so-called shared principles of justice, fairness, and the pursuit of the common good, are not necessarily present once both the technologies and the consequences of their dissemination are scrutinised more closely. The probelms and risks involved may, in fact, outweigh the 'countervailing benefits' (Shrader-Frechette, 1991). The case advanced here is that these shared objectives are in fact more likely to be achieved if our technologies are made answerable to what I have called the 'principle of integrity' (Westra 1994a). Essentially, the principle of integrity enjoins respect for ecological integrity understood – following J. Karr (e.g. Karr 1994) – as a condition resulting from biogeographical and evolutionary processes in the relative absence of human influence. In the next two sections, we will examine both the anticipated benefits, and the problems that are likely to accompany biotechnologies, first, in agricultural food production, and second, in the parallel problems of aquaculture. Attention will then be drawn to the way in which climate change serves only to amplify and exacerbate these problems. The final section will draw some conclusions from the moral point of view, particularly from the perspective of integrity, or biocentric, holistic environmental ethics. I will argue that the questions raised at the outset are inseparable, as the question of the morality of these technologies cannot be answered unless we question first of all the practical claims that have been made on their behalf.

2. AGRICULTURAL FOOD PRODUCTION, BIODIVERSITY AND BIOTECHNOLOGY: THE 'PERILS AMIDST THE PROMISE'

We are now increasingly aware of the degradation that intensive, petrochemically supported, agricultural practices entail. Agricultural examples abound. Studies concerning chemically based agriculture show the dangers of reliance on short-term solutions. A wealth of literature points out the human risks and dangers of chemical products from cradle to grave, so to speak – that is, in their manufacture, distribution, use, and eventual disposal – as well as through possible ingestion of residues on food crops (Draper 1991; Pimentel et al. 1991; Shrader-Frechette 1991; Westra et al. 1991; Pimentel et al. 1992). Pesticides protect economic interests and may seem to ease hunger, in the short term; but as well as eliminating unwanted species, they may also eliminate other species that are necessary to preserve ecosystem health and agricultural sustainability. Other results of intensive, petrochemically based agricultural practices include soil erosion, desertification, decreasing productivity, loss of nutritional value in food products, and the need for higher and higher pesticide applications to counteract more and more resistant species of pests (Pimentel et al., 1991; Westra et al. 1991; Meadows et al. 1992; Pimentel et al. 1992; Goodland and Daly 1993; Pimentel et al. 1995).

Because of these problems, chemical companies have turned eagerly towards the new technology involving 'transgenics'. Transgenic plants are crops that have been genetically engineered to contain traits from unrelated organisms. 'Adding novel genes to crops means adding new traits and abilities. Genetic engineers can move genes from any biological source – animal, plants or bacteria – into almost any crop' (Rissler and Mellon, 1993). Hence, unlike traditional breeding techniques which may only alter a specific crop after finding the desired new trait in a plant capable of breeding with that new crop through natural mechanisms, *any* organism is 'fair game' to the genetic engineer. The result of genetic manipulation is, in *every case*, a genuinely novel class of animals or plants. Armed with the new technology, the chemical companies have embarked on a public relations campaign to restore their tarnished public image and to show (or claim), that biotechnology is ‘natural’, because it uses what is already available in nature. A leading problem with this stance is that much effort has been primarily geared to producing herbicide-tolerant crops, which increase significantly both the use of herbicide and, at the same time, the profits of the corporations producing them.

Such practices should raise grave concerns for both environmental and human health reasons. An example of the latter involves the California biotechnology company Calgene who, in conjunction with the multinational company Rhone-Poulenc, is seeking U.S. government approval to sell a cotton plant genetically engineered to tolerate bromoxynil, a Rhone-Poulenc herbicide which has been shown to cause birth defects in animals and has been classified as a developmental toxicant for humans (Rissler and Mellon, 1993). Another example involves an amino acid, tryptophan, which in the late 1980s was produced and sold through health food stores, as a sleep medication. Eventually a Japanese firm, Showa Denko Co., changed the process and started to produce it with genetically engineered bacteria, with disastrous results. Particularly in the United States, where, in contrast with Canada, it was sold as ‘food’, hence not subject to testing, regulations and labelling, people started to sicken and die from ‘Eosinophilia-myalgia syndrome’. After 31 deaths, injuries to over 1,000 people, and a rash of lawsuits, Showa Denko Company closed for business. This made it impossible to test either the substance or the manufacturing/engineering process. Nevertheless as the substance was over 99% pure, the changed procedure involving genetic engineering appears to be the most likely cause of the terrible toll of death and suffering (Mayeno and Gleich, 1994; cf. Mellon, 1994b, National Wildlife Federation, 1992). Even if absolute proof is not available of the direct causal connection between genetic engineering and this case’s morbidity and mortality, several points emerge: 1) there was no required labelling to alert the public to the changed processes and the genetic engineering involved in the manufacture of the product; 2) the product was sold as ‘food’, rather than as ‘drug’, hence neither testing nor medical advice was required for its use; 3) the U.S. government itself was ‘unaware of the introduction of tryptophan made by genetically engineered bacteria’ so that, under present regulations, the tragedy was unavoidable, *even in principle* (Mellon, 1994a).

Informed choices about bioengineered products are not possible, when faced with unlabelled products and the secrecy surrounding them. This situation is in direct conflict with the individual’s right to consent, and to the right to religious freedom not only of belief, but also of practice (Westra, 1993). Like the drug industry, biotechnology is research intensive, and needs to cover the costs of its research. But unlike the drug industry, biotechnology a) is under no tight controls similar to those imposed by the medical establishment upon new drugs and medications; b) is not forced to label its products clearly for content, indications and possible side-effects; and c) targets global mass markets without the necessary intervention of a proactive professional to protect the public (i.e., a doctor), free to examine the industry claims, and to tailor the use of a product to the specific requirements of each individual patient (Westra, 1994d).

Environmental concerns about biotechnology are no less grave. Two major points need to be emphasised: 1) the commercialisation of transgenic crops carries serious environmental risks *in itself*; and 2) transgenic crops have both *initial* impacts and *cumulative* effects. Underlying both problems is the lack of stringent regulations governing these products, at least in North America. For instance USDA (United States Department of Agriculture) which governs them as ‘food’, only requires that the corporations that research and manufacture them, be prepared to do their own testing and submit the results (Westra, 1993). The tests are performed under controlled conditions which may be quite different from those where the products will be introduced, many of them in the Third World.

The importance of the changed conditions of the ecosystem/habitat where these plants will grow cannot be overemphasised. Many plants, imported into non-native ecosystems, invade their own and other adjacent areas as weeds, and this seems particularly likely to occur with transgenic varieties. They can invade crops and other habitats, play havoc with the native plant and animals species, or produce toxic and allergenic side effects when unintentionally mixed with crop seeds. They may also compete with native species. ‘Cascading effects’ may include deleterious effects on nontarget organisms, wild birds, insects, arthropods, amphibians, fish and so on. Their overall effect on the ecological integrity of ecosystems is thus simply unknown (Westra, 1994a).

When the transgenics are pesticidal, they often kill non-target and even beneficial insects and fungi, thus possibly impeding the flow of nutrients vital to ecosystem functioning (Rissler and Mellon, 1993). Similarly, the ultimate results of the evolution of pest resistance are not known. Appropriate testing, both long term in scope, and carried out by impartial parties, is vitally important to protect human and nonhuman animals and habitats. Moreover, the ‘weediness’ that appears to be associated with transgenics, may also threaten centres of biodiversity in the Third World, on which global agriculture is utterly dependent.

Transgenic virus resistant crops add yet another risk: the threat that new viral strains may arise. Some have objected that ‘coinfection of plants by multiple viruses’, as already present naturally, makes this risk negligible (Rissler and Mellon, 1993). But there have been no experimental investigations of these claims, as no outside specific testing is ever required before patenting applications for a transgene are approved. Unforeseen circumstances such as the loss of the ozone layer and climatic changes, coupled with the lack of precise predictive capacities of the biological sciences, aggravate both the risks and the uncertainty.

The introduction of alien species into complex ecosystems is as potentially hazardous as the introduction of other chemical and toxic man-made substances. *Beyond the Limits*, the second book presenting the research of the Club of Rome (Meadows et al., 1992) argues that both sources and sinks on earth are limited;

thus, every time we introduce a substance that has not evolved slowly and naturally, and that is not a native to the ecosystem to which it is introduced, we are imposing an anthropogenic stress that is hazardous to the system. This becomes, implicitly, a stress to the earth's life-support systems, in general.

What remains to be addressed is the question of the alleviation of hunger, worldwide. Is it a 'benefit' real enough to offset the global risks involved? In general, although North West countries are technologically and materially richer than developing countries in the South East, the latter are much richer in biodiversity, as they possess 'centres of crop diversity':

> They are the source of the new genes that plant breeders and genetic engineers use to adapt crops to changing environmental conditions ... most of the centers of diversity for food crops are in developing countries (Rissler and Mellon, 1993).

Hence it is fair to say that no practice that may eventually threaten these centres can be truly sustainable, thus successful in the fight against world hunger, in the long term. Not every attack on biodiversity or lessening of the genetic pool is a portent of future global tragedy, but the aggregation of localised insults repeated around the globe could seriously weaken the earth's unique life-sustaining system.

Therefore, not only the appropriate U.S. agencies, but also United Nation organisations must develop biosafety protocols that are both strict and globally valid and enforceable. Biotechnologies and transgenics are not the 'promise of the future', they offer no certainty, no guarantee of appeasing world hunger. Thus the threats and hazards they present far outweigh the promise, even if we *only* consider them from the standpoint of our use. (Of course, the case is even stronger for those who view nonhuman individuals, species and ecosystems, as *intrinsically* valuable, thus worthy of respect [Westra, 1994a]). I would argue that respect for ecological integrity is foundational for sustainability in food production, and hence for the alleviation of world hunger, and this for two reasons: 1) the loss of ecosystems' capacity that follows upon intensive petrochemically based agricultural practices; and 2) intrusive and manipulative activities such as the introduction into ecosystems of exotics and aliens (such as transgenics), which affect integrity both at the macro level (ecosystems) and at the micro level (single organisms). And the reason why this matters is that wild areas support sustainable agriculture both directly and indirectly. Directly, the biodiversity they foster remains a supply depot in which alternatives may be found for lost species; indirectly, wild areas provide the only exemplar or benchmark for comparable areas, for what is appropriate and necessary within an ecosystem to support its health and foster its function. Hence, if we continue to exploit certain areas without reference to integrity and wild areas, sustainability will be lost through the scientific incapacity to understand and predict the effects of technical interference and alterations.

I have argued elsewhere (Westra 1994b) for the necessity of a total re-evaluation of Western dietary habits in the interest of both sustainability and equity. The importance of diet changes is also emphasised in a recent paper by Kendall and Pimentel:

> About 38% of the world's grain production is now fed to livestock. In the United States, for example, this amounts (to) about 135 million tons yr. of grain, of a total production of 312 million tons yr., sufficient to feed a population of 400 million on a vegetarian diet. (Kendall and Pimentel, 1994)

Kendall and Pimentel also recommend maintaining biodiversity, as required by the principle of integrity, and the approach I have suggested (Westra 1994a).

3. ENVIRONMENTAL IMPACTS ON WATER BODIES: TOWARDS SUSTAINABLE, ECOLOGICAL AQUACULTURE

In the previous section the question of world hunger was addressed, together with the usefulness and morality of biotechnology, given that intensive petrochemical agriculture is responsible for both reduced productivity and many grave environmental problems. Since present systems of agriculture are failing to keep up with both present and projected demands for food, the opportunity and the 'promise' of transgenics appears, ideally at least, to fill that gap. But, as was noted, both moral and practical problems beset these technologies. In the present section it will be shown that these problems persist for aquaculture as well.

The urgent need for food drives agricultural production. Some aspects of that production, for instance, intensive animal production, can be indicted on both moral and environmental grounds, a point I have defended elsewhere in detail (Westra, 1994b). I have also argued that our Western style dietary habits are as inappropriate to our health as they are to an ethic of environmental concern. However, it might be claimed that the same argument cannot be made for fish, as it is both healthy and, at least normally, 'free range', so it avoids some of the problems outlined by defenders of animals' rights and interests, as well as some of the problems which beset agriculture. In fish, it appears, we have a nontoxic and non-hazardous product. We also have traditional lifestyles at stake. People have lived by fishing from time immemorial.

No doubt fishermen in Newfoundland or Spain can reach back through generations, to show their traditional dependence on the bounty of the seas. But fisheries have not remained 'traditional', in either techniques or the catches' habitats. Faster, far-reaching boats, new nets and other implements ensure larger and larger catches for multiplying humans with steadily expanding demands and often with incomes to sustain a wasteful lifestyle. In addition, many areas are too polluted and hazardous for continued use, and this double-hazard scenario is repeated all over of the world. Our wasteful, profit-driven lifestyle has resulted in depleted fish stocks and even in species extinction in some cases. For instance, Canada has recently been the site of two major controversies, or 'fish wars', one of which nearly turned to violence. The Newfoundland fishermen slowly lost their cod stocks, with the complicity of a government more interested in present votes than future sustainability. In spite of the dire predictions of scientists, the fishers continued to push for increased quotas, with the misplaced confidence that the fish would somehow always be there. Eventually, the cod population crashed, as it became depleted beyond possible recovery. This may well become a common occurrence, if ecological requirements such as those required by the principle of integrity are not followed (Hutchings and Myers, 1994).

At the 1993 International Arctic Wilderness Congress in Tromsø, Norway, representatives of Inuit and other traditional Arctic groups demanded increased fishing and hunting quotas. In earlier times, such social aboriginal claims were taken to be primary, as they derived from our strong beliefs in individual and aggregate human rights. But in times of ecological crisis, when, particularly in the Northwest, we are already living 'beyond the limits', such social sustainability can only be supported if it is based on ecological sustainability (Goodland, 1994). This was the position taken by Canadian fisheries minister Brian Tobin, throughout the recent 'fish wars'. If you argue for tight regulations, supported not only by law, but also by a 'new ethic' (CBS News Conference, April 14th, 1995), you recognise the primacy of conservation. In that case, the 'new ethic' cannot be a negotiable one based on economic choices and preferences: it must be an imperative upholding the primacy of ecosystem integrity. If you argue against such regulations instead, you must be prepared for the consequences: 'traditional' and nontraditional life styles based upon such resources will evaporate with the disappearance of the species upon which these lifestyles depend.

The only alternative for *some* sort of fish-dependent subsistence of commerce and for a healthier diet for all, might be then to turn to aquaculture. But the environmental prognosis for the latter is not good. In essence, if we turn away from natural fisheries and their losses, and try to supplement them through aquaculture, we open the door to another set of possible environmental problems. So that, aside from the possibility of ecosystem collapse engendered by species loss and pollution, overfishing may force us to yet another hazardous and unsustainable option. Aquaculture is 'the aquatic counterpart of agriculture' (Beveridge et al., 1994) and, like agriculture, is set to become increasingly dependent upon transgenic technology (Sagoff, 1988). Probably because of the problems of natural fisheries, over the last twenty years it has increased exponentially, and it now accounts for 17% of the world's fisheries.

Unfortunately, like agriculture, aquaculture has potentially deleterious effects on the environment and on human health. It is not a natural process, and it affects biodiversity in several ways: a) through the consumption of resources; b) through the transformation process itself; and c) through the production of wastes. Its effects on biodiversity are both direct and indirect. Releasing exotic genetic material into the environment is a direct impact, which effects changes to the biotic components of an ecosystem, thus causing possible loss of habitats or alterations in systems' function, which is an additional indirect impact (Beveridge et al., 1994).

It is worth looking at some of these problems in more detail. As we saw, environmental impacts from aquaculture are unavoidable, but, as it is a novel procedure, even less is known with certainty about these impacts than is known about agriculture. Moreover, in direct contrast with the latter, most often mariculture, for instance, is frequently conducted in public waters (Kapuscinski and Hallerman, 1994), hence the public is directly involved and affected at every level of production, from the standpoint of the environment. Some of the major problems are listed below:

1. The introduction of exotic species into habitats, creating many negative impacts, parallel to those noted for agricultural transgenics; particular problems include:
    a) the introduction of pathogens and parasites, with major impacts;
    b) the alteration of habitats, with negative effects on both native species and human activities;
    c) heightened competition and predation;
    d) 'gene pool deterioration', as hybridisation with indigenous species may compromise the fitness or even the genetic integrity of the indigenous species;
    e) unwanted socio-economic effects.
2. The introduction and spread of parasites and diseases, as the conditions of aquaculture operations create the very conditions for outbreaks of disease.
3. Wastes of aquaculture operations include ammonia and phosphate, which can produce eutrophication problems that are particularly troublesome in areas with limited circulation; cage culture of fishes also generates large amounts of solid wastes, which alter benthic ecology.
4. Use of feed additives such as antibiotics for both prophylaxis and therapeutics, leading to the following environmental impacts:
    a) development of drug-resistant strains of bacteria; further drug resistance can be transferred from fish to human pathogen in vitro;
    b) accumulation of antibiotics in sediments, which inhibits microbial decomposition;
    c) accumulation of antibiotics in fish and shellfish leading to further concern about antibiotic residues for human consumers.

5. There is also concern about the ecological and genetic effects of cultured stocks on wild stocks; even a small percentage of ‘escapees’ may represent large numbers relative to the native populations. The effects of the genetically modified organisms on ecosystems, wild communities and endangered species, are neither clear nor fully known at this time.
6. The use of public waters remains a problem, as it is viewed as yet another noxious industrial development.
7. Alteration of natural systems is to be expected, hence the relative impact of various forms of operation must be studied, with this issue in mind. (Kapuscinski and Hallerman, 1994).

It is easy to see the appeal of aquaculture, a technological ‘fix’ to help us adjust to the results of our own over-consumption. But it is neither logical nor morally right to deal with the results of our carelessness through a short-term remedy that will ultimately *add* ecological stress. If we turn to aquaculture to seek solutions to fish stock depletion and species extinction, both caused in part by pollution and by ecological disintegrity, then aquaculture must avoid contributing to the problems that led us to it in the first place. Further, even aquaculture operations are themselves often constrained by increased aquatic pollution from other sources, habitat degradation and reduced access to appropriate land and water resources (UDSA, 1995).

Aquaculture must be managed very carefully, so that it will neither receive nor cause negative environmental impacts. In this regard ecological integrity (including biodiversity) is particularly relevant, for while most of the wild relatives of domesticated terrestrial livestock have already been lost, wild undomesticated fish remain a major reserve of genetic diversity. Techniques such as culture-based fisheries or ranching and cage and pen culture in natural waters, constitute significant risks to wild populations and natural diversity (Costa-Pierce and Peters, 1994).

Costa-Pierce and Peters (1994) provide a useful summary of the features that might be found in a form of aquaculture that respects ecological integrity. Their ‘ecological’ aquaculture:

1. preserves the forms and functions of natural ecosystems;
2. derives most of its energy from renewable sources (solar, wind, water, biomass);
3 is a net protein producer, relying on waste animal or plant-based protein for feeds;
4. does not produce nutrient or chemical pollution;
5. develops a systems approach to nutrient recycling and regeneration;
6. plans for ecosystem rehabilitation and enhancement;
7. is integrated with agriculture;

8. does not use chemicals or antibiotics harmful to human or ecosystem health;
9. uses native or resident species;
10. is integrated with communities to maximise job creation in local industries;
11. develops enhanced fisheries;
12. is a global partner, producing information for the world.

Much of this programme is intensively innovative. For example, waste waters, manures and fish wastes may be planned for use, through an integrated approach, rather than contribute to ecosystem degradation, as they presently do. In the concluding section several aspects of both problems and solutions will be discussed from the moral point of view.

4. SOME AGGRAVATING ENVIRONMENTAL PROBLEMS: ATMOSPHERIC CHANGES AND GLOBAL WARMING

The dangers of changes to the atmosphere and climate caused by human technology have mostly been discussed in terms of their direct impact on humans, e.g., the increase of skin cancers as one effect of the ozone layer depletion. It might be possible to take measures to protect ourselves from harmful UVB and UVA rays through avoidance of the sun and the use of special blocking lotions, and by wearing protective clothing when outdoors. But there are other direct threats to human health (such as ‘killer’ heat waves in major cities, worldwide), that cannot be avoided and there is not enough scientific evidence and knowledge to give us confidence in our capacity to withstand these threats. It seems reasonable to suppose that we may anticipate not only physical havoc, such as sea levels raising, flooding in low-lying areas and violent storms, but also that we might have to prepare ourselves for dramatic increases in the spread of infectious diseases. For instance, it has been hypothesised that El Niño may have helped promote a deadly cholera outbreak in 1991 (McMichael, 1995), and even that the recent U.S. outbreak of hantavirus (27 deaths in 1993), may have been related to El Niño. It is plausible that higher temperatures may give rise to an increase in both insects and bacteria, hence the increase in bacteria-borne diseases which would follow, may be the result of environmental causes arising from human interventions.

But the potential damage to the natural life-support systems of the planet from human activities may pose an even greater long-term threat to our survival. Soil erosion is a major environmental threat to the sustainability and productive capacity of agriculture, and the loss of soil degrades arable land and eventually renders it unproductive (Pimentel et al., 1995). Large amounts of fertiliser, pesticides and irrigation are used to help offset erosion problems. But the ‘tradeoff' is the creation of pollution and health problems and the destruction of natural habitats, while boosting energy consumption and rendering agricultural systems unsustainable (Pimentel et al., 1995; Pimentel et al, 1992).

The same intensive petrochemical agricultural practices, coupled with the use of high impact mechanical equipment, combine with the effects of climate change to further aggravate the latter's adverse impacts. Soils do not always have the capacity to properly absorb floodwaters, because of the intensive agricultural practices to which they have been subjected. The chemicals, pesticides and fertilisers used to boost crop yields eliminate at the same time most of the biomass which maintained the ecosystems' functions, thus seriously affecting food production. A vicious cycle develops. Soil erosion lowers productivity as soil depth is lost, and it takes hundreds of years to replace a single centimetre of lost topsoil. Intensive agropractices may temporarily alleviate the food production problems, but in the long run, they aggravate the very problem they were intended to correct. As use of agrochemicals decimates soil biota, the soil's water holding capacity as well as its productivity, decline. Moreover, the 'vicious circle' has effects well beyond its parameters. It has strong negative effects on the environment as a whole. Some of these damages include, eutrophication of waterways, siltation of harbours and channels, loss of wildlife habitat, and disruption of stream ecology, as well as damage to public health (Pimentel et al., 1995).

The effects of atmospheric changes on both aquatic and terrestrial/agricultural ecosystems have also been documented (Caldwell et al., 1995; Häder et al., 1995). Moreover, just as the effects of atmospheric changes have negative impacts which are not fully predictable on agriculture and fisheries, so too can we anticipate correspondingly unpredictable impacts on genetically altered organisms and the systems that contain them. We can therefore take for granted that even the roster of problems and difficulties listed in the first sections of this paper is incomplete, because recent ecological damage due to climate changes is not factored in the research and findings cited.

Anthropogenic stress often interferes with the 'natural' evolutionary development of a system. But the causal effect of inappropriate human activities does more than affect something 'out there', external to the human agents. As Aldo Leopold and others have shown, our human position as part of the ecosystem's biota, renders each imposition of inappropriate stress a reciprocal one: in an 'upstream/downstream' world – everything we do comes back to affect us in some way.

Unlimited, uncontrolled technological/economic activity causes disruptions in natural systems, the effects of which are not clearly or accurately predictable. It almost appears to be the sort of 'reversibility' that is present in Kantian ethics. But it is not a truly Kantian form of reversibility, as the moral responsibility is not reciprocal. Humankind is immorally affecting natural systems, but natural systems are not equally immoral when they respond to harm, with harm; the reciprocity that follows our interventions is amoral instead. On the other hand, humankind's initial causative activity is *doubly* immoral: it affects natural systems, and it also affects humankind *through* natural systems. Hence, the superficial critique often levied against ecocentric ethics as an anti-human position, is mistaken, drawing an inappropriate cleavage between humans and other biota. Respect for ecosystems is *ipso facto* respect for all natural entities: for human and nonhuman animals, and for both biotic and abiotic components of natural systems.

To take a 'deep ecology' position and to support some preservation of the wild, does not force humans *outside* the natural environment, it simply recognises the limits within which humankind must operate in it. Of course, it is simply 'human' not 'techno-human', that belongs in natural systems (Westra, 1995), as claims about an ecological niche can only be made for an animal in its natural state. For instance, a transgenic plant or fish, no longer belongs *naturally* in an ecosystem, as it did before it was technologically altered and manipulated. The biotech fish, like the 'technohuman', no longer performs its function as part of the systems's biota; it now often wreaks havoc, as it disrupts and alters the system's natural functioning (Beveridge et al., 1994).

If a strong ecocentric position were adopted, then the preservation of the wild would be mandated as primary, and this would eventually help to ameliorate the present environmental degradation, and eventually reverse climate changes. So far, however, this has not happened: although ecosystem integrity is the goal of many regulative acts, the consequences of these mandates is neither well understood nor accepted and implemented in public policy. Public recognition and support for the foundational role of ecosystem integrity and, in general, for the ecosystem approach, is, however, now gaining momentum. In Canada, especially in the Great Lakes region, much work has been done to clarify the notion of integrity and the implications of the ecosystem approach, because of the original mandates of the great Lakes Water Quality Agreement (1978), which is a binational act (Kay and Schneider, 1994; Westra, 1995b).

The link between climate changes/global warming and the imperative of maintaining and protecting ecosystem integrity is present in two separate senses. On the one hand, deforestation of large, biodiverse areas would be prohibited from the standpoint of integrity, and the role of forests in regard to global climate would be preserved. These landscapes would be largely protected as 'core' areas, and they would be kept in their wild state, in sizes large enough to ensure safety (prudential principle). Further, the injection of greenhouse gasses (i.e., carbon dioxide, methane, nitrous oxides and chlorofluorocarbons) into the atmosphere', would not be freely permitted, even in areas beyond the wild, such as buffers, or urban areas. No 'risky business' should be allowed to operate if it can be reasonably anticipated that it would have an adverse impact on wild/core areas, buffers or on areas of 'culture' themselves (Westra, 1994a; Westra, 1995a).

5. CONCLUSION: THE MORAL PERSPECTIVE OF ECOSYSTEM INTEGRITY

According to the principle of integrity, the central necessity is to save and protect wild areas in relatively sizable proportions, say 20 to 45% of the earth's surface as areas of ecological integrity. If this is accepted, then it is our obligation to dwell in the remaining 80-55% (varying according to particular landscape requirements), in ways that produce no adverse impacts upon the core wild areas. We must consider ourselves as living in 'buffers'. I have termed these areas of 'ecosystem health', where many natural evolutionary processes persist, as distinct from urban areas, where few evolutionary processes persist, relatively to the core areas.

True buffers entail that most natural ecologically evolutionary processes be present, although these areas may be manipulated for basic needs (i.e., agriculture, forestry and perhaps careful aquaculture). All of these may utilise land and water, but without imposing degradation and disintegrity either on its own landscapes, or on those of core areas. In practice, this would mean the elimination of all hazardous and toxic substances from those pursuits, as well as the imposition of bans on the introduction of exotics of all kinds. Even in areas where human culture predominates, hence where natural evolutionary processes are restricted or minimal (that is, in urban or industrial centres), the centrality of wild integrity will need to be constantly emphasised in public policy, in order to avoid harmful interference with it. Hence I have argued that while we need to utilise and manipulate some landscapes, wild areas are required to support healthy areas through their natural functions. In spite of the abundance of scientific material supporting the foundation role of wilderness and biotic integrity for conservation biology, far less has been said about its role in regard to human health, although recent material confirms and supports much that has been said in these pages (Soulé, 1995).

What does the perspective of integrity recommend in regard to transgenes and biotechnology? First of all, by recommending not only the preservation of large wild areas, but also mandating restrictions on human activities so that these wild areas be treated as *central* and *primary* – the principle of integrity proscribes any interference that would result in a system's loss of integrity. But any non-natural or partly man-made organisms, when introduced in a system or landscape, affect its structure and its natural function, hence its integrity. Thus, from the standpoint of integrity, any genetically altered organism is at least *prima facie* undesirable. In order to view it as acceptable, its creators would bear the burden of proof to show that a) the organism does not have adverse impacts on the system, even in the long run (and this proof should be through testing *in situ*, not simply on controlled assays under laboratory conditions); and b) that the organism *itself* is not affected in its natural development. The Netherlands already has such a rule in place in regard to legislation concerning genetically altered animals, who cannot be 'altered', if the additional gene or genes would change an animal's 'natural' functioning and behaviour.

The ethics of integrity recognises the intrinsic value both of the natural structure of organisms, which defines their identity as well as their function within an evolutionary whole, and that of natural wholes, for the same reasons and, additionally, for the life support they provide for all organisms. Environmental ethics theories that are based on anthropocentrism, even of the 'weak' variety, such as that of Bryan Norton (1992) for instance, are restricted to balancing present proposed benefits (unproven) and future possible harms (also unproven). Such ethics may propose 'management' goals of ecosystem health, but they accept both management and manipulation as acceptable everywhere, under specific circumstances. At best, these theories question the 'how', not the more basic 'why' of any management goal. In other words, once manipulation and alteration is viewed as *prima facie* acceptable (in contrast with the priciple of integrity), it becomes notoriously hard to draw the line on a continuum, and a special case needs to be made to explain why *this* particular kind of manipulation may need to be restricted. Such a claim can probably be supported on anthropocentric grounds, by appeals to the unacceptability of imposing unconsented and uncompensated harms on individuals (Shrader-Frechette, 1991). But it is difficult to provide clear and uncontroversial *legal* proof of harm in the case of substances that have not existed as such until recently, although their component parts may have. I have argued in a similar vein for the public's right to know not only because of risk of harm, but also because of the right to religious freedom (in regard to dietary laws), both of which would require, minimally, clear labelling of all transgenics as *drugs*, rather than treating them as food (Westra, 1993). The tryptophan example cited above also supports a purely anthropocentric argument against the easy acceptance of biotechnologies.

Unfortunately, the lack of clear-cut scientific evidence at this time, restricts the possibility of strong legal evidence, hence it militates against the possibility of clear causal arguments against transgenics. Of course, the fact that both the money and the power to support new research are not in the hands of the public, but in those of the multi-national corporations that control their production, indicates at least one reason why the necessary impartial research is not available, and is not likely to be available in the future.

The conceptual basis of our approach to these novel substances and organisms, will determine their fate and ours. If one views them as only different in degree from other forms of acceptable manipulation of natural entities and systems, then our assent to their use may at most be conditional, but it is assured. If, on the other hand, we start from a strong position of respect for natural evolutionary systemic processes, and hence for both the structure and the function of landscapes and all the biota within them, then our first reaction will clearly be negative, and all our future responses governed by caution. Manipulation of any sort needs clear defence, in the form of evidence, primarily, of no harm, but also of expected benefits, beyond mere assertions.

The imprecisions and unpredictability of science (Funtowicz and Ravetz, 1995) will also need to be factored in our decision, calling for additional precaution. Further, respect for individuals within systems, including humans (but not limited to them), dictates that interference and alteration is always, *prima facie*, wrong, especially when no consent is available (from humans), or possible (from non-humans).

Respect is based on the recognition of intrinsic value ,which in turn is based on the existence on individual life-projects and the natural tendency of all organisms to carry out their actualisation, culminating in reproduction, as individual and species goals, respectively (Taylor, 1986; Regan, 1983). For humans, we can add autonomous will, not only tendencies and propensities, but *intended* goals, supported by life. For natural wholes and systems, intrinsic value is found in their own evolutionary development and the life-support they provide to all within them, and without, globally (as in forests and oceans, and their functions, reaching well beyond their own limits) (Westra, 1994a).

At the survival level, intrinsic and instrumental value coincide, as do anthropocentric and non-anthropocentric value. But is it the intrinsic, non-anthropocentric value that helps to provide the more far-reaching standard for morality in regard to the environment. I have argued that integrity's value is both structural and functional, although the two are hard to separate, except conceptually, since it is the undiminished and undisturbed *structure* of an organism or a system, that must support its *function*. In contrast, neither considerations of ecosystem health (as a management goal) nor that of purely human 'goods' may reach deep enough to consider and respect structures.

Therefore, taking seriously the human right to life and to the non-infliction of harm (Gewirth, 1983), in an ecologically aware world, demands recognising and respecting natural evolutionary paths in systems and all their component parts. It also demands that nonhuman individuals and wholes be respected in the same way, and that when confronted with biotechnologies and transgenics, we deem them to be 'guilty' of breach-of-integrity, minimally, until thorough and unbiased evidence to the contrary may be openly available.

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