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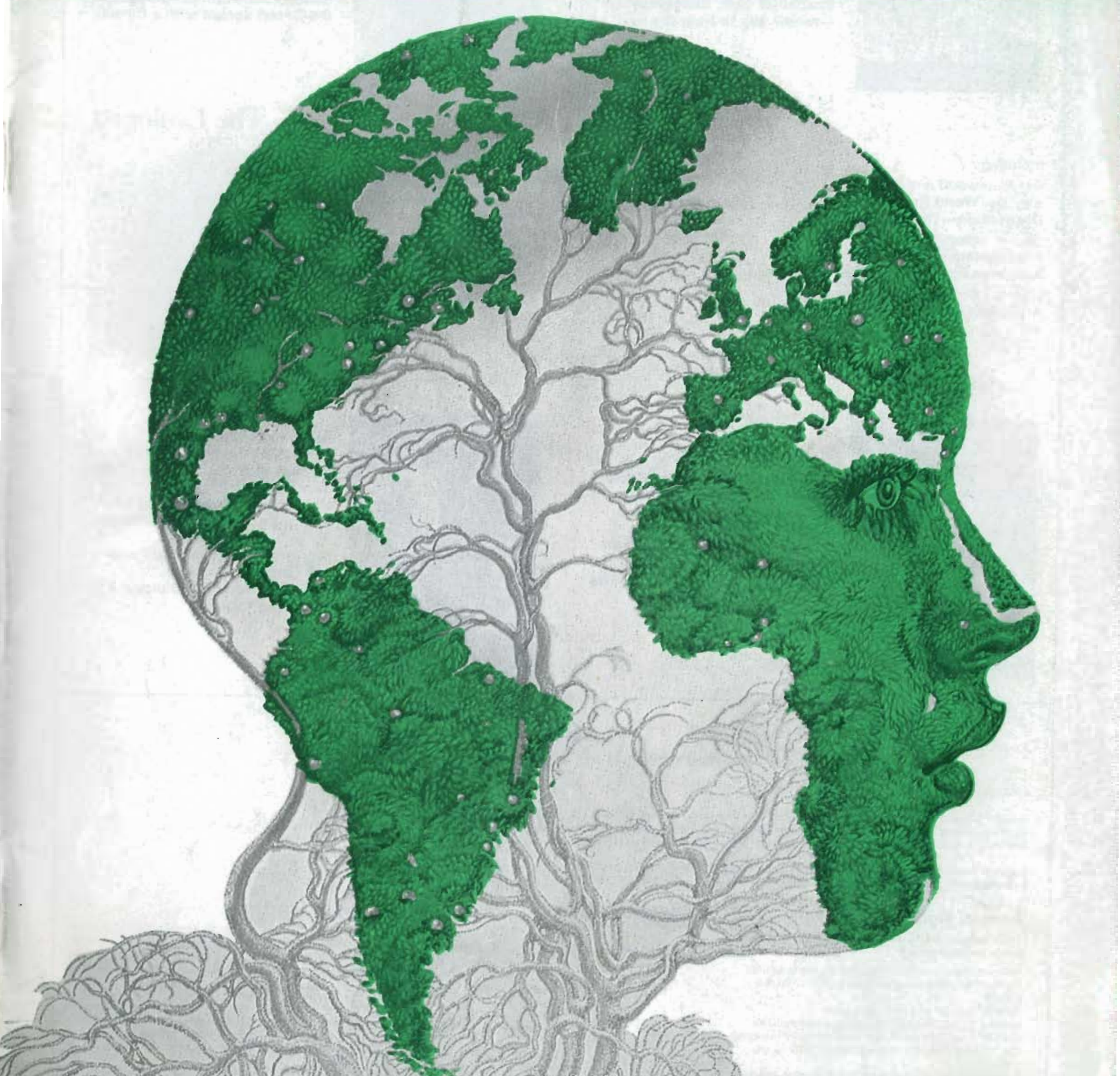

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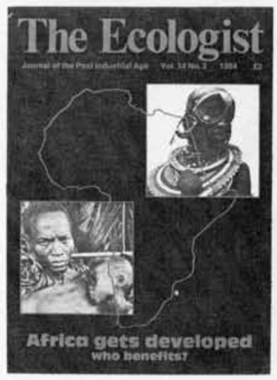

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Editorial

Feature Articles

Report

Cover: Nick McBreen (*Le Courrier de l'unesco*)

Lay-out: John McIntyre

EDITORIAL

Whatever happened to Ecology?

Thomas Kuhn, in his celebrated *Structure of Scientific Revolutions,* demonstrated more convincingly than anyone before him that a scientific theory was adopted not because it has been 'proved' to be true on the basis of some serious objective test (assuming that there can be such a test) but because it fitted in with that pattern of scientific wisdom on the subject—the 'paradigm' as he referred to it—that happened to be in vogue at the time.

The more credible epistemologists of the last two decades, such as Lakatos, Feyerabend, and Brown, have largely accepted this thesis and have generally come to agree that scientific knowledge has no special status—contrary to what logical positivists and many scientists still maintain—that distinguishes it from common or garden knowledge other than that it happens to be that which is most acceptable, for largely subjective reasons, to the scientific community of the day.

Though Kuhn himself later abandoned the use of the term paradigm (Margaret Masterman showed that he used it in at least twenty different ways), this has not prevented it from coming into general use, nor even from being applied to patterns of conventional wisdom outside the field of science.

At the same time, it has also become clear that, since scientists do not live in a closed scientific community, but are also members of a society with whose values they have been imbued like everybody else, the scientific paradigm which they entertain, is inevitably that which best fits in and hence which best helps to rationalise such values, and hence the society's general paradigm, as we might refer to it, or world view, which such values underlie.

Consistency with the reigning social paradigm is thus, in effect, the ultimate criterion of scientific truth and today this means consistency with what can be referred to as the paradigm of modernism.

This undoubtedly explains why Darwin's theory of natural selection has become gospel. It could clearly not be reconciled with the world view of pre-industrial society, hence the original opposition to the theory, but it unquestionably served to rationalise the totally different socio-economic conditions brought about by the industrial revolution. Among other things, it postulated the principle of change or 'progress', accentuated individualism and competition while ignoring sociality and co-operation. It saw the behaviour of living things as passive and random (in spite of being competitive) which of course would serve to justify the management ethic and further justify change. Biological evolution, and by extension, social evolution were seen as brought about by the agency of a crude mechanism called 'natural selection' a biological version of Adam Smith's 'invisible hand' that somehow had the mysterious ability to transform random variations into the highly integrated and perfectly coordinated parts of that most sophisticated of all creations, the biosphere.

The Darwinist thesis was rendered still more consistent with the paradigm of modernism by August Weissmann and William Bateson, once Mendel's genetics had been discovered by the mainstream scientific world.

In the 1940s and 50s, Julian Huxley, George Gayelord Simpson and others developed the co-called 'Modern Synthesis' which satisfied still more perfectly the requirements of the paradigm of modernism. All these changes were clearly noted by the great theoretical biologist C H Waddington in *The Ethical Animal.* "Since Darwin's time and in particular since the rise of Mendelian genetics," he wrote, "the emphasis has been placed on the discreteness of the individual genes, the randomness and nonrelational nature of the mutational process and the unimportance of the reaction of the organism to its environment."

What few people seem to realise is that precisely the same thing has happened to ecology. Ecology is above all a world view or social paradigm. It has been the world view of traditional peoples from time immemorial—this is why they never destroyed their natural environment and their societies displayed such incredible stability and continuity. It was also the world view of the Natural Theologists of the 18th century, of Goethe, Wordsworth and the other Romantic poets. It was also the world view of Thoreau, and Aldo Leopold the early academic ecologists such as Clements and Shelford and later of Allee and the Chicago School.

Those imbued with the ecological world view, have traditionally seen the world as a 'quasi-living entity' to use Jim Lovelock's description of Gaia. They have also seen it as perfectly designed by God or the evolutionary process to satisfy, among other things, the needs of its component populations, societies and individuals of whatever species.

In their turn, each of these has been seen as having a specific function to fulfill (its niche) in order to help assure the proper functioning of the biosphere and hence maintain the balance of nature, while disasters such as droughts, floods, epidemics have been traditionally attributed to a disturbance of this critical balance brought about by some outside interference.

Such a view is essentially teleological rather than statistical, holistic rather than reductionistic, vitalistic (in at least some sense of the term) rather than mechanistic. What is more, it must necessarily be expressed in qualitative terms for the awe with which ecologists have viewed the biosphere cannot be expressed in the language of mathematics any more than can, for that matter, such holistic concepts as the balance of nature, wholeness, teleology, life, organisation, complexity etc. concepts which modern science is incapable of dealing with.

So as to make it consistent with modern science and the paradigm of modernism, however, ecology has undergone a radical transformation. Donald Worster, in his brilliant book *Nature's Economy,* which has only just been published in England (Cambridge University Press £7.95) tells the story of this transformation. Though he obviously deplores it, he admits that if it had not occurred, then "ecologists might have disappeared as an independent class of researchers and would not occupy today such an influential position among the sciences."

Other students of the history of ecological thinking have noted this extraordinary transformation. Daniel Simberloff, for instance, in his *A Succession of Paradigms in Ecology* tells us that "Ecology has undergone, about half a century later than genetics and evolution, a transformation so strikingly similar in both outline and detail that one can scarcely doubt its debt to the same materialistic and probabilistic revolution. An initial emphasis on a similarity of isolated communities, replaced by concern about their differences: examination of groups of populations, largely superceded by study of individual populations: belief in deterministic succession shifting, with the widespread introduction of statistics into ecology, to realization that temporal community development is probabilistic: and a continuing struggle to focus on material, observable entities rather than ideal constructs . . ."

As a result of this transformation, mainstream scientific ecology no longer reflects the world view of ecology, of traditional man, of the natural theologists, of the Romantic poets, of the early academic ecologists, nor of the ecological movement of today. It is worth considering to what extent the old ecological principles have been rejected.

A well established principle of ecology is that, as natural systems become more complex, so do they become more stable. But this principle became an embarassment to the scientific ecologists and had to be discredited so as to justify both the sytematic replacement of highly complex forest ecosystems and relatively complex traditional agricultural ecosystems with the endless stretches of monoculture required to satisfy the requirements of our modern economy.

In this issue of *The Ecologist,* I shall show how the well-established principle of ecological succession towards a climax—a principle that is difficult to reconcile with the view of society as geared towards perpetual technological and scientific 'progress' has been rejected by the scientific ecologists of today (see Ecological Succession: Rehabilitated, page 104).

As already mentioned, another basic idea of ecology is the 'Balance of Nature', a principle which also came under attack by modern ecologists. It too was intolerable because it suggested that the structure of the world was critical rather than random and could not therefore be transformed with impunity at the hand of industrial man.

The assault on the principle of the balance of nature started in the time of Darwin. "When the locust devastates vast regions and causes death of animals and man" wrote Alfred Russell Wallace, "what is the meaning of saying the balance is preserved?" (Are the devastations of) the sugar ants in the West Indies and the locust which Mr Lyell says have destroyed 800,000 acres, an instance of the balance of species? To human apprehension there is no balance but a struggle in which one often exterminates another".

As ecology became more scientific, so did the balance of nature become ever less acceptable. Charles Elton the famous English ecologist of the inter-war years went so far as to say that "The balance of nature does not exist and perhaps never has existed."

Daniel Simberloff is equally disparaging. "The myth of the balance of nature" he laments "persists in the popular consciousness, and takes systems ecological form in Barry Commoner's condensation of all ecology into 'You can't change just one thing.' " He even attacks the 'ecosystems paradigm —the view that the ecosystem is the correct unit of ecological study—on the grounds that it is but another way of formulating the 'balance of nature' paradigm.

The even more fundamental holistic principle that "the whole is more than the sum of its parts" also came under attack. It is difficult to believe that people who call themselves 'ecologists' can deny this principle which appears to be at the very heart of ecology. If this principle is abandoned one might ask, what is left of ecology? Reductionistic ecology would indeed seem to be a contradiction in terms.

The fact is however that holism is unacceptable to science and to modern industrial society without which there would be no science, and if ecology has to become scientific and conform to the paradigm of modernism then it must clearly cease to be holistic, cease, in fact, to be ecological.

The reductionist approach to ecology is normally traced to the writings of Gleason whose article *The Individualistic Concept of the Plant Association* was first published in 1917. Significantly Gleason's individualistic theory was, to begin with, totally rejected by the ecological community. It simply did not fit in with the ecological paradigm of the times. But as ecology became scientific and respectable it was revived with alacrity just as neo-Darwinists revived Mendel's genetics.

As Pool writes (see McKintosh's article H A Gleason *Individualist Ecologist* 1882-1975) "Forty years of Gleason's views became acceptable" and today as Krebs notes "the present view of the nature of the community lies closer to the individualistic view than to Clement's superorganismic interpretation.' Collier *et alia* (see McKintosh) have gone so far as to say that the individualistic concept "constitutes one of the most influential and widely accepted views at the present time."

So successful has it proved, in fact, that Worster considers that holism has no protagonists left within the ecological community. Simberloff insists that still one remains. It is the great Eugene Odum of the University of Georgia, who "with something of the fervour of a baptist minister is still heard in the land." True enough, Odum's ecology has not been perverted. He still dares to tell us that "the old Folk wisdom about the forest being more than just a collection of trees is the first principle of ecology." He is also an ardent member of the ecological movement.

There must be many others who feel the same way as Odum, and one can only hope that they can be induced to speak out more strongly against the way their discipline has been perverted in the last decades, and induced too to put their knowledge at the disposal of the ecological movement instead of helping to rationalise the suicidal policies that it seeks so desperately to oppose.

Edward Goldsmith

GAIA: A Natural Scientist's Ethic for the Future

by Charles J Hughes

Few books are likely to prove as influential as Jim Lovelock's *Gaia: A New Look at Life on Earth.* However Lovelock's conclusions seem difficult to reconcile with his premisses. If the biosphere is a 'single quasi-living entity', as he suggests it must be, if we are to explain the coordinated way in which organic processes have created those atmospheric conditions that most favour the maintenance of its incredible stability, how can one tolerate, as Lovelock seems to suggest we can, its pollution, indeed its transformation by industrial man?

Interactions *within* plant and animal communities that constitute the biosphere, and interactions *within* the physical environment of earth (including global tectonics, igneous activity, weathering and erosion, the hydrological cycle, atmospheric circulation, radiation and ozone recycling, heat balance, etc.) are enormously complex. What we now discern of interactions *between* the biosphere and the physical environment adds a further dimension of complexity. This complexity includes the physical and chemical cycles of water, carbon, oxygen, nitrogen, iodine, sulphur, and many other minor elements, and the linking role of various forms of energy. The actual compositions of the oceans and of the atmosphere and of soils reflect an extraordinarily delicate *kinetic* equilibrium with life processes, the net result of a great many ongoing processes. Yet another dimension is added by an appreciation of geological *time* and of the rock and fossil record, leading to the realisation that this great equilibrium has changed and is still changing.

We live in an era of rational science when all this is considered not as a sublime mystery but rather as something obeying natural and consistent laws that are capable of scientific investigation and understanding. This attitude, in fact, has become so distinctive a trait of our modern technological civilisation that we would consider it to be merely common sense. But natural scientists (and it is a measure of the dominant position of science in our society that there are far more of them actually alive and working today than have ever lived and passed on) are commonly trained in but one aspect of this great system. A research scientist invariably becomes specialised in some smaller aspect still. Numerous pressures in academic, governmental and commercial professions tend to keep the great majority of scientists specialised and thus, paradoxically, many are surprisingly ignorant of the great drama that enfolds us all.

As a natural scientist myself, fortunately free of constraining pressures, I nowadays keep posted above my desk the following remarkable quotation taken from an essay by Gabrielle Horne, winner at age 15 of the 1979 New Scientist/BAYS essay competition: "Why be a scientist? Because I feel that only as a scientist can I begin to understand that unity of which I am an infinitesimal part, and hopefully find a role in helping to preserve it. And beyond the point where understanding fails, it is only as a scientist that I can stand before it in true reverence."[1]

Once natural scientists emerge from their ivory towers, open their eyes, and achieve the same vision as that of Gabrielle Horne, tempered perhaps by some specialist knowledge and insight and a realisation of Nature's complexities, their reaction is invariably one of awe, humility, and respect. To fully describe this, metaphysical concepts seem unavoidable. For example, Darwin's famous apology of over a century ago still rings in our ears: "There is grandeur in this view of life, with its several powers, having been originally breathed by the Creator into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being evolved."

Lewis Thomas, in his *Lives of a Cell,* records that on a night drive in New England it suddenly came to him that Earth "Is *most* like a single cell" and "It has the organised, self-contained look of a live creature, full of information, marvellously skilled in handling the sun." Again, "It is hard to feel affection for something as totally impersonal as the atmosphere, and yet there it is, as much a part and product of life as wine or bread."[2]

"A part and product of life"—this is the key to understanding. What we customarily regard as the biological and physical environments—the biosphere, lithosphere,

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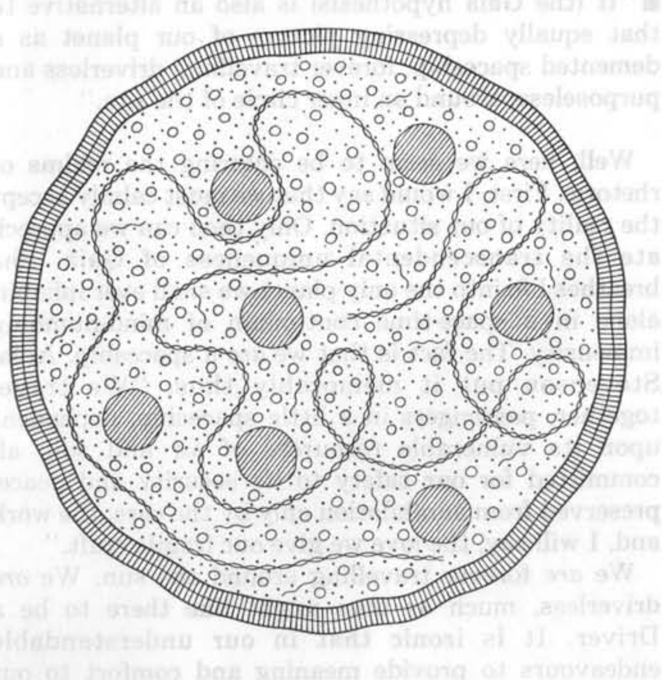

Earth is most like a single cell.

hydrosphere and atmosphere—are in fact so complexly interwoven that as systems they must logically be regarded as one. We find that whatever we may examine can only be fully understood in terms of its reaction with another sphere which itself is critically influenced by what we are examining! We are currently seeing scientific articles written with titles such as *The Salt Sea—Accident or Design?*[3]

Jonathan Schell in his *The Fate of the Earth* has commented: "The more closely scientists look at life and its evolution, the less they find it possible to draw a distinction between 'life', on the one hand, and an inanimate 'environment', on the other."[4]

These ideas have been developed and carried a step further by Dr J.E. Lovelock in his book *Gaia: A New Look at Life on Earth.*[5] Now it is a measure of this book's interest and importance that a majority of my scientific colleagues who have read Gaia once, perhaps with a sense of impatience the first time, have come to reread it at least once again. I hope and expect that many more, and not just scientists, will come to read it, and consider their own reaction to Gaia.

The book begins by documenting numerous apparent disequilibrium features of the Earth's atmosphere and hydrosphere that can only be ascribed to kinetic equilibria involving life processes. Some of these equilibria are surprisingly complex, and the documentation of several depends on extremely sensitive measurements, some using an instrument known as the electron capture detector invented by Dr Lovelock himself. Dr Lovelock proposes that life on Earth is not only a response to and controlled by physical conditions but also modifies and controls its own environment! Naming this concept "Gaia", after the name given by the ancient Greeks to their Earth-Goddess (the same name but differently transcribed, Ge, gives us geology), Dr Lovelock in collaboration with Dr Lynn Margulis defines Gaia as follows: "We have since defined Gaia as a complex entity involving the Earth's biosphere, atmosphere, oceans, and soil; the totality constituting a feedback or cybernetic system which seeks an optimal physical and chemical environment for life on this planet."

This notion I find hard to swallow. It is the expression of sentient feedback as a mechanism that gives me difficulty. Can the great system really be dissected to reveal a causative or controlling agent? Who is to presume to judge, given the known complexities of the many equilibria involved? Is cybernetic the right term—communication between the biosphere and other spheres, yes, but control? Is Dr Lovelock making too extravagant a claim that can in turn lead all too readily, as we shall see, to unwarranted complacency?

Perhaps the fairest conclusion is that Dr Lovelock's claim can neither be proved or disproved. The artefact of man that seems to come closest to describing the great system of Gaia is called General Systems Theory in which variables in a system interact in such a way that, by definition, cause and effect *cannot* be separated. Such a system can be perturbated resulting in changes that are difficult to predict. The system may (or may not) have a built-in tendency to 'homeostasis', that is to say a tendency to reachieve the original equilibrium.

In practical terms, any consideration of the interpretation of Gaia presented by Dr Lovelock leads inevitably to a review of the way in which we must look at ourselves and the environment. To quote from the synopsis on the book's front paper jacket: "This fresh look at life on Earth questions whether conservationists and environmentalists are concerned about the right problems." The issues raised are not trivial. They should be discussed. Again following the concise statements on the jacket, they can conveniently be considered as three philosophical corollaries to the book's concept of Gaia. I believe that I am not doing an injustice to Dr Lovelock's theme by using these three quotes—in any event, they are there, they will be read and noted, and they deserve comment in their own right.

■ "The Gaia hypothesis is an alternative to that pessimistic view which sees nature as a primitive force to be subdued and conquered."

Agreed. We desperately need such an alternative philosophy. Many have commented on the dangerously short-sighted attitudes arising from an acceptance of the view that Nature was created for man. One of the most cogent discussions of this is Lynn White's landmark article *The Historical Roots of our Ecological Crisis,* where the point is made that our ecological crisis will continue to worsen until we consciously reject the axiom, implicit in much of our economic activity, that nature has no reason for existence save to serve us. White concludes "Since the roots of our trouble are so largely religious, the remedy must also be essentially religious, whether we call it that or not."[6]

The life of John Muir reveals the dialectic very clearly. He came to struggle and rebel for years against the rigid views of his Calvinist father, finally left home and walked practically across America, before he achieved spiritual independence and a new vision of living in harmony with nature, a vision incidentally that saved the California redwoods and led to the formation of the Sierra Club.[7] As a counterweight to the type of Calvinism apparently displayed by John Muir's father, I should like to mention the fine book *Earthkeeping: Christian Stewardship of Natural Resources* compiled by the Fellows of the Calvin Center for Christian Scholarship.[8] Its title is a good indication of its expression of deep concern for the proper management of the natural resources of this planet.

The view, however, that the whole of Nature is a God-given domain for man to exploit is a very convenient one for the lobbies of powerful resource industries. It finds a prominent place in the pulpits of some evangelical preachers, notably on American television where aggregate viewing audiences are reckoned in nine figures. It is strongly and perniciously rooted in the greed of the Old Adam in each of us. And it is, unfortunately, flowering in a New Fascism exemplified by the crass ignorance, lies, and posturings of several political figureheads in the world today. Gaia is indeed a meaningful alternative.

■ "Thanks to Gaia, our fears of pollution-extermination may be unfounded."

The assumption here is that Gaia is self-cleansing and has a strong built-in tendency to homeostasis as defined above. While a very comforting notion, the statement is just a bit too facile. It begs numerous questions by attaching too strong and emotive a term ("extermination") to the grim, nagging, ongoing realities of pollution, environmental degradation and the loss of topsoil, forests, habitats, and genetic diversity. Granted, Gaia does have known self-cleansing and stabilising mechanisms—biodegradation of many complex and poisonous organic compounds, carbon dioxide equilibration between atmosphere and hydrosphere, temperature control by radiation and by virtue of the high specific and latent heats of water, an apparently self-sustaining concentration of ozone in the stratosphere, and much more. But we cannot ignore man's activities and the *rates* of disruption and re-establishment of equilibria. Dr Lovelock speculates that Gaia could break down when and if the human population reached ten billion. This figure (which might be approached late next century at a date when Dr Lovelock will be comfortably dead) seems a little bit too glib and well-rounded. Many would say, at least as an insurance policy, let's monitor Gaia's pulse now. We just cannot ignore the fact that this planet contains one purposive species, already exceeding in biomass that of any other species, already using up resources at a non-sustainable rate, and exhibiting an unprecedented rate of population increase. Neither can we ignore that this species is us! Neither, incidentally, can we ignore the fact that extermination following a nuclear holocaust *is* now a real possibility.[9]

■ "It (the Gaia hypothesis) is also an alternative to that equally depressing picture of our planet as a demented spaceship, forever travelling, driverless and purposeless, around an inner circle of the sun."

Well, here we seem to be entering the realms of rhetoric. First, I would say that we must calmly accept the reality of our situation. Only then can we appreciate the transcendental uniqueness of Gaia. She breathes life into the only planet we shall ever inhabit, alone in a space-time continuum of mind-numbing immensity. The fact is that we *are* a spaceship. Adlai Stevenson put it memorably thus: "We travel together, passengers in a little spaceship, dependent upon its vulnerable resources of air and soil; all committed for our safety to its security and peace; preserved from annihilation only by the care, the work and, I will say, the love we give our fragile craft."

We *are* forever travelling around the sun. We *are* driverless, much as man might like there to be a Driver. It is ironic that in our understandable endeavours to provide meaning and comfort to our mortal lives on Earth we have, here and there, erected symbols that at times obscure a true appreciation of Gaia. Our spaceship *is* purposeless. Life exists in a moral vacuum of extinction take the hindmost, in a process of purposeless evolution and extinction. The fossil record, an indisputable historical fact, teaches us this, amply. Evolution, incidentally, is slow; extinction is abrupt.

From this apparently bottomless and potentially depressing existential pit, I think it is possible for a natural scientist to surface with a basis of deep morality and a definite course of action. Like the existentialists in their sociological/philosophical domain, we can search for and achieve an "individual responsibility in an uncertain, changing, and even purposeless world."

My conclusion is simply this. Given that *Homo sapiens* has somehow, very suddenly, arrived at such a position of dominance in numbers, intellect, consciousness, purposiveness, and technology on planet Earth and has been granted some insight into Gaia (call Gaia God's handiwork if you will), should we not do our utmost to preserve Gaia as we are privileged to see Her and form a living and breathing part of Her today? To put things in their lowest terms, it could very well be in our own self-interest to do our best to prevent gross man-made disturbances to the physical and ecological equilibria of Gaia. Should we not preserve the breath-taking heritage of Gaia intact for our descendants? Should we not, right now, abandon complacency where Gaia appears to be threatened? Should we not instil a love of Gaia into everyone on this planet? Should we not be prepared to worship Her and to sacrifice for Her?

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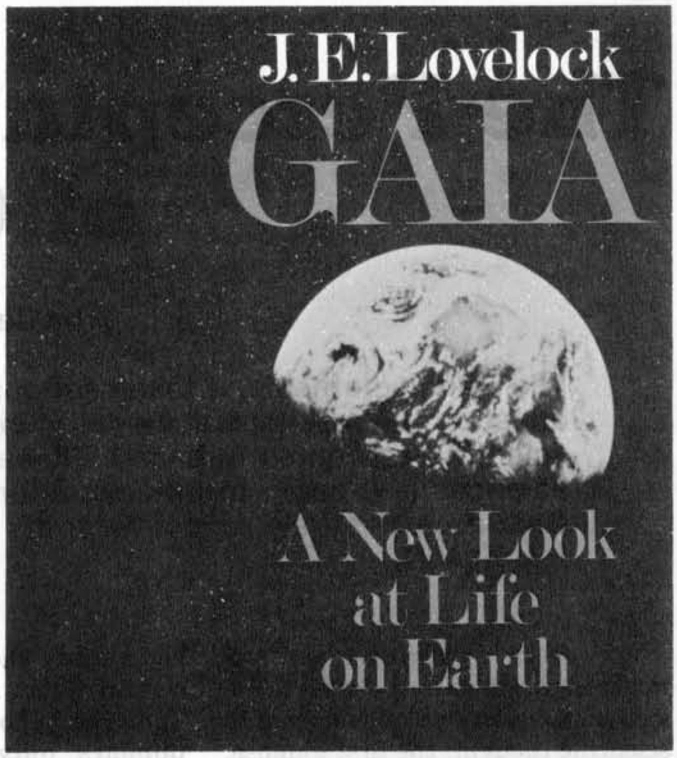

Jim Lovelock replies:

The first Gaia book was written ten years ago. At that time gaia was little more than a speculative hypothesis. It had survived a few tests and made a few predictions that were confirmed but we could only guess the mechanism of planetary self regulation. Ten years ago was also the time of some feverish hype about threats to the world from pollution. It was all too frequently claimed that the minor depletion of ozone by man made chemicals "Would destroy all life on Earth". That spills of crude oil on the sea would render the oceans anoxic. I thought then that this kind of woolly exaggeration would discredit ecology and worse divert attention from the real threats to homeostasis. Namely the large scale destruction of natural habitats, particularly those of the tropics and perhaps also those of the continental shelves. Now we are more sanguine; the rapid growth of the early 1970s has given way to a near stasis, whatever the economists may otherwise claim. Ten years on and ozone far from having become depleted is now itself becoming a threat because of its rapid growth in abundance in the troposphere. The oceans though depleted in whales are healthier than we would have dared to predict. Gaia is becoming visible, she operates through an automatic consensus of her constituents. She is as pitiless as an ICBM. She may not eat her children but she employs the market forces of natural selection to rid her Earth of the lame, the sick and the losers. I am sorry that my enthusiasm has unintentionally given to some readers an erroneous belief in a sentient Gaia that looks after us like a nannie. She is in fact as I described her on page 152 of Gaia, a self stabilising system comprising all of us living things and the environment as a single dynamic entity.

This issue of *The Ecologist* is timely. Peter Bunyard's splendid article has captured the content and the feeling of one the first of new approaches of science to global problems. The day is passing when ambitious academic scientists with ecological doom scenarios can frighten the public into supporting their extravagant researches. In its place there is a realisation that we have a brief breathing space in which to get things right.

The science of gaia portrays a stern and unforgiving entity; her existence like that of life itself depends on the strict rules that run the universe. Without constraints there could be no life or gaia. But there is rarely ever love without pain, beauty without discipline. The metaphor of gaia, is of a very lovely world where we need also the encouragement and optimism of David Abrams and the thoughtful criticism of Charles Hughes to learn to live with her.

The Perceptual Implications of Gaia

by David Abram

The Gaia hypothesis, if taken seriously, has logical implications that call into question the mechanical model of perception upon which most contemporary scientific discourse is based. These implications reach beyond the separate sciences and begin to influence our ordinary perceptual experience. To view Gaia as an entirely objective entity only trivializes the radical nature of the hypothesis.

The Gaia hypothesis, as formulated by geochemist James Lovelock, represents a unique moment in scientific thought: the first glimpse, from within the domain of pure and precise science, that this planet might best be described as a coherent, living entity. The hypothesis itself arose in an attempt to make sense of certain anomalous aspects of the Earth's atmosphere. It suggests that the actual stability of the atmosphere, given a chemical composition very far from equilibrium, can best be understood by assuming that the atmosphere is actively and sensitively maintained by the oceans, the soils, the plants, and the creatures—indeed, by the whole of the biosphere. In Lovelock's own words, the hypothesis states that:

> The entire range of living matter on Earth, from whales to viruses, and from oaks to algae, could be regarded as constituting a single living entity, capable of manipulating the Earth's atmosphere to suit its overall needs and endowed with faculties and powers far beyond those of its constituent parts.[1]

It is gratifying to see that this hypothesis is slowly gaining a hearing in the scientific world, while being further substantiated by biologist Lynn Margulis, whose meticulous research on microbial evolution has already shown the existence of certain Gaian regulatory systems.[2] That the hypothesis will gain proponents only slowly is to be expected, for to accept it as valid is to throw into question many deeply ingrained scientific and cultural assumptions. In fact the recognition of Gaia has powerful implications for virtually every realm of scientific and philosophical endeavour, since it calls for a new way of perceiving our world. In this essay I will explore just a few implications that the Gaia hypothesis holds for our understanding of perception itself.

Our Immersion in Gaia

It is significant that the first evidence that the surface of this planet functions as a living entity should come from a study of the atmosphere, the very aspect of the Earth that we most commonly forget. The air is so close to us that we tend to leave it out of our thinking entirely—much as we do not often attend to the experience of breathing, an act so essential to our existence that we take it for granted. The air that surrounds us is invisible to our eyes; doubtless this has something to do with why we usually act and speak as though there were nothing there. We refer to the *space* between things, or the space between two people; we do not speak of the *air* between us, or the air between oneself and a nearby tree. We generally assume, unless we stop to think about it, that the space between us is roughly coextensive with the space between planets. This is attested by our everyday language—we say that we dwell *on* the Earth, not that we live *within* the Earth. Yet if the Gaia hypothesis is correct, we shall have to admit that we exist *in* this planet rather than *on* it. In direct contradiction to the earlier scientific assumption that life on Earth's surface is surrounded by and adapts to an essentially static environment, Gaia indicates that the atmosphere in which we live and think is itself a dynamic extension of the planetary surface, a functioning organ of the Earth.

It may be that the new emphasis it places on the atmosphere of this world is the most radical aspect of the Gaia hypothesis. For it carries the implication that before we as individuals can begin to recognise the Earth as a self-sustaining organic presence, we must remember and reacquaint ourselves with the very medium within which we move. The air can no longer be confused with mere negative presence or with the absence of solid things: henceforth the air is itself a density—mysterious, indeed, for its invisibility—but a thick and tactile presence nonetheless. We are immersed in its depths as surely as fish are immersed in the sea. It is the Medium, the silent interlocutor of all our musings and moods. We simply cannot exist without its support and nourishment—without its vital participation in whatever we are up to at any moment.

In concert with the other animals, with the plants, and with the

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microbes themselves, we are an active part of the Earth's atmosphere, constantly circulating the breath of this planet through our bodies and brains, exchanging certain vital gases for others, and thus monitoring and maintaining the delicate make-up of the medium. As Lovelock has indicated, the methane produced by the microorganisms that make their home in our digestive tracts—the gas we produce in our guts—may conceivably be one of our essential contributions to the dynamic stability of the atmosphere (less important, to be sure, than the methane contribution of ruminant animals, but essential nonetheless). Small wonder that we of literate culture continue to forget the air, this ubiquitous presence, for we prefer to think of ourselves serving a loftier 'purpose', set apart from the rest of creation. Our creativity, we assume, resides not in the depths of our flesh but in some elevated realm of pure thoughts and ideas that stands somehow outside the organic.[3]

PHOTO: DAVID ABRAM

The Tibetan name for Mt Everest, in the centre, is 'Jomolungma' meaning 'Mother Goddess of the Wind.'

Yet it is only by remembering the air that we may recover a place in the real world we inhabit. For the air is the invisible presence, so little understood, that materially involves us in the internal life of all that we see when we step out of doors, in the hawks and the trees, in the soil and the sea and the clouds. Let us return to this point later. For now it is enough to discern that the Gaia hypothesis implicates the enveloping atmosphere as a functioning part of the overall system. Thus, if we choose to view this planet as a coherent, self-sensing auto-poetic entity, we shall have to admit that we are, ourselves, circumscribed by this entity. If Gaia exists, then we are inside her.

Our Perception of Gaia

Traditionally perception has been taken to be a strictly one-way process whereby value-free data from the surrounding environment is collected and organised by the human organism. Just as biologists had until recently assumed, for simplicity's sake, that life adapts to an essentially passive environment[4], so psychologists have assumed that the senses are passive mechanisms adapted to an environment of random, chance events. The interior human 'mind' or 'subject' is kept apprised of these random happenings in the exterior 'objective' world by the sense organs, mechanical structures that register whatever discrete bits of sensory data—bits of light, sound, pressure—they come into contact with, and transfer these separate bits of information on into the nervous system. Here these separate sensations are built up, step by step, into a representation of the external world. It is this internal representation that is ultimately viewed and given meaning by the innermost 'mind' of the perceiver.

Each of the contemporary sciences must still pay lip service to a model of perception constructed in accordance with nineteenth century notions of the mechanical nature of the physical world and the absolute separation of mind from matter.

Such is the classic model of perception described by the founders of modern scientific psychology toward the end of the last century,[5] and although it has undergone many revisions and qualifications, this account still underlies most of the scientific discourse of our time. Within this account, 'meaning' and 'value' are assumed to be secondary, derivative phenomena resulting from the internal association of external facts that have no meaning in themselves. And the external world is tacitly assumed to be a collection of purely objective, random things entirely lacking in value or meaning until organised by the ineffable human mind. If this sounds like the assumption behind the agenda of today's 'value-free' sciences, we should note that each of the natural sciences completely depends, at some level, upon the exercise of human perception for the accumulation of its data—whether through a microscope, a telescope, or even the keyboard and screen of a computer. Yet none of the separate sciences has ever come up with an alternative description of perception that could supplant the traditional account. (Even quantum physicists, who have long recognised the untenability of this description of perception with regard to the sub-atomic domain, have proposed no substantial alternative.)

Each of the contemporary sciences, then, must still pay lip service to a model of perception constructured in accordance with nineteenth century notions of the mechanical nature of the physical world and the absolute separation of mind from matter. One important reason for our prolonged adherence to an obsolete model may be the fact that, although it does not describe perception as we actually experience it, this model does describe perception as we need to conceive it if we are to continue in our cultural programme of natural manipulation and environmental spoilage without hindrance of ethical restraint. The traditional account of perception as a uni-directional mechanical process is the only account possible if we still assert the convenient separation of psyche, subjectivity, or self-organisation from the material world that surrounds us.

The atmosphere *is* the spirit, the creative awareness of this planet.

The Gaia hypothesis immediately suggests an alternative view of perception. For by explicitly showing that self-organisation is a property of the surrounding biosphere, Gaia shifts the locus of creativity from the human intellect to the enveloping world itself. The creation of meaning, value, and purpose is no longer accomplished by a ghostly subject hovering inside the human physiology. For these things—value, purpose, meaning—already abound in the surrounding landscape. The organic world is now filled with its own meanings, its own syntheses and creative transformations. The chaos of weeds growing in an 'empty' lot is now recognised for its essential, almost intelligent role in the planetary homeostasis, and now even a mudflat has its own mysteries akin to those of the human organism.[6] We begin to glimpse something of the uncanny coherence of enveloping nature, a secret meaningfulness too often obscured by our abstractions. This wild proliferation is not a random chaos but a coherent community of forms, an expressive universe that moves according to a diverse logic very different from that logic we attempt to impose. But if, following the Gaia hypothesis, we can no longer define perception as the intake of disparate information from a mute and random environment, what then can we say that perception is?

The answer is surprisingly simple: perception is communication. It is the constant, ongoing communication between this organism that I am and the vast organic entity of which I am a part. In more classical terms, perception is the experience of communication between the individual microcosm and the planetary macrocosm.

Let us think about this for a moment. If the perceivable environment is not simply a collection of separable structures and accidental events; if, rather, the whole of this environment taken together with myself constitutes a coherent living Being "endowed with faculties and powers far beyond those of its constituent parts",[7] then everything I see, everything I hear is bringing me information regarding the internal state of another living entity—the planet itself. Or rather about an entity that is both other and not-other, for as we have seen, I am entirely circumscribed by this entity, and am, indeed, one of its 'constituent parts'. Perhaps it is misleading, then, to use the term 'communication' to describe a situation in which one of the communicants is entirely a part of the other. The word 'communication', so often associated with a purely linguistic interchange, has overtones of something rather more conscious and willful than what we are trying to describe. Here we are referring to an exchange far more primordial, and far more constant, than that verbal exchange we carry on among ourselves. What is important is that we describe it *as an exchange*, no longer a one-way transfer of random data from an inert world into a living organism, but a reciprocal interaction between two living presences—my own body and the vast body of the biosphere. Perhaps the term 'communion' is more precise than 'communication'. For by 'communion' we refer to a deeper mode of communication, more corporeal than intellectual, a sort of sensuous immersion—a communication without words.

Perception, then—the whole play of the senses—is a constant communion between ourselves and the living world that encompasses us.

Recent Studies of Perception

Such a description of perception, as a reciprocal phenomenon organised as much by the surrounding world as by oneself, is not entirely new to contemporary psychology. Indeed, recent developments in the study of perception indicate that sooner or later it must be reconceptualised as an interactive phenomenon. For example, research on the evolutionary development of perceptual systems in various species suggests that these systems simply cannot be understood in isolation from the communication systems of those species.[8] And at least two of the most important twentieth century investigators working (independently of each other) on the psychology of human perception—Maurice Merleau-Ponty in France and James J. Gibson in the United States—had already begun, decades ago, to speak of the surrounding physical world as an *active* participant in our perceptual experience.

Recognising Gaia from within, as a psychological presence, greatly constrains the extent to which we can consciously alter and manipulate the life of this planet for our own ends.

J. J. Gibson and 'Direct Perception'

James J. Gibson published his text *The Perception of the Visual World* in 1950 and followed it with *The Senses Considered as Perceptual Systems* in 1966 and *The Ecological Approach to Visual Perception* in 1979.[9] In these books Gibson challenged the traditional account of perception, which as I indicated above, describes perception as an internal process whereby an initially meaningless mass of sensory data (resulting, say, from the impingement of photons on the retinal nerve cells) is built up into an internal representation of the external world. This account, true to its Cartesian foundations, assumes a fundamental disjunction between the psychological (human) perceiver, described ultimately in mentalistic terms, and the purely passive environment, described in terms borrowed from physics. Gibson called this entire paradigm into question by asserting that perception must be studied as an attribute *of an organism and its environment taken together.* He showed that if we assume a natural compatibility between an animal and its environment—what he and his followers refer to as an 'animal-environment synergy'—then perception is recognised not as an indirect process carried out inside the organism but a direct exchange between the organism and its world.

Gibson felt that artificial laboratory situations had misled psychologists into conceptualising perception as a physically passive, internal, cerebral event. He believed that researchers studying perception should not construct artificially isolated and static experimental conditions that have nothing to do with everyday life—instead they should strive to approximate natural conditions. If they did so they would come to understand the senses not as passive mechanisms receiving valueless data but as active, exploratory systems attuned to dynamic meanings already there in the environment. These dynamic meanings, or 'affordances' as Gibson has called them, are the way specific regions of the environment directly address themselves to particular species or individuals. Thus, to a human a maple tree may afford 'looking at' or 'sitting under', while to a sparrow it affords 'perching', and to a squirrel it affords 'climbing'. But these values are not found inside the minds of the animals. Rather they are dynamic, addressive properties of the physical landscape itself when the landscape is comprehended in a manner that does not artificially separate it from the life of the various organisms that inhabit it and contribute to its continuing evolution—that is, when the environment is understood as but one part of an 'animal-environment synergy'.

In short, for Gibson and those who carry on Gibson's work (the 'direct perceptionists') perception is elucidated as a reciprocal interchange between the living intentions of any animal and the dynamic affordances of its world. The psyche, as studied by these psychologists, is a property of the ecosystem as a whole.

Merleau-Ponty and 'the Primacy of Perception'

Maurice Merleau-Ponty had already come to some very analogous conclusions in his major study, *The Phenomenology of Perception*, published in France in 1945.[10] He did not seek to build a finished theory of perception but simply to attend as closely as possible to the experience of perception and to describe it afresh. In doing so he steadfastly refuses to construct an explicit system which we might reify into yet another frozen concept, another 'internal representation' to set between ourselves and our environment. Instead he seeks a language, a way of speaking that will not sever our living bond with the world.

One of the major accomplishments of his *Phenomenology* was to show that the fluid creativity we commonly associate with the human intellect is, in actuality, an elaboration or recapitulation of a deep creativity already underway at the most immediate level of bodily experience. For Merleau-Ponty, it is the body—the organic, sensitive body itself—that perceives the world and, ultimately, thinks the world—not some interior and immaterial mind. Through an intricate and lucid analysis, Merleau-Ponty slowly discloses perception as an almost magical activity in which the 'lived-body' orients and responds to the active solicitations of the sensory world, a sort of conversation carried on beneath all our speaking between the body and the gesturing, sounding landscape it inhabits. In numerous later essays, Merleau-Ponty disclosed this perceptual 'pact' between body and world as the very foundation of truth in history, in political thought and action, in art and in science.

Perception itself is a communication or communion between an organism and the living biosphere.

In the book on which he was working at the time of his early death in 1962—published posthumously, in unfinished form, as *The Visible and the Invisible*[11]—Merleau-Ponty took up this earlier analysis of perception and carried it a step further, seeking to describe experientially the actual world to which our senses give us entry, the common domain that we investigate with our reason and science. He found that the invisible in man—the region of thought and ideality—is inextricably intertwined with the shifting, metamorphic, intelligent nature of the enveloping world. If perception gives way in us to thought and reflective awareness, these are not properties closed within the human brain, but are the human body's open reply to questions continually put to it by the subtle self-organising character of the natural environment.

Merleau-Ponty's thought is far too complex and elusive to be summarised here. Yet I believe it is possible to experience Merleau-Ponty's radical undoing of the traditional 'mind-body problem', simply by dropping the conviction that one's mind is anything other than the body itself. If one is successful in this then one may abruptly experience oneself in an entirely new manner—not as an immaterial intelligence inhabiting an alien, mechanical body, but as a magic, self-sensing form—a body that is itself awake and aware, from its toes to its fingers to its tongue and its ears—a thoughtful and self-reflective animate presence. (This corresponds, roughly, to the first stage in Merleau-Ponty's investigation—the period of the *Phenomenology of Perception*.) Yet if one maintains this new awareness for a duration of time, becoming comfortable enough with it to move about without losing the awareness, one will begin to experience a corresponding shift in the physical environment. Birds, trees, even rivers and stones begin to stand forth as living, communicative presences.

For when my intelligence does not conceive of itself as something apart from the material body but starts to recognise its grounding in these senses and this flesh, then it can no longer hold itself apart from the natural world in which this body has its place. As soon as my awareness forfeits its claim to a total transcendence and acknowledges its inherence in this physical form, then the whole of the physical world shudders and wakes . . . This experience corresponds to the second, unfinished phase in Merleau-Ponty's writing, when he refers less often to the body as the locus of perceptual experience and begins to write of the collective 'Flesh', his term for the animate, sensitive existence that encompasses us (of which our own sentient bodies are but a part).

Thus Merleau-Ponty, who in his earlier work had disclosed the radically incarnate nature of awareness and intelligence, ends by elucidating the world itself from the point of view of the intelligent body—as a wild, self-creative, thoroughly animate macrocosmos. Perception is now understood as the 'Chiasm', the continuous intertwining between one's own flesh and 'the Flesh of the World'.

Lovelock is underscoring the fact that neither humanity nor any other species we know can exist outside the incredibly complex Terran metabolism of which our own bodies and minds are an internal expression.

So both Gibson and Merleau-Ponty, pursuing two different styles of analysis inherited from their respective intellectual traditions, arrive at an alternative understanding of perception not as a cerebral event but as a direct and reciprocal interchange between the organism and its world. While Gibson's followers strive to map this interchange in precise, systematic theorems, Merleau-Ponty sought a new language which could ground the various disciplines in an awareness of perception as radical participation. In doing so he began to uncover, hidden behind our abstractions, a sense of the Earth as a vast, inexhaustible entity, the forgotten ground of all our thoughts and sensations.

These two steps toward a post-Cartesian epistemology are remarkably consonant with the Gaia hypothesis and the implication that perception itself is a communication or communion between an organism and the living biosphere.

Reconsidering Perception

Still, we must further clarify our Gaian definition of perception by answering two obvious objections. Some may object that it is meaningless to speak of perception as a direct communion between oneself and the planetary macrocosm, since in many situations one's senses are directly engaged only in relation to another individual organism—as when one is simply talking with another person. Furthermore, even when one is perceptually attuned to many different phenomena at once—when, for example, one is hiking through a forest—still one's senses are then interwoven within a single specific region of the planet, a 'bioregion' or ecosystem that has its own internal coherence distinct from the planet as a whole. Therefore, if perception is a communion it is at best a communion with relative wholes within Gaia.

But this is merely a provisional objection. We may certainly define specific regions or worlds within Gaia as long as we acknowledge Gaia's presence behind these. For if Lovelock's hypothesis proves correct, then it is the overall planetary metabolism that lends organic coherence to the myriad systems or wholes within it. A forest ecosystem is one such whole. A human ecosystem or culture is another, and when conversing among ourselves we are directly involved in the whole linguistic culture that provides the language for our exchange.

A closer look at perception is also called for at this point. Traditional research on perception has sought to study each sense as a separate and exclusive modality. Merleau-Ponty, however, has shown that in immediate experience perception is a thoroughly *synaesthetic* phenomenon. In everyday life, in other words, the so-called 'separate' senses are thoroughly blended and intertwined, and it is only in abstract reflection, or in the psychologist's laboratory, that we are able to isolate the various senses from one another. Thus, my perception of the waves breaking upon the shore in front of my cabin is far more than a visual encounter. The swell of each wave as it rolls toward me, the tumbling crash of those waters before they sweep across the beach, only to hiss back down, overturning all the pebbles, to meet the next vortex—these are experiences in which visual, aural, and visceral/tactile modalities all envelope and inform each other. A certain ocean smell, as well, permeates the whole exchange, lending it an unmistakable flavour.

Very little is known about the mysterious chemical senses of smell and of taste. Yet it is with these subtle senses that we perceive the state of the very medium in which we move. We both smell and 'taste' the atmosphere in the course of our breathing, and these sensations are so constant, so necessary, and yet so unconscious (or unattended to) that we may say they provide the hidden context for all the rest of our perceiving. And as Lovelock's work indicates, the atmosphere is a complex but thoroughly integrated phenomenon, perhaps the most global of all the Earth's attributes. As I become more aware that this organism I am not only perceives things *through* the atmosphere but also perceives the atmosphere itself—that I constantly smell, taste, and touch the atmosphere as well as hear it rustling in the leaves and see it billowing the clouds—I will come to realise the extent to which my senses do indeed keep me in direct and intimate contact with the life of the biosphere as a whole.

This wild proliferation is not a random chaos but a coherent community of forms, an expressive universe that moves according to a diverse logic very different from that logic we attempt to impose.

A second important objection to our ecological view of perception as a communion with the Earth will come from those who point out that there is much we perceive that is not of this planet—the other planets, the moon, the stars, and our own star, the sun. While obviously not unfounded, this objection still rests on the assumption that we dwell *upon the surface* of an essentially inert planet. Yet if we recognise Gaia as a self-regulating entity, we must recognise the enveloping atmosphere as a part of that entity. All that we know of other worlds reaches us via the rich and swirling atmosphere of our own world, filtered through the living lens of Earth's sky. Even when we consider the dependence of vision on the radiant light of the sun, we must acknowledge that the sunlight we know is entirely conditioned by the air that envelops and is a part of the living biosphere. While Gaia depends on the sun for its nourishment, we depend on Gaia. If we venture beyond the edges of its atmosphere it is the living Earth that enables us to do so: we go in vehicles made of Earth and filled up with Earth's sky—we need this in order to live. This, I believe, is the deeper significance of James Lovelock's other planets in order to make them habitable by human life, Lovelock is underscoring the fact that neither humanity nor any other species we know can exist outside the incredibly complex Terran metabolism of which our own bodies and minds are an internal expression—if we wish to colonise other worlds we shall have to bring this metabolism with us. We are entirely a part of the life that envelops this planet, and thus the ideas concerning what he calls the 'terraformation' of other planets (mentioned by Margulis and Sagan in their article in *The Ecologist* 13:5, and criticised by Bunyard in the same issue). By contemplating how humanity might someday transfer the complex Gaian metabolism to living Earth as a whole is the constant intermediary between ourselves and the rest of the universe.

Our senses never outstrip the conditions of this living world, for they are the very embodiment of those conditions. Perception, we must realise, is more an attribute of the biosphere as a whole than the possession of any single species within it. The strange, echolocating sensory systems of bats and of whales, the subtle heat-sensors of snakes, the electroreception of certain fish and the magnetic field sensitivity of migratory birds are not random alternatives to our own range of senses—rather they are necessary adjuncts of our own sensitivity, born in response to variant aspects of a single harmonious whole.

Once perception is understood in this light, as interaction and exchange, as communion and deep communication, then several of the puzzles which haunt contemporary psychology will begin to resolve themselves. For instance, the notion of 'extra-sensory perception', itself a contradiction in terms, may be recognised as the necessary by-product of the contemporary assumption that ordinary perception is an entirely mechanical phenomenon. If we assume that the senses are merely passive mechanisms geared to an environment of random, chance events, then any experience of direct, non-verbal communication with others will inevitably be construed as a bizarre, ineffable occurrence that takes place in some extraordinary dimension outside the material world. But we have only to consider the amount of chemical information regarding the changing internal state of an organism that is continually exhaled, expelled, and secreted into the ambient air—information that may be picked up, consciously or unconsciously, by the chemical senses of any nearby organism—to realise the extent to which a form of subtle communication may be carried on by our bodies at an entirely prereflective level. In a like manner our eyes and our ears are capable of discriminations far more subtle than those to which we normally attend. When

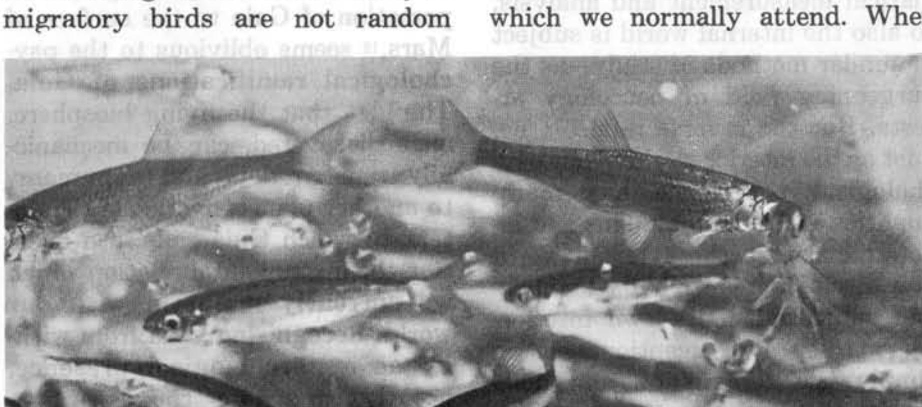


PHOTO: AMBIO

We are immersed in Gaia as surely as fish are immersed in the depths of the sea.

these organs are taken together with the organs of taste, smell and touch, as interactive components of a single synaesthetic perceptual system, we may discern that the living body is a natural clairvoyant, and that 'extra-sensory perception' is *not* extrasensory at all.

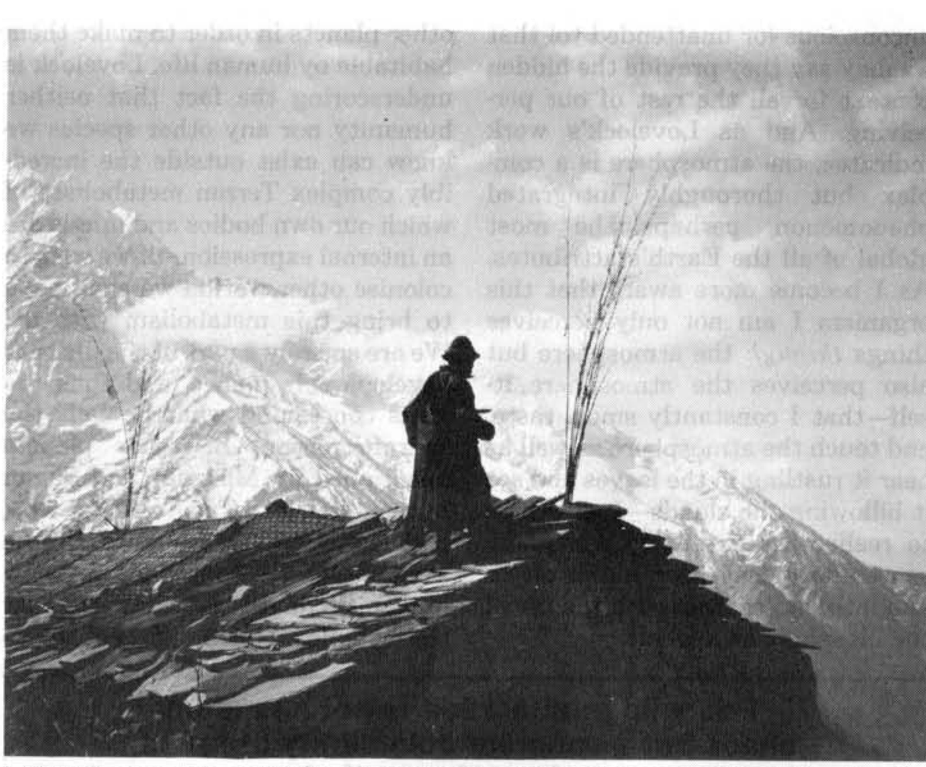
Perception as Communion

The concept of a living biosphere enveloping the Earth provides a condition for the resolution of numerous theoretical dilemmas. I have focused, in this article, on the paradox engendered by the assumption that, within the physical world, awareness is an exclusively human attribute. If the external world exists only according to mechanical laws of determinacy and chance, what then is the point of contact between such a determinate world and human awareness—i.e., what is perception? I have suggested that in fact the external world is not devoid of awareness—that it is made up of numerous subjective experiences besides those of our single species—and furthermore that these myriad forms of biotic experience, human and non-human, may collectively constitute a coherent global experience, or life, that is not without its own creativity and sentience.

If such is the case, as the evidence for Gaia attests, then perception is no longer a paradox, for there is not the total disjunction between 'inside' and 'outside' worlds that was previously assumed. Just as the external world is subject to mathematical measurement and analysis, so also the internal world is subject to similar methods of study—as the burgeoning field of neurology attests. But the reverse is also true. Just as the interior world of our psychological experience has many qualities that are ambiguous and indeterminate, so the external world now discloses its own indeterminacy and subjectivity—its own interiority, so to speak. Perception, then, is simply the communion and deep communication between our own organic intelligence and the creativity that surrounds us.

We cannot transform Gaia

A recognition of the perceptual ramifications of the Gaia hypothesis



A Himalayan shaman, or Djankri, consecrates a neighbour's house by ritually invoking the spirits of the mountains and the wind.

PHOTO: DAVID ABRAM

is, I believe, essential to any genuine appraisal of the hypothesis. Without an awareness of Gaia as *this very world* which we engage not only with our scientific instruments but with our eyes, our ears, our noses and our skin—without the subjective discovery of Gaia as a sensory, perceptual, and psychological power—we are apt to understand Lovelock's discovery in exclusively bio-chemical terms, as yet another scientific abstraction, suitable for manipulating and engineering to fit our purposes.

Lovelock himself, in his most recent speculations regarding the exportation of Gaia to the surface of Mars,[12] seems oblivious to the psychological ramifications of Gaia. The idea that the living biosphere, once discovered, can be mechanically transferred, by and for humans, to another planet, overlooks the extent to which Gaia calls into question the instrumental relation which we currently maintain with our world. Recognising Gaia from within, as a psychological presence, greatly constrains the extent to which we can consciously alter and manipulate the life of this planet for our own ends.

As I have attempted to show, the discovery of a unitary, self-regulating biosphere, if accepted, completely undermines the classical account of perception upon which each of the separate sciences, until now, has been based. If our senses, our perceptions, and our whole manner of thinking have taken shape in reciprocal coevolution and communion with a coherent living biosphere, then in all probability it is our own Earth whose traces we actually discover in our most abstract investigations of quantum and astronomical spaces, the living Earth peering back at us through all our equations. For until we have recognised *perceptually* our organic embeddedness in the collective life of the biosphere—until we have realigned our thoughts with our senses and our embodied situation—any perception of other worlds must remain hopelessly distorted.

The theoretical discourse of our time has largely alienated us from the world of our everyday senses, while accustoming us to speak casually of the most far-flung realities. Thus other galaxies, 'black holes', the birth of the universe, the origins of space and of time, all seem quite matter-of-fact phenomena easily encompassed by the marvellous human mind. But Gaia, as a reality that *encompasses us*, a phenomenon we are immediately *in* and *of*, suggests the inconsistency of such blackboard abstractions. Gaia is no mere formula—it is our own body, our flesh and our blood, the wind blowing past our ears and the hawks wheeling overhead. Understood thus with the senses, recognised from within, Gaia is far vaster, far more mysterious and eternal than anything we may ever hope to fathom.

I have suggested that the most radical element of the Gaia hypothesis, as presently formulated, may be the importance that it places on the air, the renewed awareness it brings us of the atmosphere itself as a thick and mysterious phenomenon no less influential for its invisibility. In Native American cosmology, the air or the Wind is the most sacred of powers. It is the invisible principle that circulates both within us and around us, animating the thoughts of all breathing things as it moves the swaying trees and the clouds.[13] And indeed, in countless human languages the words for spirit or psyche are derived from the same root as the words for the wind or the breath. Thus in English the word 'spirit' is related to the word 'respiration' through their common origin in the Latin word 'spiritus', meaning 'breath'. Likewise our word 'psyche', with all its recent derivations, is related to the ancient Greek 'psychein', which means 'to breathe' or 'to blow (like the wind)'.

If we were to consult some hypothetical future human about the real meaning of the word 'spirit', he might reply as follows:

> Spirit, as any post-industrial person will tell you, is simply another word for the air, the wind, or the breath. The atmosphere *is* the spirit, the creative awareness of this planet. We all dwell within the spirit of the earth, and this awareness circulates within us. Our individual psyches, our separate subjectivities are all internal expressions of the invisible awareness, the air, the psyche of this world. And all our perceiving, the secret ongoing work of our eyes, our nostrils, our ears and our skin, is our constant communication and communion with the life of the whole. Just as, in breathing, we contribute to the ongoing life of the atmosphere, so also in seeing, in listening, in real touching and tasting we participate in the evolution of the living textures and colours that surround us, and thus lend our imaginations to the tasting and shaping of the Earth. Of course the spiders are doing this just as well . . .

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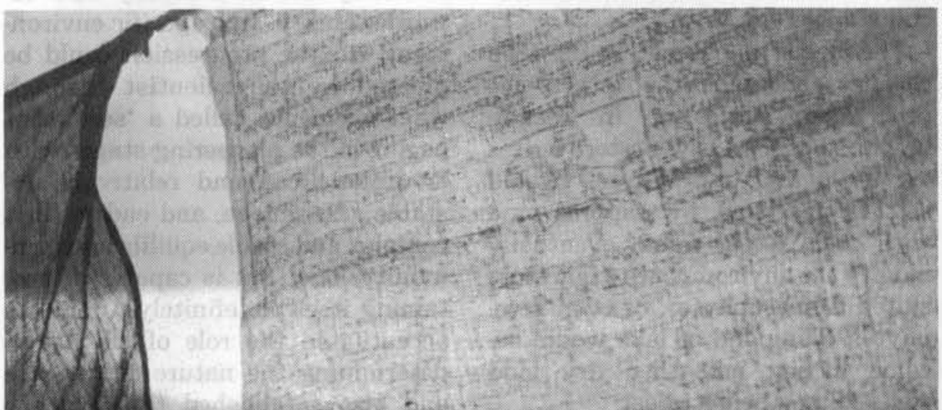


PHOTO: DAVID ABRAM

Tibetan prayer flags: It is believed that the Wind, after brushing these flags will carry the prayers written on them wherever it wanders.

Ecological Succession Rehabilitated

by Edward Goldsmith

Ecology, so as to be made scientifically respectable and also compatible with the paradigm of modernism, has become reductionistic, mechanistic and quantified. To achieve this, has meant seeking to discredit the basic principles of ecology, formulated by the great early ecologists such as Thoreau, Clements and Shelford. One such basic principle is that of "ecological succession". The author shows what were the real reasons for "discrediting" this principle. Rather than being objective as science is supposed to be, they were in fact largely ideological and political. The old well-established principle of ecological succession to a climax must be rehabilitated.

An important principle of ecology is that ecosystems develop in a series of stages which must all occur in the right order—a process referred to as 'succession' which continues until a 'climax' is reached—a situation from which there is then little change as it is the most stable one achievable in the circumstances.

The idea is an old one. In the 18th century, naturalists observed the process of succession in Scandinavian bogs. As Worster writes "water-loving hydrophytes would settle a pond and, by trapping mud with their roots, would eventually modify the environment to one more suited to mesophytes, or even xerophytes. The pond or lake would become a bog and then dry land covered by a dense forest."[1]

The principle of succession was clearly formulated by Warming. He considered that it proceeded in a definite direction—towards a climax formation or final community. This notion Warming regarded as central to the new discipline of ecology.

Later (1899) H C Cowles made his pioneer studies of succession of plants on the sand dunes of Lake Michigan while V E Shelford studied succession among animal populations. Both studies showed that as the dunes became older so were the species of plants and animals inhabiting them completely replaced by different species.

Succession was regarded by Frederick Clements as fundamental to the developing science of ecology. Nature, he considered, did not move aimlessly but as a steady flow toward stability. In a specific environment, a clear progression could be plotted by the scientist through what Clements called a 'sere' that begins in the pioneering stages with an unbalanced and relatively unstable assemblage, and ends with a complex and stable equilibrium community, one that is capable of sustaining itself indefinitely. Clements accentuated the role of climate in determining the nature of the sere and also established the principle that in any given habitat the sere could only end in a single climax (monoclimax). He was later to be seriously attacked on both these counts.

As Worster notes, Clement's theory of succession and the climax undoubtedly reflected his "underlying, almost metaphysical faith that the development of vegetation must resemble the growth process of an individual plant or animal organism."[2] This view is unacceptable to modern science and hence to modern scientific ecology on a number of counts.

Firstly, it tends to confirm the unacceptable idea that an ecosystem is a 'superorganism' as Clements maintained, or at least that it resembles an organism in a significant way. Secondly, it implies that the development of an ecosystem is not the result of random changes selected by an undefined environmental 'invisible hand' in accordance with their competitive skills (as all life processes tend to be viewed today) but occurs instead according to an orderly strategy. Thirdly, it implies that this strategy is carefully coordinated by the ecosystem. This means that ecological development is at once teleological and holistic—a nightmarish thought for our scientists and hence for our scientific ecologists who are ideologically committed to a random and atomised world.

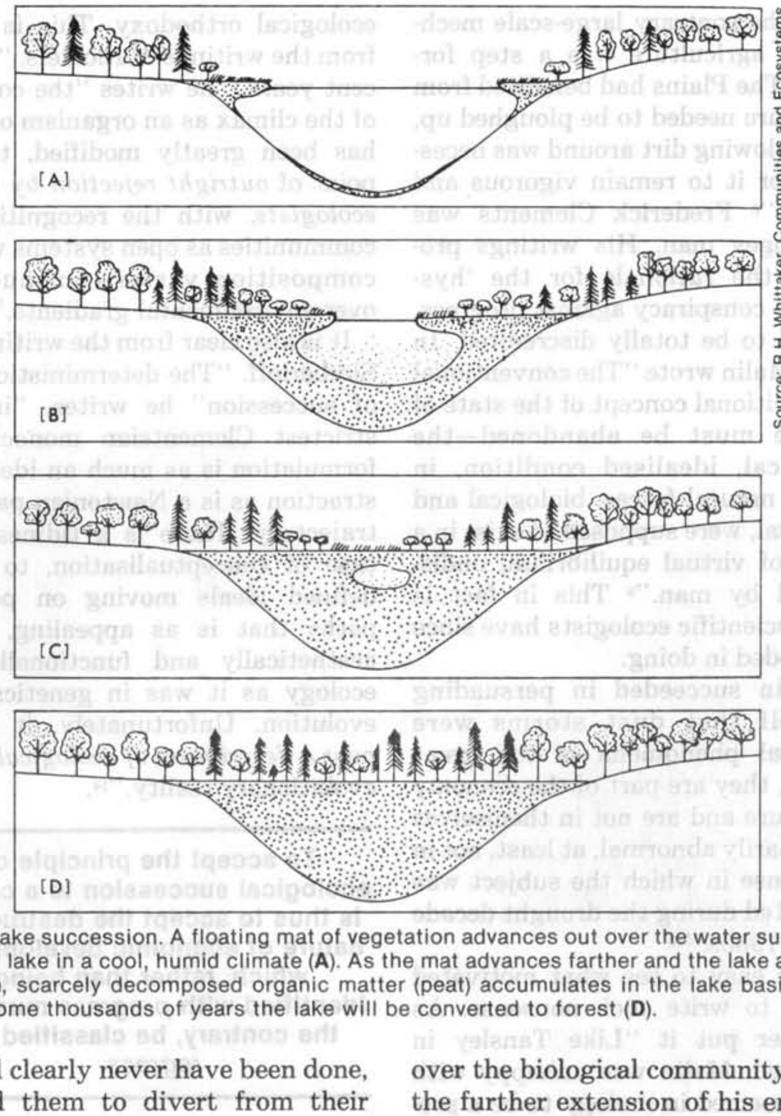
It is unacceptable for yet another closely associated reason, which is that it implies that the goal of ecological development is the achievement of stability, whereas our modern industrial society is committed to perpetual change in a single direction, which can only occur by reversing the successional process or sere or by artificially maintaining the ecosystem at its most productive pioneering stage which happens to be, ecologically, the least advanced—the stage most marked by discontinuities such as floods, droughts, epidemics, population explosions and wars.

To accept the principle of ecological succession to a climax is thus to accept the destructive nature of economic development which, from the ecological point of view, rather than being identified with *progress* must, on the contrary, be classified as *'regress'*.

It was mainly—though perhaps subconsciously—for these reasons that ecologists imbued with the paradigm of modernism, eventually came to reject Clement's thesis. Clements may have gone too far—for instance, climate is clearly not the only factor in determining the nature of a climax, nevertheless, his basic thesis is obviously correct.

Gleason, not surprisingly, was one of the first to reject it. In 1910 he wrote "it is impossible to state whether there is one definite climax association in each province: it seems probable that there are several such associations each characteristic of a limited portion."[3] And in 1927 he said ". . . succession is an extraordinarily mobile phenomenon whose processes are not to be stated as fixed laws, but only as general principles of exceedingly broad nature, and whose results need not, and frequently do not, ensue in any definitely predictable way."[4]

Succession, in this way, ceased to be a directive process tending towards a definite goal. Gleason tended to regard it instead as a random process just as he regarded the association as a random arrangement of individuals. "In the centre of an association" . . . he wrote ". . . we see only the fluctuations in structure from year to year."[5] He even suggested that succession might be retrogressive.



A bog lake succession. A floating mat of vegetation advances out over the water surface in a small lake in a cool, humid climate (**A**). As the mat advances farther and the lake ages (**B**) and (**C**), scarcely decomposed organic matter (peat) accumulates in the lake basin, until after some thousands of years the lake will be converted to forest (**D**).

Controversy over the dustbowl

The whole question came to a head during the debate over the great dustbowl in the late 1930s. Ecologists, at the time, showed that the crisis was a man-made one. Ploughing the southern plains, which should clearly never have been done, caused them to divert from their climax state and the dustbowl was the consequence. During the debate that followed, the very notion of a 'climax' came under attack. Tansley, the Oxford ecologist was particularly keen to discredit the concept. He insisted that man, with his great ingenuity, was capable of creating his own climax, an 'anthropogenic climax' as he called it, which was superior to the natural variety. Tansley's motive was clear. To quote Worster, he "did not want to accept any climax achieved by purely natural processes as an ideal for man to respect and follow. His concern was not to re-establish man as a part of nature, but to put down the threat to the legitimacy of human empire posed by the natural climax theory. If Tansley was right and there were no meaningful differences between the balance achieved by nature and that contrived by man—if the two systems were at least equals in quality and performance—then what reasonable objection could there be to man's rule over the biological community, or to the further extension of his empire? The effect of Tansley's proposal, in other words, would be to *remove ecology as a scientific check on man's aggrandising growth*. The Clements stand of the climatic climax must be replaced, he was saying, by a kind of environmental relativism: there would then be no exterior model against which the artificial environment could be evaluated scientifically. The yardstick would be tossed away, *and man would again be free to design his own world*."[6]

Clement's climax was also attacked very bitterly by the agricultural historian James Malin in 1956. According to Worster, it was the latter's purpose over a number of decades, to defend the battered reputation of the farmers "against the 'Evangelical conservationists' ". "No more brazen falsehood", Malin insisted "was ever perpetrated upon a more gullible public than the allegation that the dust storms of the 1930s were caused by the 'plough that broke the plains'."[7]

On the contrary large-scale mechanised agriculture was a step forward. The Plains had benefited from it, nature needed to be ploughed up, and "blowing dirt around was necessary for it to remain vigorous and fertile."[8] Frederick Clements was the bogey man. His writings provided the rationale for the 'hysterical' conspiracy against progress. It had to be totally discredited. In 1953 Malin wrote "The conventional or traditional concept of the state of nature must be abandoned—the mythical, idealised condition, in which natural forces, biological and physical, were supposed to exist in a state of virtual equilibrium, undisturbed by man."[9] This in fact is what scientific ecologists have since succeeded in doing.

Malin succeeded in persuading himself that dust storms were 'natural phenomena of the great plains, they are part of the economy of nature and are not in themselves necessarily abnormal, at least, not in the sense in which the subject was exploited during the drought decade of the 1930s."[10]

It is easy to see what motivated Malin to write such nonsense. As Worster put it "Like Tansley in England, Malin was unhappy with what seemed in ecology to be a prejudice against civilisation: a belief that 'only civilised man was evil' and that he had no moral right to alter the natural order. The preservationist's oft-repeated charge of 'rape' for what modern man had done to the grassland especially enraged him, in part because it implied that nature is more than a mere thing, that it has personal character, that it is female and vulnerable. Nor would he accept any distinction between the environmental impact of the Indian and of the White man."[11]

Neither James Malin, nor his associate Carl Sauer, even bothered to disguise their motives. The idea of the climax, they asserted "assumes the end of change"—which they had been clearly taught to see as providing a panacea to every possible problem.[12]

The position of modern scientific ecologists

Ironically, it is the anti-ecological ideas of Gleason, Tansley and Malin that have come to be regarded as the ecological orthodoxy. This is clear from the writings of Ricklefs, "In recent years," he writes "the concept of the climax as an organism or unit has been greatly modified, to the point of *outright rejection by many ecologists*, with the recognition of communities as open systems whose composition varies continuously over environmental gradients."[13]

It is also clear from the writings of Simberloff. "The deterministic path of succession" he writes, "in the strictest Clementsian monoclimax formulation is as much an ideal abstraction as is a Newtonian particle trajectory. There is a tidiness, an ease of conceptualisation, to well-defined ideals moving on perfect paths that is as appealing, both aesthetically and functionally, in ecology as it was in genetics and evolution. Unfortunately, it is as *poor a description of ecological* as of evolutionary reality."[14].

To accept the principle of ecological succession to a climax is thus to accept the destructive nature of economic development which, rather than being identified with *progress* must, on the contrary, be classified as *regress*.

It is equally clear from the writings of Whittaker. "The more closely vegetational dynamics are observed", he writes, "the less clear-cut becomes the distinction between climax and successional communities. Vegetation does not really consist of climaxes and successions leading toward them. In a long-range perspective, the vegetation of the earth's surface is in incessant flux; what we observe in the field are not simply successions and climaxes, but only different kinds and degrees of vegetational stability and instability, different kinds and rates of population change."[15]

Elsewhere, he makes the same points somewhat differently: "If one seeks to view this complexity in perspective," he writes, "in terms of species populations in space and successional and evolutionary change and without the intervention of man's ecological abstractions, then the view of the forest is not one of clear and orderly associations, successions, and phylogeny. It is one of a veritable shimmer of populations in space and time."[16]

It is also clear from the writings of Pickett: "The classical interpretation of succession as development of vegetation through discreet stages culminating in a regional climax . . ." he writes, "has been abandoned by modern ecologists." Though he has the grace to admit that "no ecological complete, contemporary model has replaced it."[17]

In line with current scientific dogma, ecological succession tends to be explained today in terms of competition and in terms too of the properties of populations rather than of whole ecosystems. This is pointed out by Connell and Slayter for instance,[18] and also by Pickett.[19] It is also the view of Putnam and Wratten.

Pioneering species, the latter tell us, are replaced "not just because the environment does not suit them but because they are poor competitors and competition is more intense in climax ecosystems."[20]

It is difficult to see how they can really believe this. The operation of all sorts of internally generated negative-feedback mechanisms which Odum even refers to as 'environmental hormones'[21] and which inhibit the growth of species that are replaced by other species in the succession towards a climax is clearly visible to all but the most prejudiced eye.

Ricklefs alludes to the operation of such a mechanism when describing the process of succession on abandoned farmland in the piedmont region of North Carolina. He describes how "Decaying horseweed roots stunt the growth of horseweed seedlings:" and how "this self-inhibiting effect, whose function and origin is not understood, cuts short the life of horseweed in the sere. Such growth inhibitors presumably are the byproduct of other adaptations that increase the fitness of horseweed during the first year of succession. If horseweed plants" he writes, "had little chance of persisting during the second year, owing to invasion of the sere by superior competitors, self-inhibition would have little negative selective value."[22]

Putnam and Wratten also refuse to see the development of an ecosystem and the achievement of a climax as the result of a long-term strategy, indeed not even in terms of any of the intrinsic features of a developing ecosystem.

If ecosystem development is not in this way, an orderly strategy, then the climax cannot be its logical outcome, instead it must be seen as 'thrust upon' the system from the outside. For this reason they suggest that we abandon the use of the term climax altogether and use instead the term 'end community'.[23]

How then does their version of succession occur? Putnam and Wratten offer but the most simplistic answers—the only ones, as one might have guessed, that can be quantified and modelled by systems ecologists, the only ones reconcilable too with the simplistic view of life adopted by modern science today.

What they actually suggest is that succession is simply the result of 'an accumulation of biomass' which stops when there is no opportunity to accumulate any further biomass, because the process has in fact come up against gross features of the environment that are immutable—physical barriers— a shortage of resources for further growth.

Alternatively they see it in purely energetic terms as "an imbalance within the energy relations of the community resulting in the accumulation of biomass by the community."[24]

Both these explanations are based on the notion that the behaviour of an ecosystem is random, mechanistic, individualistic and hence uncoordinated, and also passive and externally controlled as indeed must be all life processes if they are to be fitted Procrustean-like into the paradigm of modernism.

Putnam and Wratten then reveal their ideological bias still more clearly. Productivity they tell us is often low in a climax by comparison to that of earlier stages in the succession "due to the complexity of web-design, cycling of materials through the system is extremely slow."[25] Such features of a climax have traditionally been regarded as beneficial. But Putnam and Wratten wonder if they really are.[26]

They point out that there are "many examples of far more productive, indeed far more diverse communities characteristic of earlier, pre-climax seral stages." They then ask whether a climax is in fact tantamount to over-maturity?"[27]

The argument assumes that productivity is the yardstick for judging ecosystems. This also was the argument of Tansley and Malin—of those, if we remember, who opposed the application of any constraints on man's ecologically destructive activities. It is the ultimate irony that those who advance it should call themselves 'ecologists'.

A non-biological explanation

But Putnam and Wratten, in line with other modern ecologists, go still further in their efforts to rationalise their ideological commitment to technological progress. They tell us that a biological explanation of succession towards a climax may not be necessary at all. All we are witnessing, they suggest is an example of a "statistical process known as a 'regular Markov chain'".[28]

A Markov chain, they tell us, is a "stochastic process in which characteristic probabilities depend only on a current state and not any previous state". As it develops it eventually settles into a pattern "in which various states occur more or less with characteristic frequency that are independent of initial states".

"No more brazen falsehood," Malin insisted, "was ever perpetrated upon a more gullible public than the allegations that the dust storms of the 1930s were caused by the plough that broke the plains".

It is argued that this final 'stationary distribution' of states is the analogue of the climax community and that climaxes must occur by the statistical certainties that the Markov process always settles into a stable pattern.

It is further suggested that "the different climax communities imply different probabilities of transition among the states, rather than different initial communities, thus convergence too is a necessary statistical artefact".[29]

Putnam and Wratten cite various researchers who have shown the 'close fit' between Markovian processes and succession. The most 'sophisticated' we are told is Horn, who insists that 'general properties of succession are direct statistical consequences of a species-by-species replacement process, and have no uniquely biological basis."[30]

Horn further tells us that "the process of succession must stabilise by statistical necessity in a 'climax state'—the fact that different pioneer communities may converge to the same climax could also arise merely as a statistical necessity."[31]

What is more, if a community is temporarily disturbed, something like the original community returns. This too is a function of Markovian processes. Finally Markovian development, like succession, is characterised by rapid changes followed by undetectably slow changes. This means that stability, in the naive sense of 'absence of change' increases 'tautologically' as succession proceeds. What is important is that 'none of these characteristics' Putnam and Wratten insist is 'necessarily of biological origin'.

They then magnanimously admit that this "does not mean that there is no biological reality about succession; it does however suggest that many of its characteristics are not necessarily biologically determined". Thus if there is an imbalance between community production and community respiration, with its resultant accumulation of biomass providing the driving force, (one of their original explanations of succession) for them the community will undergo a directional successional *change as a statistical necessity.*

"The biological explanation we have presented," they then tell us, "for the mechanism of the process may prove no more than observation of how the statistical necessity is accommodated", the biological systems are not in themselves the explanation for the process.

They then suggest that the idea of succession as a stochastic Markovian process perhaps explains why climax seres (succession) are not always the ideal community they are supposed to be: why climax states often appear overmature, (in that they do not maximise productivity).[32]

The whole argument is an example of a fallacy we can best refer to as 'mathematical realism'. Children often think that because a word exists there must be something in the real world to correspond to the word, a notion known as 'nominal realism', Piaget gives many examples of this. Thus he cites a child who says that "pigs are rightly named because they are so dirty", and that "the sun is rightly named because it is so hot."[33]

Oxford linguistic philosophers are, in the same manner, guilty of what might be called, 'linguistic realism'—of assuming that there must be some intrinsic and universal wisdom in the structure of the English language, (in this case) which casts light on the workings of the biosphere which in reality, it only represents, crudely at that, for conversational puposes.

Putnam and Wratten, like Horn and other scientific ecologists, are in fact, committing the same error. They suppose that because someone has developed a mathematical model which simulates, in a rudimentary manner, some aspects of the real world, *then it must be capable of simulating, in a sophisticated manner, all aspects of the real world.*

It is of course astonishing that the Markov chain can imitate, however crudely, any aspects at all of such real-world processes as succession to a climax. That one must thereby be able to derive other, apparently scientifically acceptable information about succession from the behaviour of a Markov chain is absurd, just as absurd as to suppose that because a puppet can be made to resemble a policeman, an examination of the cotton wool with which it is stuffed will enable you to understand a policeman's digestive system or the circulation of his blood.

What they are proposing is in fact, little more than a modern form of divination—one that, because the diviners are actually scientists, performing their scientific rituals on scientifically consecrated premises, enjoys credibility among the naive and the gullible.

Eugene Odum's view of succession

Eugene Odum's view of succession reflects his very different ideological commitment. In his latest

A tabular model of ecological succession: trends to be expected in the development of ecosystems.

SOURCE: EUGENE P ODUM

Ecosystem attributes	Developmental stages	Mature stages
Community energetics		
1. Gross production/community respiration (*P/R* ratio)	Greater or less than 1	Approaches 1
2. Gross production/standing crop biomass (*P/B* ratio)	High	Low
3. Biomass supported/unit energy biomass (*P/B* ratio)	Low	High
4. Net community production (yield)	High	Low
5. Food chains	Linear, predominantly grazing	Weblike, predominantly detritus
Community structure		
6. Total organic matter	Small	Large
7. Inorganic nutrients	Extrabiotic	Intrabiotic
8. Species diversity—variety component	Low	High
9. Species diversity—equitability component	Low	High
10. Biochemical diversity	Low	High
11. Stratification and spatial heterogeneity (pattern diversity)	Poorly organised	Well-organised
Life history		
12. Niche specialization	Broad	Narrow
13. Size of organism	Small	Large
14. Life cycles	Short, simple	Long, complex
Nutrient cycling		
15. Mineral cycles	Open	Closed
16. Nutrient exchange rate, between organisms and environment	Rapid	Slow
17. Role of detritus in nutrient regeneration	Unimportant	Important
Selection pressure		
18. Growth form	For rapid growth ("*r*-selection")	For feedback control ("*K*-selection")
19. Production	Quantity	Quality
Overall homeostasis		
20. Internal symbiosis	Undeveloped	Developed
21. Nutrient conservation	Poor	Good
22. Stability (resistance to external perturbations)	Poor	Good
23. Entropy	High	Low
24. Information	Low	High

textbook, he quotes Clemerec's description of a secondary succession of benthic animals off the coast of Brittany. "After storms caused a redistribution of sediments and disruptions of bottom fauna, a period of relative calm followed. During this period, in the absence of outside interference a more or less directional and *predictable* sequence of populations established dominance. First were bivalve suspension feeders, then bivalve deposit feeders, and finally the benthos became dominated by polychaete worm detritus feeders, thus confirming the theory that uninterrupted succession converts an inorganic environment to a more organic one."[34]

In this example, the main features of succession are illustrated: its sequential or successional nature, the "more or less *directional* and *predictable* sequence of populations", its ability to correct diversions from its optimum course (Waddington's chreod) that which will lead to the requisite climax, and its achievement of an increasingly sophisticated and stable state as it reaches its climax, thereby converting "an inorganic environment to a more organic one".

Odum states explicitly that he regards ecosystem development as resulting from "(1) modification of the physical environment by the community *acting as a whole* and (2) the interaction of *competition* and coexistence between component populations."

He regards Clements' main thesis "that ecological succession is a developmental process and not just a succession of species each acting alone," as *"one of the most important unifying theories in ecology."*[35]

In an earlier textbook, he is still more explicit. Succession, he tells us is "(1) The orderly process of community changes: these are directional and, therefore, predictable. (2) It results from the modification of the physical environment by the community. (3) It culminates in the establishment of as stable an ecosystem as is biologically possible on the site in question." He also points out that ecological succession "is *community controlled*" and insists that "each set of organisms changes the physical substrate and the microclimate (local conditions of temperature, light, etc.), thereby making conditions favourable for another set of organisms and that "when the site has been modified as much as it can be by biological processes, a *steady state develops*—at least in theory."[36]

In the same book, he accentuates the similarity between the development of an organism and that of an ecosystem. He also asks us to think of the "temporary communities as developmental stages analogous to the life-history stages through which many organisms pass before reaching adulthood." At the same time, he notes that "the mature community with its greater diversity, larger organic structure, and balanced energy flows is often able to buffer the physical environment to a greater extent than the young community, which, however, is often the more productive. Thus, the achievement of a measure of stability or homeostasis, rather than a mere increase in productivity, in a fluctuating physical environment, may well be the *primary purpose* (that is, the survival value) *of ecological succession when viewed from the evolutionary standpoint.*"[37]

It is unlikely that any other ecologist today would dare state this unfashionable principle quite so explicitly—yet if it is not faced, there is no way in which the behaviour of an ecologist can be understood.

The Climax as the adult state

I think that many of the controversies on ecological theory would be cleared up if it were accepted that ecosystems, in fact grow, as Clements always maintained, just like any other natural system until they reach their climax which must unquestionably be regarded as a state of adulthood.

The 'isomorphism' or rather 'isotelism' may be still closer. Thus it has often been argued that, like an organism and indeed like any other natural system, an ecosystem can also age. In his textbook *Ecology* Odum suggests biological changes may be occurring, which, in the individual, we would call ageing. Thus, young trees may not be quite replacing the old ones as they die, or regeneration of nutrients may be lagging and the whole metabolism thus slowing down. There are few data at present, but one wonders if communities may not suffer gradual ageing after reaching maturity, just as do individual organisms."[38]

A useful approach is to view the main features of ecosystems such as diversity, complexity, stability etc. in their correct successional context. As Loucks points out "there have been few opportunities to date to view diversity, and its associated ideas—stability and productivity—*as time-based functions,* potentially dependent on the stage of development of the native communities."[39]

The associated changes involved

There is no doubt that as a system moves towards its climax i.e. becomes more mature, so do changes occur to all the variables in terms of which it can be described. These are not just random changes, *but are all on the contrary, closely associated* and all equally necessary for the ecosystem to fulfill its changing role as it nears maturity.

Margaleff describes that constellation of changes in the following way.

"Structure, in general, *becomes more complex, more rich, as time passes;* structure is *linked to history*. For a quantitative measure of structure it seems convenient to select a name that suggests this historical character, for instance, *maturity*. In general, we may speak of a more *complex ecosystem* as a more *mature ecosystem*. The term maturity suggests a trend, and moreover maintains a contact with the traditional dynamic approach in the study of natural communities, which has always been a source of inspiration.

Maturity, then, is a quality that increases with time in any undisturbed ecosystem. Field ecologists use many criteria to estimate the maturity of an ecosystem, without the need of assessing its precise place in an actual succession. Empirical knowledge of succession leads one to consider as more mature the ecosystems that are more complex; that is, composed of a great number of elements, with long food chains, and with relations between species well defined or more specialised. Strictly *stenophagous* animals, parasites, all sorts of very precise symbiotic or defensive relations, are commoner in mature ecosystems. Furthermore, situations are more *predictable*, the average *life of individuals* is longer, the number of produced offspring lower, and *internal organisation* of ecosystem turns random disturbances into quasi-regular rhythms."[40]

Eugene Odum considers these changes in still greater detail in his seminal paper 'The Strategy of Ecosystem Development'. In it he lists 24 different changes that occur as succession proceeds, under six different general headings. He notes, for instance, that the rate of primary production as a proportion of the rate of respiration falls until eventually, in a mature ecosystem, they equal each other and the ecosystem ceases to grow any more.

At the same time, he notes, food chains which started off by being 'linear' become web-like, more complex and with detritus providing *an increasingly* important source of nutrients. "In a mature forest", for example, "less than 10 per cent of annual net production is consumed (that is, grazed) in the living state: most is utilized as dead matter (detritus) through delayed and complex pathways involving as yet little understood animal-microorganism interactions."[41]

That one must be able to derive other, apparently scientifically acceptable information about succession from the behaviour of a Markov chain is absurd, just as absurd as to suppose that because a puppet can be made to resemble a policeman, an examination of the cotton wool, with which it is stuffed, will enable one to understand a policeman's digestive system or the circulation of his blood.

The total organic content of an ecosystem also increases as succession proceeds. Also, inorganic nutrients which were originally derived from outside the ecosystem slowly become intra-biotic in that they are constantly recycled within it. Species diversity as well as biochemical diversity increases and their organisation improves. Species become increasingly specialised and organisms become larger, life cycles longer and more complex. He notes too how mineral cycles which were once open became closed. "Mature systems" he writes, "as compared to developing ones, have a greater capacity to entrap and hold nutrients for cycling within the system. For example, Bormann and Likens have estimated that only 8 kilograms per hectare out of a total pool of exchangeable calcium of 365 kilograms per hectare is lost per year in a stream outflow from a Northern Temperate watershed covered with a mature forest. Of this, about 3 kilograms per hectare is replaced by rainfall, leaving only 5 kilograms to be obtained from weathering of the underlying rocks in order for the system to maintain mineral balance."[42]

The principle of succession is clearer if it is seen in the light of the general systems approach. It then becomes apparent that it is not a unique phenomenon but rather a specialised instance of a very much more general principle, one which is best referred to as 'sequential development'.

In addition, the nutrient cycle rate within the ecosystem becomes much slower since the process involved becomes more highly differentiated. Odum shows how the survival rate improves as organisms are better equipped for individual survival and parental care (increased K-selection replaces R-selection) which means that reproduction does not aim at maximising the quantity of offspring but rather their quality or sophistication.

Odum notes how Clements ascribed the increasing stability of successional stages in a sere to an increasingly tight organisation and to the integration of community components The development of internal symbiosis i.e. increased co-operation or mutualism between the parts of the ecosystem he takes as being an essential aspect in this integration. Among other things, it clearly increases the ability of an ecosystem to conserve nutrients.

Stabilising mechanisms

In his 'Basic Ecology' Odum shows how this increasing stability is achieved by the operation of "homeostatic mechanisms, which we may define as checks and balances (or forces and counter-forces) that dampen oscillations." This he maintains "operate all along the line, and hence not only at the level of the individual where for instance they "keep body temperature . . . fairly constant despite fluctuations in the environment."[43] They are also operative at the level of the population, the community and the ecosystem.

Odum notes how "we take for granted that the carbon dioxide content of the air remains constant, without realising, perhaps, that it is the integration of organisms and environment that maintains the steady conditions despite the large volumes of gases that continually enter and leave the air."[44]

Significantly, James Lovelock describes, in his celebrated book *'Gaia, a New Look at Life on Earth* how similar stabilising mechanisms maintain or 'steady condition' at the level of Gaia, i.e. the biosphere itself.

Margalef shows how, as an ecosystem becomes more mature, so does it develop correspondingly more effective homeostatic mechanisms. Up to a certain level, these homeostatic mechanisms, Margalef considers, can protect a system from disruption from external agents. "Maturity is self-preserving". Margalef, like Odum also compares the successional development of an ecosystem with evolution. "Maturity is related to evolution," he writes "in a way that permits generalisation concerning the type of organisms to be found in ecosystems of more or less maturity and stability. As evolution proceeds, there is a trend toward adjustment to maturity."[45]

What is important is that all these changes are closely associated, what is more, sheer commonsense explains why they must be if the ecosystem is to achieve its goal, that of increased stability.

What is also important is that the changes brought about by industrial man, are in fact, *reversing ecological succession*, that is why we must consider industrial development or 'progress' as an *anti-evolutionary process*.

By reversing ecological succession it is giving rise to ever greater ecological instability—of which the symptoms are increasing soil erosion and desertification, growing water-shorages, population explosions of microorganisms (often leading to epidemics affecting plants and animals and other organisms including man), the extinction of plant and animal species, climatic changes and other increasingly severe discontinuities that are rapidly making our world ever less habitable.

What remains of an ecosystem after it has been devastated by the activities of modern man, Eugene Odum refers to as a "disclimax" (a disturbance climax) or an "anthropogenic (human generated) sub-climax." It is significant that the term disclimax is not (to my knowledge) used by any other modern ecologist. Its use, would, of course, be difficult to reconcile with Tansley's notion of the superiority of the anthropogenic climax over the natural climax, incompatible too with the very notion of technological progress.[46] Margalef does not use the term, but he does point out that modern man's interference with the functioning of ecosystems must return them to a lower successional stage, one that is very much less stable.

Sequential development

The principle of succession is clearer if it is seen in the light of the general-systems approach. It then becomes apparent that it is not a unique phenomenon as modern ecologists tend to see it, but rather a specialised instance of a very much more general principle, one which is best referred to as 'sequential development'.

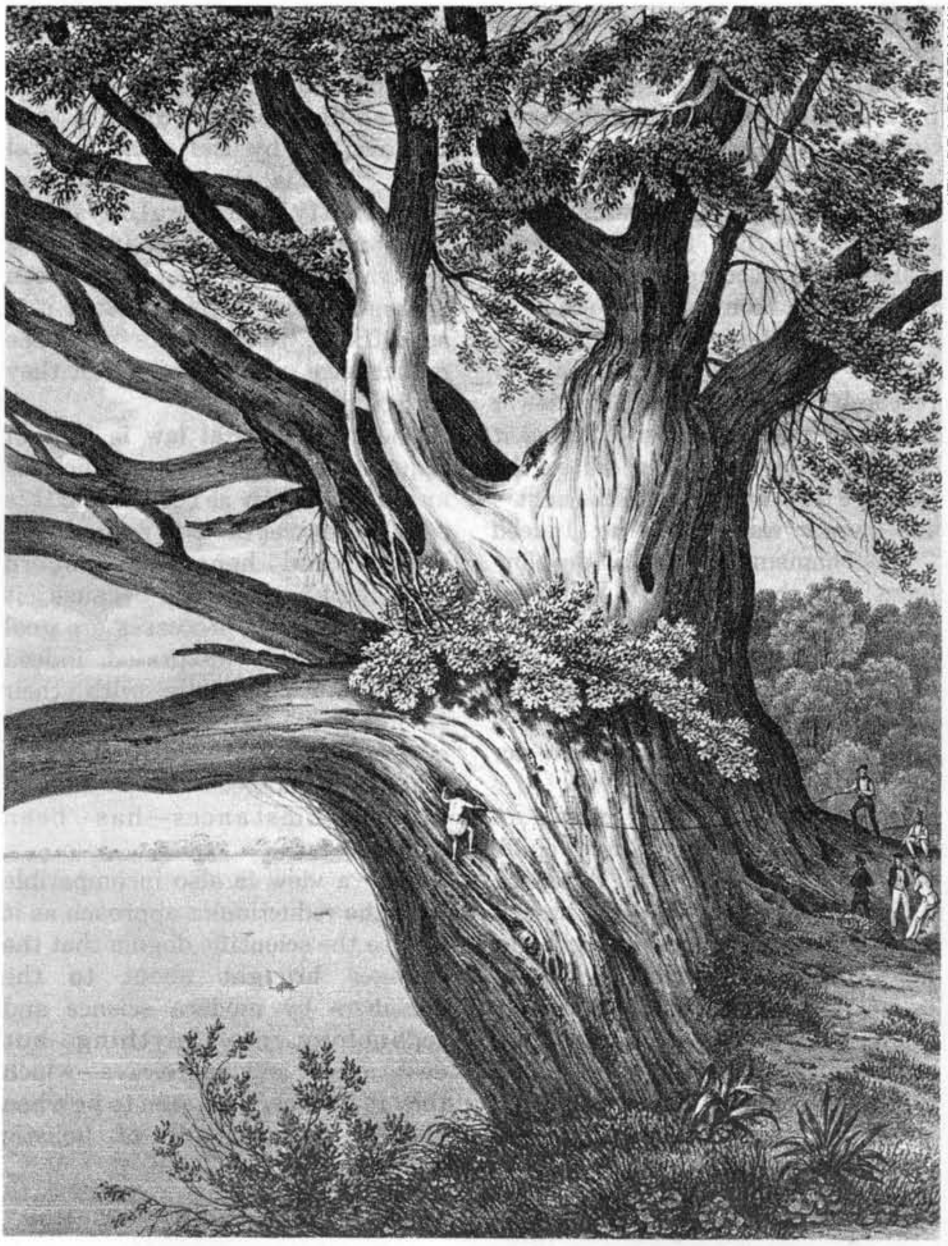
All life processes can be shown to be sequential. This implies, that their various stages must occur in the right order, so much so that if one stage is left out, then the succeeding stages will not occur or will occur but imperfectly. It also implies that each stage must occur in the correct spatio-temporal environment, the only one to which behaviour at a given stage is adaptive. Let me make this a little clearer.

All behaviour must be seen as modifying the environment. Such modification is not random from the point of view of the strategy of which the behaviour is an integral part. On the contrary, the new environment will be that which will best serve to trigger off the next stage in the strategy. This does not mean that the whole process is predetermined in a precise way, for at each stage, there may be a large number of possible variants of a basic behavioural response, of which only one or more, are likely in given conditions, to be mediated.

There is a third feature of sequential development. It is that it must occur at the appropriate rate. If it is speeded up or slowed down, the end product is unlikely to be optimum. The reason is that any behavioural process or strategy, because of the hierarchical nature of the biosphere, is likely to be part of a larger process or strategy with which it must be correctly synchronised. The inertia, caused by the need to synchronise a process with a host of others, Rupert Riedl refers to it as its 'burden' [47]

Piaget is struck by the "sequential character of development". He defines sequential development as "une suite de stades dont chacun est necessaire, donc dont chacun résulte nécessairement du precedent (sauf le premier), et prepare le suivant (sauf le dernier). Dans le domaine de l'embryogenèse des Métazoaires il semble en etre ainsi, puisque les grands stades se retrouvent toujours et dans un ordre constant." [48]

Indeed, because embryological development occurs within a highly protected and ordered environment



LITH. DE J. BRODTMANN

This incredible tree clearly survived the destruction of Tonga's climax forests.

and because it so obviously constitutes a planned strategy, its sequential nature is apparent to all.

Piaget notes how Waddington explains this in his famous book *The Strategy of the Genes*—"les actions polygeniques et pléiotropiques du genome" Waddington maintains, according to Piaget "ne sont pas a concevoir comme un système exclusivement ascendant, mais, à chaque étape, de nouveaux gênes jusque-là non actifs (quoique naturellement presents dés le départ) sont mis en activité par les resultats des actions déjà effectuées par d'autres gênes; par exemple le résultat X produit par les genes a, c, et e, active en retour le gene b qui, synergiquement avec a et d produit le resultat Y, qui va activer d'autres genes, etc. Il y a donc là un système à boucles, et dont les etages superieurs sont modifiés par le milieu, puisq'il s'agit du phénotype, mais par un processus sélectif 'sous controle genique' puisque relatif à ces syntheses successives dependant du génome."

Cognitive development in a child also proceeds in a sequential manner. This is unquestionably the view of Piaget who writes "le problème du caractère sequentiel des stades se retrouve en psychologie pour ce qui est du dévelopment des fonctions cognitives et il est important de noter, qu'en ce domaine les stades sont d'autant plus nets et d'autant plus sequentiels que l'on a à faire a des regulations mieux differenciées et portant sur un champs plus large."[49]

Dr Inhelder, who worked with Piaget for many years, pointed out at Arthur Koestler's famous Ansbach Symposium that "learning is definitely dependent upon the subject's development level. Generally, in all this research, it has been shown that the child never manages to accomplish more than the passage from one sub-stage to the next without ever jumping a stage." She also noted that her research now enabled her to answer the often asked question whether it was possible to accelerate the passage from one stage to the next—the answer was clearly no. Indeed "if mechanisms in mental development can be compared to what Waddington 'in embryology' calls 'creodes' or necessary paths with a 'time-tally', it appears obvious that development always has an optimum rate, neither too slow nor too fast." [50]

In summing up her views of cognitive development in a child, she stated that "the research undertaken in Geneva over the last 40 years has brought to light the fact that development does not occur by chance through encounters with the physical and social environment but follows a certain direction. In the development of thought, particularly, there are sequences or stages of progressive structuration. We took this development to obey laws of self-regulation of endogenous origin, but to be subject to continuous modifications under the influence of the feedback resulting from exchanges with the environment." [51]

In other words, for her, cognitive development is governed by precisely the same laws that govern embryological development. This is not after all very surprising since the development of a foetus within the womb and that which occurs after a child is born clearly form a single process. The notion that they should be governed by different laws is only conceivable because scientific knowledge is arbitrarily compartmentalised and those two sub-processes are thereby studied by separate disciplines.

It is for the same reason too that the idea can be seriously entertained that this wider process is itself radically different from other life processes such for instance, as the development of an ecosystem. Indeed, at a certain level of generality all life processes must be seen as governed by the same general laws. This is the thesis of Von Bertalanffy's General Systems Theory and it is a very important one which few scientists have been willing to face, largely because it is so difficult to reconcile with the reductionist method to which they are so committed.

One such general law is that of sequential development which is known in ecology as succession. It is equally unacceptable to mainstream science and hence to modern "scientific" ecology—because it implies that life processes are goal directed, highly integrated, indeed linked mutualistically with their environment and come to an end once their goal—the maximum stability or homeostasis possible in the circumstances—has been achieved.

Such a view is also incompatible with the reductionist approach as it is with the scientific dogma that the changes brought about to the biosphere by modern science and technology are anything but destructive and regressive—which they must clearly be seen to be when viewed in the light of holistic ecology.

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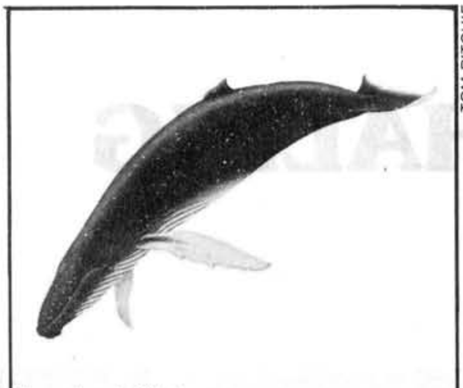
LET'S ALL GO WHALING

by Sidney Holt

PHOTO: DAVE CURREY/FILM LONDON 1983

Norwegian whalers harpooning Minke Whale in Barents Sea with a cold harpoon.

The 37th annual meeting of the International Whaling Commission (IWC) is to be held in Bournemouth in July of this year. This may be the last opportunity to overcome the stubborn refusal of the remaining whaling nations—in particular Japan—to subordinate their petty short-term economic interests to the biospheric imperative of assuring the survival of whale species. Dr Sydney Holt—a world authority on this critical issue—describes, in detail, the record of the IWC since it was set up under the 1946 convention and the expedients resorted to by the whaling nations to prevent it from achieving its purpose. We can only pray that, at this meeting, they may finally come to face their global responsibilities.


TOM RITCHIE

Humpback Whale
Megaptera novaeangliae

The International Convention for the Regulation of Whaling (1946) begins by "Recognising the interest of the nations of the world in safeguarding for future generations the great natural resources represented by the whale stocks". A fine start! Those who have come to believe that wildlife populations should not all be regarded as 'resources' for human use might have some reservations about it. But apart from that I think it represents as good an environmental and political statement as one might expect from an intergovernmental conference: certainly better than most, and quite exceptional considering when it was written. The Preamble to the Convention concludes with a statement of its purpose: "to provide for the conservation of whale stocks and thus make possible the orderly development of the whaling industry". So this is, without ambiguity, a treaty for the conservation of certain renewable resources, in the interest of the human species, present and future, and it aims at creating the conditions whereby nations that wish to catch whales can arrange among themselves to do so in an orderly manner. Conservation is thus a necessary, though obviously not a sufficient, condition for peaceful international use of these marine resources.

It is widely known that the International Whaling Commission (IWC), established under the 1946 Convention, presided during the first twenty years of its existence over the depletion of nearly all the world's whale populations. It utterly failed to safeguard whales for future generations. And the whaling industry, instead of enjoying an orderly development, experienced a disorderly, though long drawn out, collapse. The collapse was not complete and the 'experience' was not, for the industry, a particularly painful one. Enormous profits were made in those twenty years, while two of the most productive species—the blue and humpback whales—were brought to the brink of extinction. That sorry tale has been told many times and it is not my purpose to repeat it.[1]

By 1970 the situation was so bad that some countries inside the IWC, and others which had never joined it, were coming to the conclusion that if whales were to survive, as species and as resources, either strong external pressure had to be put on the IWC to change its ways, or responsibility had to be removed from it, by 'the nations of the world', and vested instead in the United Nations. The opportunity came with the UN Conference on the Human Environment, held in Stockholm in 1972. A resolution was passed by 53 votes, none against, but with 12 abstentions, calling for a ten-year moratorium on all commercial whaling, for increased research on whales, and for 'strengthening' of the IWC. The resolution was later that year confirmed by the UN General Assembly, but a similar one presented to the IWC by the Commissioners for the United States and the United Kingdom was supported by only 4 members, with 6 against and 4 abstentions. A similar proposal for a commercial moratorium was moved at the 1973 IWC meeting by the US, Argentina and France. This received 8 votes in favour and 5 against, with 1 abstention, but it was not adopted because the 1946 Convention requires that for a decision of this kind—technically the setting of catch limits—there must be a three-quarters majority of voting Member States.

Enormous profits were made in those twenty years, while two of the most productive species—the blue and humpback whales—were brought to the brink of extinction.

The third attempt to persuade the IWC to accept the view of the 'nations of the world' as expressed in Stockholm was made by the US and Mexico at the 1974 meeting. This time the proposal was not put to the vote. Instead, an amended resolution tabled by Australia and Denmark was adopted by simple majority. Apparently by oversight it was not published by the Commission, though the following year its operative paragraphs were incorporated in the Convention itself, by consensus. These changes formalised a New Management Policy, later a Procedure (NMP), about which more later.

From 1972 the whales in general, and the blue whale in particular, had become firmly established in the public mind as powerful symbols of man's devastating effects on the biosphere during the industrial era, and of the urgency of worldwide action to halt this. That is the context in which the IWC acknowledged, reaffirmed and to a degree expanded upon the broad principles which embellish the 1946 Convention. The Commission was, its 1974 resolution said, "motivated by the need to preserve and enhance whale stocks as a resource for future use when food needs of the world will be greater because of increased human population and by the need to maintain marine ecosystems in a well-balanced condition capable of high productivity". The Commission noted "that whale stocks are a common concern to mankind", and it recalled that "the historic decline in whale populations occurred not only because of excessive exploitation, but also because knowledge was inadequate to protect the species". Now this was a strange way of pointing at the deficiencies of science, because of course those deficiencies did not in themselves cause declines. Rather, it was the continuation of over-exploitation because the Commission refused to impose cautionary restraints in the face of scientific uncertainty and controversy, that was at the root of the problem. Nevertheless this was a first recognition of a basic fact, which is as true today as it was ten years ago.[2]

Strengthening the IWC

By the mid-1970s this idea had been resolved into five components, in addition to implementing the NMP. These were:

1.) Conducting an International Decade of Cetacean Research (IDCR)—moved by US, Panama and USSR.

2.) Appointing a full-time Secretary and a nucleus of scientific staff.

3.) Revising the Convention as a whole.

4.) Fully implementing an International Observer Scheme (IOS).

5.) Persuading other countries, particularly whaling countries, to join the Commission.

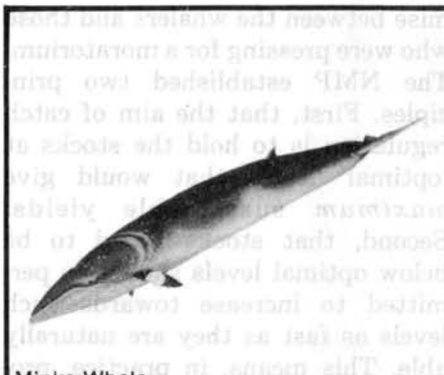
Vast plans were laid for the IDCR, but only a small fraction of the proposed funds for it were provided. It has, however, had one real success: we now know, from direct counting, roughly how many minke whales there are in the southern hemisphere. 'Roughly' means within a factor of, say, 50 per cent either way. That is very much better than estimates for any other whales, with the exceptions of the bowhead and gray whales of the North Pacific, of which direct counts have also been made.

A Secretary and staff—smaller than intended—were appointed and an office set up at Histon, near Cambridge. The main text of the 1946 Convention cannot be amended by the Parties to it. Several conferences of states in the 1970s to draft a new convention got nowhere, and this 'project' is now on the shelf. After more than a decade of negotiation the IOS was implemented for the large scale factory ship operations. Under this scheme the whaling countries exchange 'inspectors' among themselves: the original idea had been to have independent IWC appointed observers, but that was not accepted by many of the whaling countries. The scheme has been applied also to some of the land-based whaling operations but not, significantly, to some of those for which there is the greatest suspicion of sharp practice. The biggest whaling industry for which there is still no international surveillance, and only partial national inspection, is that for minke whales in the Northeast Atlantic by Norwegian mini-factory ships.

That brings us to the crucial issue of IWC membership. Of the fifteen countries that originally signed the 1946 Convention, two whaling countries—Chile and Peru—had never ratified it. A third—Brazil—had left the IWC in 1966. In 1972 the Commission agreed to try again to bring these three black sheep into the fold, with Spain and Portugal. Except for Brazil, which re-joined in January 1974, this effort failed. Portugal is still not a member, but its whaling is now reduced to small catches of sperm whales in the Azores, a commercial operation conducted for export of industrial oil and of teeth as ivory for scrimshaw, carried out part-time by methods which would have been quite familiar to Melville. Not until 1979 did the composition of the IWC begin to change substantially, and then not quite in the way that had been expected.

Meanwhile the Japanese whaling and whalemeat industry with support from the Government, encouraged non-members to step up their activities and to export more of the products to Japan. In addition, and with the connivance of contacts in Norway, Spain, Taiwan and South Africa, Japanese interests organised a fleet of 'pirate' whaling vessels—combined catcher and factory ships—flying flags of convenience such as those of the Bahamas, Cyprus, and Somalia, to kill whales of any species they encountered. The meat they produced was clandestinely transferred to refrigerated cargo vessels flying the Japanese flag. Most of the whales killed in this way were a tropical species, the Bryde's whale, which had for decades been effectively protected in the open oceans by a general prohibition of operation of factory ships in the tropics, designed to give some protection to the other species on their breeding grounds. The IWC had no way to deal with this traffic, except by passing resolutions asking the Japanese Government to put a stop to it. The response was that the Government had no power to do so. At the end of the 1970s it was proven that the Government Fisheries Agency had itself been aiding and abetting the 'pirates'; a domestic law was enacted prohibiting import of whale products from non-members of IWC, and the 'pirate' activities collapsed. Two of these vessels came to untimely ends: one capsized under the weight of a large fin whale and the other was rammed and sunk by radical 'conservationists'.[3]

It was the continuation of over-exploitation, because the Commission refused to impose cautionary restraints in the face of scientific uncertainty and controvery, that was at the root of the problem.



TOM RITCHIE

Minke Whale
Balaenoptera acuturostrata

The New Management Procedure

The 1946 Convention provides for complete protection of species that are agreed to be endangered. This provision was originally applied to the gray whale and to the 'right' whales which had been brought close to extinction in the nineteenth century. In 1959 the IWC accepted in principle that catches of baleen (whalebone) whales in the Antarctic—at that time blue, fin, humpback and sei whales only—should be cut back to *sustainable* levels. Notwithstanding a scientific consensus on the need to protect the blue and humpback whales, it was a decade before this was actually done. During that time the Commission's scientists tried without success to persuade the IWC to regulate the catching of each species and population separately, instead of by setting a quota of 'Blue Whale Units' (BWU) in which four species were lumped together. One difficulty was that the scientists kept changing their minds about what level of catch might be sustainable. In 1959 it was thought it could be as high as 10 per cent of the stock; it was later found that baleen whales lived twice as long as had been thought and the rate of sustainable catch had consequently to be halved.

In 1974 the Australian/Danish proposal was touted as a compromise between the whalers and those who were pressing for a moratorium. The NMP established two principles. First, that the aim of catch regulation is to hold the stocks at 'optimal' levels that would give *maximum* sustainable yields. Second, that stocks found to be below optimal levels should be permitted to increase towards such levels as fast as they are naturally able. This means, in practice, protecting them from further whaling until they have recovered; such stocks are classified as 'Protection Stocks' (PS), with a connotation quite distinct from that of 'Protected Species' and having nothing to do with the likelihood of extinction. An additional principle was that in setting quotas for stocks other than PS stocks there should be some 'safety factor' to allow for error in estimating the maximum sustainable yield (MSY); this was set at 10 per cent. Finally, it was agreed that every stock of every species would be treated separately, and the catch limits for all of them reviewed annually.

Under the NMP fin and sei whales were quickly protected everywhere except in the North Atlantic. There, the data from the whaling operations in Iceland and Spain were so poor that depletion could not be proven. It also turned out to be impracticable to apply the NMP to sperm whale populations, even to those for which it had at first seemed that data were adequate. For all these, continued catching was permitted under arbitrary quotas which were in most cases simply averages of past catches—a sure recipe for continuing depletion. But, meanwhile, something more important was happening.

In 1972-1973, with the depletion of stocks of the four biggest of the six species of rorquals *(Balaenoptera)*, the Japanese and Soviet whalers started catching the smallest of them, the minke whale, in very large numbers in the Antarctic. This species has provided the basis for Norwegian whaling in the North Atlantic since about 1938, and contributed to the profitability of Japanese coastal whaling throughout the post-war period. In the 1970s South Korea also joined in, the meat being for export to

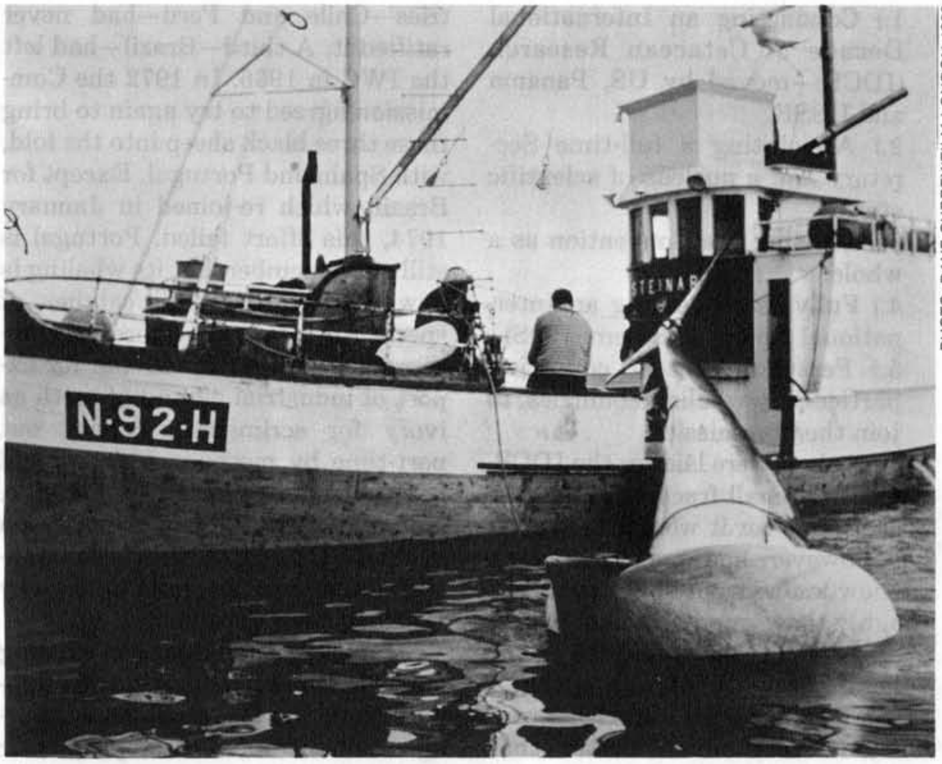


PHOTO: DAVE CURREY/FILM LONDON 1983

Norwegian whalers hauling Minke whale on to small whaling/fishing boat.

Japan. The Bryde's whale also became important as a source of meat for Japan, not only from the 'pirates' but also from the coastal waters of Peru and Japan, and in the open North Pacific at the limit of its range, just beyond the warm waters that were out of bounds to factory ships. For none of these stocks was there scientific evidence on which to base classifications and catch limits.

So the effect of the 'compromise' of 1974 was to close down whaling where there was good information, which in all cases demonstrated depletion, and to legitimise arbitrarily high catches of all other stocks. By 1979 it was becoming clear even to optimists that the NMP was not going to save the species which had now become the mainstay of the whaling industry.

The Attitudes of Scientists

One reason that the moratorium proposals of 1973 and 1974 were not acceptable to more governments was that the IWC Scientific Committee opposed them. The Convention says that important decisions, including setting of catch limits, "shall be based on scientific findings", and also that they "shall take into consideration the interests of the consumers of whale products and the whaling industry". The Committee said that what it called 'a blanket moratorium' was contrary to its prolonged efforts to persuade the Commission to regulate catching from each stock separately. The Commissioners for whaling countries, and for some of the others, too, said that a cessation of commercial whaling—even a temporary one—could not be in the interests of the industry and the consumers, so was unconstitutional. Some of them still say that, despite the fact that in 1974 the IWC had decided to take into consideration the *long range* interests of consumers and industry.

The Scientific Committee opposed the moratorium for two other reasons. One was that scientists said they needed biological 'samples', and these could in practice only come from commercial whaling. The other was that if different whale species were competing with each other for food, and if some were more depleted than others, then it was desirable to kill the more abundant ones in order to prevent them from impeding the recovery of endangered species such as the blue whale. This argument was applied in particular to the minke whales in the southern hemisphere.

It has taken ten years for these stone-walls to be reduced to rubble. The first would be valid if we really knew what we were doing. But it is increasingly evident that we *do not know*. Even where we have useful estimates of the numbers of whales, we have not been able to measure the rate of sustainable yield. We are now sure it is less than 5 per cent; some scientists think it may be as high as 4 per cent while others, including myself, think the available evidence is that it is less than 2 per cent and may be as low as 1 per cent. Put this uncertainty together with the two-fold range even of the best population estimates, and we have a possible *eight-fold* range in 'advice' about sustainable catch limits!

As for 'samples', we have more samples already than we know what to do with—literally. One consequence of trying so hard to apply the NMP, and looking for other kinds of scientific advice when it fails, has been a critical appraisal of the methods of population dynamics as applied to whales. Many 'data-massaging' procedures have been found to be flawed, and well established methods to have large biasses. An example is the finding, only last year, that marking experiments, carried out for decades, have been exaggerating the numbers of whales because whales are able to extrude the bullet-like marks implanted in their flesh, just as they would relieve themselves of parasites.

Under the 1946 Convention Governments can, without restraint, grant permits for the killing of whales for scientific purposes, provided that the products from the whales so killed are not 'wasted'. Some countries have used this authority very sparingly; but others have abused it. In the 1960s the United States helped keep its West Coast whaling industry profitable for a few years by 'sampling' the (then) protected grey whale. In the 1970s Japan authorised the taking of so many Bryde's whales from the Indian and South Pacific Oceans that meat production from them equalled imports from major clients such as Spain and Peru! This was all part of an effort to get those tropical regions opened to factory ships, just as a 'Sanctuary' in the Pacific sector of the Antarctic had, in the 1950s, been opened when whales in the other sectors had been depleted. The most blatant misuse of the 'scientific permits' at present, though on a small scale by comparison, is the capture of fin whales in the Faroes, under a permit granted by the Government of Denmark, against the advice of the IWC Scientific Committee.[14] This permit allows the taking of a maximum number of whales every year, indefinitely; no substantive reports of the 'scientific' results have so far been given to the IWC (as the Convention says they must be). A worrying feature of all this is that, being tolerated by the Commission, it is the more difficult to check bigger potential abuses. One that looms is a proposal, by an official investigatory commission in Japan, that if it is decided to succumb to external pressure and stop commercial minke whaling in the Antarctic under quota, then large catches could be continued under permits.

The arrogance of the scientific community—and I count myself as a part of that—in claiming that we now know how to 'manage' wildlife, must be counted as a factor that impeded for a decade the conservation of whales.

The third 'scientific' argument for continued whaling—the supposed interactions between competing species—has been more difficult to counter. There seemed to be evidence of interactions from changes noticed in the reproductive rates of some species, notably the minke whale. These could not be the expected responses to changes in their own abundance, because they occurred *before* these species were depleted, but *after* the depletion of the blue whale and other feeders on Antarctic krill. Similar changes were supposed to have been found in crab-eater seals. The work of the Australian scientist Bill de la Mare, working in England, and the British scientist Justin Cooke, working in Canada, has shown that these 'observations' are in fact artefacts arising from the ways that samples are taken and the data from them treated. There is no evidence of interactions, and the image of minke whales as 'pests' to be 'culled'—'rabbits of the sea' as the Japanese Commissioner recently picturesquely labelled them—is fading.

We have not been able to measure that rate of sustainable yield. We are now sure it is less than five per cent; some scientists think it may be as high as four per cent while others, including myself, think it is less than two per cent and may be as low as one per cent.

Our experience is, however, that pseudo-scientific myths take a long time, and much pounding, before they finally disappear.

The IWC Scientific Committee consists primarily of nominees from member Governments. As such its members are not entirely free to engage in objective discussion and critical research, though some are very much freer than others, as might be expected. We also all have our prejudices and there is no doubt that these affect judgements as to what is a 'reasonable' management decision in the circumstances, and what is not. The situation has in recent years been much improved by the participation of invited 'independent experts', who have made decisive contributions methodologically and to analyses of both old and new data. A new difficulty has arisen, however. Critical data available to Japanese scientists have been withheld from the Scientific Committee, or from certain members of it, or submitted selectively. Some of these data come from the industry and are treated as industrial secrets. Other data are said to be the property of individual scientists, who must be allowed first knock and given time to publish results as a contribution to the advancement of their careers. It may seem quite incredible that the conservation of "the great natural resources represented by the whale stocks", of "interest to the nations of the world", should be subject to such considerations, but that's the way it is.

Despite the difficulties—or perhaps because of them—more and more members of the Scientific Committee came, between 1973 and 1983, to accept that a moratorium represents a rational response to the forces pressing for continued whaling in the face of deep ignorance of the biology of whales and great uncertainty about their numbers and dynamics. Nevertheless, the arrogance in the scientific community—and I count myself a part of that—in claiming that we now know how to 'manage' wildlife, must be counted as a factor that impeded for a decade the conservation of whales. How much more dangerous are those who, for example, truly believe that enough is known about the Antarctic marine and coastal ecosystem to 'manage' it by various manipulations, including 'culling'?[4]

What do the Decisions of the IWC mean?

According to the 1946 Convention the Commission can, by simple majority, "make *recommendations* to any or all Contracting Governments on any matters which relate to whales or whaling and to the objectives and purposes of the Convention". These are not binding on Governments. It has a more limited power to amend the *Schedule*, which is an integral part of the Convention. This contains some important definitions, and a series of *regulations,* the permissible types of which are listed in the body of the Convention. They cover such matters as catch quotas, minimum size limits, closed areas and seasons, kinds of whaling gear and the basic catch data and biological records that the whaling industries are required to provide. The Commission is specifically prohibited from restricting the number or nationality of whaling operations and from allocating quotas to particular ships or fleets—which means, in practice, to particular nations. Any such allocations must be made by agreement among the countries concerned, outside the Commission.

The Convention applies to "all waters in which whaling is prosecuted" by ships and stations under the jurisdiction of members; that is it covers territorial waters, even *internal* waters, of its members, as well as the high seas and, now, the 200-mile Exclusive Economic Zones claimed by most States. This last causes problems because some States consider that it is in conflict with their jurisdiction under the new Convention on the Law of the Sea, even though that convention is not yet in force. However, in the LoS Convention *all* whales and dolphins

PHOTO: DAVE CURREY/E.I.A.

Longfin Pilot whales lined up for butchering on a quay. Fuglafjordur, Faroe Islands. August 1984.

are listed as 'highly migratory species' (regardless of whether they are biologically so) and are as such subject to a special regime of control through multilateral agreements and appropriate inter-governmental organisations.

Neither whales nor whaling are defined in the 1946 Convention. Until now it has been tacitly agreed that whaling is the deliberate taking and killing of whales by means of harpoons. 'Aboriginal subsistence whaling' has been accepted by the commission as meaning whaling for the purposes of local consumption by native peoples for their own subsistence; 'commercial whaling', to which the NMP applies, is everything else. Limited aboriginal subsistence whaling is permitted on some stocks that are so depleted as to be protected from commercial whaling.

Whales include all the very large species of cetaceans, as well as the minke whale, the so-called 'killer' whale (Orca) and the bottlenose whale of the North Atlantic (not to be confused with the bottlenose dolphin commonly exhibited in marine circuses). The Schedule lists a few other species of cetaceans as whales—the pilot whales, several beaked whales, and three other species of bottlenose whale, one of which—Baird's beaked whale of the North Pacific—is substantially bigger than the minke. There is, however, great controversy over the power of the IWC to regulate the catching of these 'small' cetaceans. In particular, Japan resists the international regulation of the oceanic Baird's beaked whale, and Denmark of all the smaller listed species. The Danish position seems to derive from before Greenland and Faroes won partial independence. In these countries the hunting of the white whale (beluga), pilot whales and the narwhal are local traditions. The Danish administration has, moreover, devised the most contorted legalistic argument to exclude all these and other species from IWC responsibility. No other Government will swallow it, but it is a measure of the difficulty the IWC experiences in 'providing for the conservation of whale stocks' that this argument prevents consensus and thus effectively vetoes action. The argument is that the species in question are not included in a list of the vernacular names of whales drawn up in various languages during the 1946 Conference. So because no one thought in 1946 to write down the English, Dutch and French, names of Baird's beaked whale and the pilot whales, and append them to the Final Act of the Conference, they are not whales at all!

Decisions to amend the Schedule require a three-quarters majority of votes; that is excluding abstentions and, of course, absent delegations. This requirement for a large majority was written in to give greater authority to the Commission; the more usual treaty practice is for decision by two-thirds majority. A recent, very important, exception is the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR) negotiated under the Antarctic Treaty. This requires full consensus for adoption of any fishery regulations. Thus, although CCAMLR has some fine words in it about conservation, and it has been widely hailed as an advanced agreement because it says that decisions about each exploited species must take into account the expected effects on other species, the chances of restraining regulations being adopted in due time to prevent depletion are minimal. Any hope that CCAMLR will be able to prevent the depletion of the vast fisheries resources of the Southern Ocean by a few voracious fishing nations led by Japan and the Soviet Union must be set against the fact that the States which negotiated the whaling convention and then depleted the whale stocks are practically the same ones that negotiated the CCAMLR—Consultative Parties to the Antarctic Treaty plus three fishing states. (See Table).[5,6]

IWC decisions are binding on all members that do not object to them within a certain time after their adoption—basically ninety days after, with limited possibility of extension. Bound countries are then expected to make national regulations in conformity with the IWC decision. The Commission has no power of enforcement. Countries are simply expected to report to it violations and infractions by their own nationals, and what penalties, if any, they imposed.

The Achilles heel of the IWC is the provision for objections. At the 1946 Conference the British, New Zealand and Norwegian delegations strongly resisted the introduction of this Article, on the grounds that it would unacceptably weaken the Convention. But they eventually bowed to US insistence on it. The irony in this is that now virtually the only effective pressure on objecting countries comes from the threat of US laws which invoke sanctions against any who act in such a way as "to diminish the effectiveness of the IWC"—*and that includes catching whales in excess of IWC quotas, irrespective of whether or not the country has objected to them* [7,13]

Contracting Parties have another way of avoiding developments they do not like—they can leave the IWC. All they have to do is give six months notice of withdrawal. Over the years a few countries have used this option: Brazil, Netherlands, Norway. They re-joined when it suited them. Others have withdrawn—and some have re-joined—for different reasons. There have been frequent threats of withdrawal, some of them formal and some—more recently—the diplomatic equivalent of States muttering under their breath.

Whaling Economics

In 1965, with IWC approval, FAO tried to make an economic study of

Parties to the Convention for the Regulation of Whaling, 1946 and Consultative Parties to the Antarctic Treaty, 1959

A. As at 1959

	IWC	ATCP
Argentina	(1)	+
Australia	+	+
Belgium		+
Brazil	+	
Canada	+	
Denmark	+	
France	+	+
Iceland	+	
Chile	(2)	+
Japan	+	+
Mexico	+	+
Netherlands	+	
New Zealand	+	+
Norway	+	+
Panama	+	
Peru	(2)	+
South Africa	+	+
Sweden	+	
USSR	+	+
UK	+	+
USA	+	+

(1) Signed in 1946, ratified in 1960
(2) Signed in 1946, ratified in 1979

B States invited to negotiating conference for CCAMLR, in addition to CPATs: Poland, East and West Germany. Any state having an interest in the conduct of research or in exploiting the fisheries resources of the Southern Ocean may join CCAMLR, provided that they agree to conduct themselves as if they were Parties to the Antarctic Treaty; they must also "acknowledge the special obligations and responsibilities of the Antarctic Treaty Consultative Parties for the Protection and Preservation of the Antarctic Treaty Area". In forming their 'club' the ATCPs of course took upon themselves these "obligations and responsibilities".

C States joining IWC, from 1979, in order of accession: R. of Korea; Seychelles; Spain; Switzerland; Oman; China; India; St Lucia; Dominica; Jamaica; Uruguay; Costa Rica; Philippines; Egypt; Kenya; Monaco; Fed Rep Germany; Belize; Senegal; Antigua and Barbuda; Mauritius; St Vincent and Grenadines; Finland; Ireland.
Switzerland is the only land-locked state Member.
Philippines joined as a non-whaler, then started whaling for export to Japan.
Jamaica and Panama have succumbed to Japanese pressure and withdrawn from IWC.
Mauritius has not yet attended a meeting.

D The following countries are involved in aboriginal subsistence whaling: Denmark (Greenland); St Vincent and Grenadines; USSR; USA.
Canadian native people engage in subsistence whaling, but not for species the catching of which is at present regulated by the IWC; Canada left the Commission in 1981, having stopped commercial whaling in 1972.
Of non-member countries, aboriginal subsistence whaling on a small scale is conducted in Tonga (humpback whales) and Indonesia (sperm, and possibly fin, sei and/or Bryde's).
The only non-member known to be conducting commercial whaling is Portugal (Azores)—now on a small scale and by primitive methods, for sperm whales.
In addition to the fin whales taken under scientific permits, mentioned in the text, large numbers of pilot whales are taken in Faroes. (see Ref. 14)
Various species of dolphins are killed in many countries, both deliberately and incidentally in fishing nets.

commercial whaling. Another attempt was made by FAO and UNEP in the period 1973-1976. The industries withheld data and no reports were made. The most tangible proofs of profitability are the city of Sandefjord, the whaling centre in southern Norway constructed from whaling income, and the massive growth of Norwegian commercial shipping, which was to a great extent financed, in its initial stages, by the sales of oil from the Antarctic blue and fin whales. The Japanese industry expanded much later and its profits are more dispersed and less spectacularly invested.

It is commonly assumed that the 'enlightened self-interest' of wise investors naturally thrusts them towards conservative exploitation of renewable resources. This idea was promulgated for years by fisheries economists. Only in 1976 did Colin Clark, a mathematician at the University of British Columbia, remind us that "this ain't necessarily so". It all depends on the relation between the intrinsic rate of natural increase of the resource and the rates of discount applied to investments and operating costs. The natural increase rate of whales, like that of hardwood trees, is much lower than applicable discount rates. Clark wrote "If the object of whaling is . . . to maximise the present value of the discounted net economic revenue, thereby accounting for the compromise between short-term economic benefits and the possibility of future benefits" then "the economic incentive for conservation of (whale) resources may be quite minimal . . . The economic values of the whaling industry . . . may not coincide with the long-term economic values of society as a whole . . . The opportunity cost of capital exceeds the socially optimal time-preference rate (and, additionally) . . . society may be willing to absorb greater risks than individual industries"[8].

Although the several international whaling agreements of the 1930s spoke about conservation, their purpose was mainly to avoid overproduction of whale oil (then by far the most valuable product) and thus depressing the market. This was to be effected by limiting total catches. That there was no agreed sharing of these catches then, or indeed until the early 1960s as far as the Antarctic was concerned, meant that extreme over-capitalisation was inevitable. The scramble to rebuild and expand whaling fleets after the Second World War was fuelled by shortages of edible oils, especially in Europe, and stimulated through the encouragement of Japanese expansion by the occupying State, the US. Norway, whose policy throughout was to control the expansion of others by, among other ways, restricting the employment of skilled Norwegian nationals as crew on other flag vessels, managed to stop the entry of West Germany and Argentina to Antarctic whaling. *FAO, as usual on the side of 'development' rather than 'conservation', even expressed concern that the newly formed IWC was not*

Sei Whale
Balaenoptera borealis

doing enough to encourage fleet expansion! (That particular form of international irresponsibility reared its head again in 1982 when FAO again came out of the closet and argued against the commercial moratorium that was decided that year).

The later agreements to allocate national shares of catch quotas did not relieve the industry pressures to keep overall quotas high; they simply increased the profitability of whaling by removing much wasteful and expensive competition. Antarctic depletion continued, as we have seen, and as Clark later explained. Depletion of the remaining species has continued under the NMP. Commercial whaling never has been, is not now, and economically speaking probably never can be, based on sustainable exploitation from a stock which is kept near to or above its biologically optimal level. *Whaling is esentially an extractive industry, akin to mining.* Targetted depletion of one whale 'seam' stops when it becomes uneconomic to extract more, and the industry moves on to other places and species. Increases in efficiency ensure that this process is continuous so long as undepleted resources are left, somewhere. The less efficient producers, and the less mobile ones, get forced out: Australia, Canada, New Zealand, Netherlands, South Africa, UK, USA all dropped out of whaling in the post-war period; Norway eventually had to withdraw from the Antarctic. Those that stayed in, without exception, maintained profitability by selling frozen whalemeat to Japan[9].

1979—All in the IWC!

As the lively 1970s drew to a close, and one ex-whaling country after another changed its policy, Japan could see the way the wind was blowing, and didn't like what it saw. The 1972 and 1973 calls for all whaling countries to join the IWC suggested a shelter. All client whaling countries were urged to join. The carrot was the prospect of mutual security since, because of the three-quarters majority rule, one whaler's vote was equivalent to three determined ex-, non- or anti-whalers'. The stick was the prospect of being denied access to the vital Japanese market. Chile, Peru, South Korea and Spain all joined in 1979. There was now a potential blocking vote of Japan plus eight clients, in a total membership of twenty-four, but it was not yet properly organised—that had to wait until 1980.

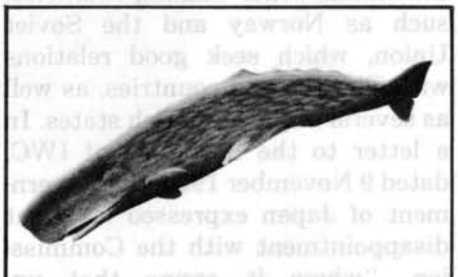
Having withdrawn in 1964, Sweden re-joined in 1979. It surprised everyone that the tiny, newly independent Republic of Seychelles also joined the IWC in 1979. Since then those two countries have been among the most active proponents of whale conservation. From 1980 to 1982 eighteen more non-whaling countries, ranging from the very large to the very small, have joined the IWC, although a handful of those have not been very active or have dropped out altogether. Finland joined in 1983, and Ireland in 1985. After more than thirty years 'the interest of the nations of the world' was beginning to be taken literally. Most of the new members were, naturally, countries of the so-called 'third world' which had never had access to whale resources when they were abundant.

At the 1979 meeting Seychelles, having made prior consultations with all Indian Ocean coastal states, whether or not they were members of IWC, proposed that the Indian Ocean be declared a whale sanctuary—and that was accepted, after an amendment which ensured that it would not impede Japanese and Soviet minke whaling near the Antarctic ice[10]. Seychelles also proposed a three year moratorium on catching sperm whales, which were of special interest to Indian Ocean countries, and about which, it was argued, not enough was known to set safe quotas. This initiative was lost—three of the new whaling members were then catching sperm whales. But Panama and Sweden proposed a moratorium on the use of factory ships in whaling. Again, a compromise was necessary to allow continued minke whaling, and with that exemption the proposal was adopted. It led to the *de facto* protection of sperm whales in the southern hemisphere, and the cessation of all factory ship operations in the North Pacific.

That for a while, was the end. Between the 1979 and 1980 meetings the whalers bloc was organised and it held through to the 1982 meeting. But in the meantime IUCN, UNEP and WWF produced the World Conservation Strategy (WCS). This, for the first time in a widely distributed, internationally respectable document, not only called for a moratorium on commercial whaling, but also specified some of the conditions that should be met before it was lifted[11]. With the failures of the NMP to stop depletion, the growing recognition of the inadequacy of whale science—now within the Scientific Committee as well as outside it—and a new political awareness of the nature of this problem, the time was ripe for renewing the pressure, in the IWC, for a moratorium.

At the 1982 meeting a proposal for an *indefinite* moratorium was adopted. As with the Sanctuary proposal, some compromises were needed to achieve this. Implementation was to be delayed until the 1985/86 Antarctic season and until 1986 elsewhere. The decision would be reviewed by 1990 at the latest, by which time a 'comprehensive assessment of the effects of this decision on whale stocks' would be undertaken. Although the formulation finally adopted was proposed by Seychelles, Australia, France, New Zealand, Oman, St Lucia, Sweden, UK and USA were all involved—a motley bunch, by normal diplomatic standards. In the whalers' bloc Spain broke ranks (having been assured of a satisfactory quota of fin whales during the three year delay period!) and the moratorium was adopted by 25 votes to 7, with 5 abstentions.

Japan, Norway, Peru and USSR lodged objections. Chile and South Korea had agreed to stop anyway. The Icelandic Parliament voted by a majority of *one* not to object. Brazil,


Sperm Whale
Physeter macrocephalus

under US pressure, did not object. Peru susbequently withdrew its objection, but it is far from sure that Peru will actually stop next year. Its Government has caused more trouble than any other by not paying its IWC subscription, by being caught committing many infractions of the reguations, and by rather openly saying it will violate the Convention because it can do what it wishes in its 200-mile zone.

And then there were three—or more?

The machinations during the three years breathing space are too complicated to go into here and they are not yet finished, by any means. Japan, Norway and the Soviet Union have all declared, time and again, that they will continue whaling. At the 1983 and 1984 meetings they fought for high quotas everywhere in which they had an interest. But united resistance began to crumble further. In 1984 Iceland and Korea, like Spain in 1982, agreed not to help Japan and the USSR get what they wanted, in return for some crumbs—higher quotas than the inconclusive scientific evidence warranted. In 1983 Norway had to accept a two-thirds cut in its minke quota for the North-east Atlantic—on the basis of its own scientists having shown that the stock had been declining for thirty years. The UK and some other EEC countries tried to help Norway out (It was whispered that Norway had reminded them that they had interests in fishing in Norwegian waters) but failed in the face of the determination of the new members and some of the old ones.

The months between the close of the meeting in June 1984 and the lead up to the 1985 meeting have seen the most active manoeuvring and diplomatic shuttling since the grave whaling crisis of 1959-1962. Norway, with some encouragement from the US, has been sounding out some governments about the idea that it would consider withdrawing its objection to the moratorium if the IWC would agree to define a third type of whaling—a sort of 'non-commercial commercial' whaling—that would be exempt from the moratorium decision and, presumably, also from the NMP. This would include coastal whaling for minke whales, which it is claimed is artisanal in character, and would involve stopping international trade in meat. A problem is that for the last few years much of the Norwegian meat production has been sold to Japan and, although fisheries officials have tried to convince the world that this kind of whaling is 'traditional', and in some ways comparable with Inuit subsistence hunting of bowhead whales in Alaska, it in fact dates back only to the 1930s and is technologically highly sophisticated.

Japan would like to join in the 'traditional coastal whaling' gambit, but also wants to continue catching Bryde's and sperm whales, using large and powerful catcher boats. Brazil uses one such boat to kill minke whales, and claims special consideration as a developing country with much poverty in its North-eastern region. Iceland catches minke with small boats and consumes some of the meat, but it also uses six large catchers to take fin and sei whales for export; the Annual Conference of the Conservative Party—the party with the most parliamentary seats—resolved in April to strive for the continuation of both types of operation. Even the whalers in North-western Spain would dearly like to continue; they take fin whales with several large catchers, but have no domestic market.

Spain, it is presumed, will in any case have to stop whaling when it joins the EEC. But what of the others that did not object to the moratorium? To the extent that they can persuade three-quarters of the IWC members to agree to a third category of whaling the definition of which covers their kinds of operations, then they would be able to continue. But they have a difficult task before them. Norway will be politically uncomfortable whaling under an objection, and in growing isolation. The situation in the North Atlantic, with no reasonable assessments of any of the whale stocks that are still exploited, is increasingly embarrassing to those countries in the region that pride themselves on their advanced civilisation and technical/scientific prowess[12].

But inevitably the spotlight is on Japan (the Soviet Union stays in the wings). Its Foreign Ministry has said that if the United States does not apply sanctions under the Packwood-Magnuson Amendment then it will withdraw its objection to the moratorium, but post-dated to be effective only from 1988[7]. A similarly post-dated withdrawal of Japan's objection to zero catch limits for sperm whales has already been posted. Yet observers remain sceptical of Japanese intentions. The most recent communication makes it quite clear that these offered withdrawals are not irrevocable, and it is well known that by 1988 the US laws will have little bite left in them; they may not even still be in force, and in any case US policy is to phase out foreign fishing from the 200-mile zone and to establish joint fishing ventures. Japan also says it will continue to press for the third type of whaling in some form. If all else fails, a reduced bloc of whaling countries might leave the IWC together, and try to agree among themselves about continued whaling and trade. This would cause a political storm. They might be able to weather it, but it could also lead to the whole question being moved to the United Nations.

Japanese interests organised a fleet of pirate whaling vessels—combined catcher and factory ships—flying flags of convenience such as those of the Bahamas, Cyprus, and Somalia, to kill whales of any species they encountered.

There are signs that the Government of Japan may be preparing to provoke a final crisis, but it would be one that could seriously embarrass certain other whaling countries, such as Norway and the Soviet Union, which seek good relations with Third World countries, as well as several of the other rich states. In a letter to the Secretary of IWC, dated 9 November 1984, the Government of Japan expressed its great disappointment with the Commission, "where it seems that unscientific and unreasonable decisions are adopted using the voting strength of the radical anti-whaling countries". (The only national delegation which has expressed itself in such a way that it could reasonably be said to represent an anti-whaling country, is that of Australia. Australian policy favours a *ban* on commercial whaling, rather than merely a pause.) Japan claimed that decisions are taken by abusing majority position, and charged "manipulation of deliberations by some irresponsible members" and "unfair management of the Scientific Committee". The letter proposed that to correct these alleged faults an "administrative system (should be established) composed of a few responsible member countries for the sole purpose of restoring the IWC's original functions, namely to achieve a balanced aim of conservation and the utilisation of resources".

A proposal, by an official investigatory commission in Japan, that if it is decided to succumb to external pressure and stop commercial minke whaling in the Antarctic under quota, then large catches could be continued under permits.

Apart from the fact that the original functions of the IWC are here misquoted, this can only be understood as an expression of belief in a sort of international apartheid, wherein some sovereign States are fully 'responsible' while others are child-like and thus should not be accorded full rights. It is certainly a direct attack on the notion of 'the interest of the nations of the world' being properly expressed through their membership in inter-governmental organisations. These passages in the now notorious letter of 9 November remind me of the opinion recently expressed by the Director of the British Antarctic Survey that "the Third World . . . has shown little or no interest in the (Antarctic) region until very recently—in marked contrast with the commitment of the Antarctic Treaty Nations"[4] (see Table). The writer continues in this vein, with no evidence of his recognising that most of the Third World nations have only recently freed themselves from colonialism and necessarily had other priorities for a few years, or that he is advocating one law for the relatively poor and another for the relatively rich, and the institutionalisation—in the international sphere—of first come, first served. As expressed in a recent cartoon: "The meek shall inherit the earth—when the rest of us have finished with it"! An individual, even—I suppose—a scientist in a senior administrative capacity, is entitled to express his personal opinion but it is scarcely credible that the Japanese Government could publicly air such secret thoughts.

The 9 November letter was written as the opening shot to a Working Group of selected member Governments on the Future of the IWC. It looks as if the Government of Japan may not want the IWC to *have* any future. But then a charitable interpretation could be that someone from the Japan Whaling Association—the industry lobby—wrote the letter and smuggled it through the London Embassy, and that it was never seen by any 'responsible' official in the Foreign Ministry. The Japanese Government had an opportunity to wriggle out of this when some other governments raised their metaphorical eyebrows, on the occasion of the first meeting of the Working Group, in February. But it didn't; instead, it reaffirmed its hard line. The 37th Annual Meeting of the IWC, at Bournemouth in July 1985, should be quite interesting.


PHOTO: GREENPEACE

One of the sperm whales taken by a Japanese whaling ship during November 1984 in defiance of the IWC ban on sperm whaling, introduced in 1981.

References and Notes

1 The best account is given by J N Tonnessen and A O Johnsen in their 800 page book *The History of Modern Whaling*, published in 1982 by C Hurst and Co, London. This is an English version of the four volume Norwegian original, published from 1959 to 1970. It has additional material taking the story forward to 1978, but this is more sketchy. Modern whaling dates from the early years of the twentieth century and involves the use of powered catcher boats using fixed cannon to fire harpoons with, usually, explosive grenades.

2 See Holt, S J (1981) "Maximum Sustainable Yield and its Application to Whaling", p 21-55 in *Mammals in the Seas*, Volume III, published by the Food and Agriculture Organization of the United Nations (FAO), Rome. This volume contains several important—and not highly technical—papers on the principles of managing whaling.

3 Greenpeace International has documented the clandestine activities of whalers in a series of publications entitled *Outlaw Whalers*. See also documents submitted to the IWC 1979 meeting by the Government of Seychelles, available from the Seychelles High Commission in London and the IWC Secretariat in Cambridge. Mr Nick Carter, of the Peoples' Trust for Endangered Species, the Dolphin Action and Protection Group, South Africa and, now, the Environmental Investigation Agency (EIA) (23b Highbury Crescent, London N5 1RX) has also played an important role in these investigations, as well as contributing to development of the ideas of justice and equity in international relations in the context of the IWC.

4 An extraordinary, and disturbing, insight to the cast of some scientific minds can be gained from a recent article entitled "International Stewardship of the Antarctic: Problems, Successes and Future Options", by R M Laws, Director of BAS (*Marine Pollution Bulletin* 16 (2): 49-55, 1985). See also my "Who really threatens whales and seals?", in *Oryx*, Vol XVII, April 1983, p68-77, and "How red herrings and soft variables are killing the whales" in *Siren*, May 1984, published from the Regional Seas Programme of UNEP, Geneva.

Contracting Parties have another way of avoiding developments they do not like, they can leave the IWC. All they have to do is give six months notice of withdrawal.

5 For a recent commentary see editorial "Antarctica's living resources: are they in safe hands?" in *Oryx* Vol XIX, April 1985 p65.

6 The full texts of the 1946 Convention and the CCAMLR convention, and analyses of both of them, are given by Simon Lyster in his "International Wildlife Law" (Grotius, Cambridge, UK, 1985, 470pp). This new book also deals with other international agreements which effect the conservation of whales: the Convention on International Trade of Endangered Species of Wild Fauna and Flora, 1973 (CITES), the Convention on the Conservation of European Wildlife and Natural Habitats, 1979 (the Berne Convention), the Convention on the Conservation of Migratory Species of Wild Animals, 1979 (the Bonn Convention).

7 The laws are the Packwood-Magnuson Amendment of 1979 (mark well that date) to the 1976 Fishery Conservation and Management Act, which requires the Secretaries of Commerce and of State to 'certify' offending countries, leading automatically to a great reduction in the fish catch they are allowed to take from the US 200-mile zone; and the Pelly Amendment which, although its application is discretionary, similarly restricts trade in fish products. In recent years the threat of these laws has been sufficient to change the attitudes of some countries to IWC decisions. The US courts are now considering a case in which a coalition of environmental organisations is seeking to force a reluctant Administration to apply the Packwood-Magnuson Amendment to Japan for continuing sperm whaling in the face of a zero quota. The future of the IWC itself may well hang on the outcome of this litigation. I have tried to explain to a lay public the ramifications of these and other recent events in a series of short articles in the monthly *BBC Wildlife Magazine* from July 1984 to July 1985. More full periodic reviews can be obtained from IWC Commissioners Briefing (*not* an official IWC publication), Temple House, 25/26 High St, Lewes, BN7 2LU, UK, and analyses of particular topics from the International League for Protection of Cetaceans (ILPC), 2 Meryon Court, Rye, TN31 7LY, UK (*Occasional Papers Series*). I have written an extended account of the last decade of efforts to conserve whales through 'reform' of the IWC, for the July 1985 issue of *Marine Policy* (Butterworth, Guildford, GU2 5BH, UK), entitled "Whale Mining, Whale Saving".

8 See, for example, C W Clark "Economic aspects of renewable resource exploitation as applied to marine mammals" in *Mammals in the Seas*, Vol III, p7-19 (see note 2 above).

9 Mining the Minke, ILPC/*International Fund for Animal Welfare*, June 1984. Available from ILPC (see note 7 above). This paper analyses the national and international trade in whalemeat over the past 15 years.

10 See M Ferrari "Of Whales and Politics", and S J Holt "The Indian Ocean Whale Sanctuary", both in a special issue of *Ambio* on the Indian Ocean, 12 (6), 1983.

11 Prepared and published in 1980 by the International Union for the Conservation of Nature and Natural Resources (IUCN), with advice and cooperation from the World Wildlife Fund and the UN Environment Programme.

12 Farley Mowat's latest book *Sea of Slaughter*, McClelland St Stewart, Ontario, 1984, is highly recommended reading for those interested in a non-technical but accurate account of the North Atlantic whaling story (particularly on the Western side), from the Basques in the sixteenth century, through the English, Dutch and Yankees in the seventeenth to nineteenth, to the Norwegians in the twentieth century up to the present time.

13 Private organisations can exert other pressures. A coalition of non-governmental organisations landed, in February this year, a boycott of Japan Air Lines, executed through travel agents worldwide. This was decided because of Japans sperm whaling in defiance of an IWC vote of twenty-five to one for a zero rate quota and because JAL is largely state-owned. It is too early to judge the effect of this action.

14 See *Pilot Whaling in the Faroe Islands* by J Gibson and D Currey, EIA, 1985 (see note 3 for address). This illustrated report also refers to the fin whaling.

Who should be responsible for the societal burdens upon the collapse of a fishery? Should the industry and the investors always be the major winners in the cycle of bloom and recession; receiving low cost loans or subsidies for initial investments, and being given tax relief or even benefitting from buy-back schemes when the economic returns decline?

The fishermen and shore-based support facilities and labour forces are too often left holding an empty bag, the profits having been exported along with the catches. The taxpayers will be passed the bills for the initial investments as well as the relief programmes after a collapse occurs.

Of course all this takes place behind the smoke-screen provided by the continuous speculations of various 'experts' on what could or should be done to rationalise the fishery once the declines are noted. The tug-of-war between Industry, Fishery Science and Politics is resolved only by the collapse of another resource. The onus is always on the 'scientist' to prove his position, rather than upon industry, whose position is usually to take short-term gains and move on. It appears to be a huge tragic-comedy in which the self-righteous scientist is the goat, the fishermen and national taxpayers are the posers, and the exporters and outside investors usually remain anonymous winners.

From the Introduction to the Proceedings of a Consultation on Neritic Fish Resources, held by the Food and Agriculture Organisation of the United Nations (FAO) in Costa Rica, April 1983. FAO Fish. Rep. 291, *Vol 2, 1983.*

Sidney Holt *is a fisheries biologist who has been involved in the affairs of the International Whaling Commission since 1959. Dr Holt spent the greater part of his professional life in the United States system, serving at various times as Director of FAOs Division of Fisheries Resources and Operations, Secretary of Unescos Intergovernmental Oceanographic Commission, Special Adviser in FAO on Antarctic problems, and leader of a joint programme of FAO and UNEP on the conservation and management of marine mammals. Since he retired in 1980 he has acted as scientific adviser to the delegation of the Republic of Seychelles to the IWC, and as consultant on marine affairs to several governments and non-governmental organisations. Dr Holt was awarded the Gold Medal of the World Wildlife Fund for his contributions to marine conservation. He is the author of more than two hundred scientific and popular articles and books on fisheries, whales and seals.*

World Climate and Tropical Forest Destruction

by Peter Bunyard

Across the globe the destruction of the world's remaining tropical rain forests has been gathering momentum as the forests are cleared for timber, agriculture, cattle raising, minerals and for the energy that can be harvested from the rivers that course through them. If action is not taken now, the next 50 years may see the complete eradication of the once mighty forests that encircled the lands of the equator. Although encompassing a relatively small proportion of the planet's total land mass, the regions now covered in tropical rain forest are biologically extremely productive, indeed, as is now increasingly appreciated, the interaction of the rainforest with its environment has consequences that stretch far further than the narrow belt where the forest is found. The earth's hydrological cycle, the transfer of heat from the tropics towards the poles, the chemistry of the atmosphere, and global climate are all influenced by the tropical biota, and the drastic changes to the vegetation being wrought at the hand of man are bound to cause changes. Just what those changes are likely to be we cannot predict with our present knowledge and tools, but some attempt was made to put them into perspective at the *International Conference on Climatic, Biotic and Human Interactions in the Humid Tropics, with particular emphasis on Vegetation and Climate Interactions in Amazonia* organised by the United Nations University and held in late February 1985 at the Brazilian National Institute of Space Research (INPE), São Jose Dos Campos. During the five days of the conference climate modellers from all over the world rubbed shoulders with experts on tropical earthworms, with atmospheric chemists who calculated the loading of the atmosphere with methane from rice paddy and cattle rumens, with agroforesters, soil scientists, tropical specimen collectors, anthropologists, hydrologists and with INPE's staff concerned with interpreting LANDSAT remote sensing images of the Amazon Basin.

As the UNU organisers of the conference appreciated in gathering such a diverse group, the tropical rainforest is a complete biological system in which every component, from the soil upwards through the canopy to the outer atmosphere plays its part. A change in one component is therefore likely to ripple through the system; for instance the compaction of soil, brought about through clearing the forest with heavy machinery, alters run off, destroys the relationships between soil organisms and disturbs the energy balances of the system with ultimate effects on climate. Whether those effects are micrometeorological or macro depends on the extent of rainforest destruction.

Even though hard and fast conclusions are hard to come by, all including the Brazilian hosts to the conference, agree that effective action to control deforestation has to be taken now if major perturbations to world climate and to the overall health of the planet are to be avoided.

If Nero fiddled while Rome burned, he did no more than most of us are doing in this day and age of mass destruction of our planet's surviving tropical forests. And while the world could clearly tolerate the loss of Rome, the same is not true of the eradication of enormous tracts of tropical forest such as has been taking place at an accelerating pace throughout the humid tropics, in South East Asia, in Central Africa and increasingly over the past decade in Brazil's Amazon region.

How much of the tropical forests has already gone is a contentious point, but certainly in some countries, Nigeria for example, and parts of Indonesia, the process is virtually complete. FAO estimates the present rate of deforestation at just over 100,000 square kilometres per year, whereas Norman Myers, who includes all degradation of primary forests, including logging operations where some trees are left standing, estimates deforestation at more than double that rate. His pessimistic figure is not significantly different from that of 200,00 square kilometres per year given in 1980 by the US National Academy of Sciences. Nevertheless, even at the deforestation rates given by FAO as much as one fifth of the world's remaining tropical forests will be gone within the next 15 years. However, in many of the countries concerned, including Brazil, the deforestation rate is growing rapidly year by year and the total may have gone by 2030 unless steps are taken now to control the devastation.

Deforestation in Brazil

As concern has grown in Brazil that deforestation is leading to a major environmental catastrophe, attempts have been made in recent years to delineate the extent of the problem. Climatologists need to know how much forest has gone in order to see whether their climate models are sensitive enough to pick up any changes or perturbations. Thus in 1978 a collaborative venture was undertaken by the Brazilian Institute for Forest Development (IBDF) and the National Institute for Space Research (INPE) to assess to what extent the Legal Amazon—an area of just under 5 million square kilometres—had been deforested. Landsat images indicated that by 1978 deforestation had taken place in 77,172 square kilometres, or 1.55 per cent of the total. The largest deforested area was in Mato Grosso State where 28,255 km² of forest had gone, followed by the State of Para's 22,445 km² and Goia's 10,288 km². Philip Fearnside, a biologist from the Department of Ecology, the National Institute for Research in the Amazon (INPA), who has spent some 10 years in the Amazon disputes those figures, for a start pointing out, the naturally forested area of the Legal Amazon is little more than 2,600,000 km², and therefore just half the total area in question. Thus deforestation will be at least double that recognised officially. Moreover by 1979 approximately 8 per cent of the Amazon Basin was covered in degraded secondary forest; a fact not picked up in the satellite image, Fearnside also claims that the satellite image failed to pick up small areas of deforestation which had not yet coalesced into larger ones.

Fearnside also disputes the results of the INPE/IBDF study on the grounds that it has failed to pick up the massive deforestation that took place in the Zona Bragantina in the State of Para during colonisation in the latter part of the 19th century. Altogether some 30,000 km² were cleared, a deforestation that is greater than the 28,595 km² indicated by the satellite study as having been cleared from the entire Legal Amazon by 1975 and almost four times the 8,654 km² indicated as cleared then in the State of Para (see Table).

The tragedy is that although the clearing of the forest has been justified on humanitarian grounds by the Brazilian Government as a means of settling the landless poor from the deprived areas of the country, Brazil has no intrinsic need of the Amazon to settle hundreds of thousands of peasant farmers. Even without including the Amazon in its total land area, Brazil has the same population density as the United States—some 65 people per square mile. Indeed, as Catherine Caufield notes in her recent book *In the Rainforest*, "Brazil has 2.3 acres of farmland per person which is more than the United States, the world's greatest exporter of food. Taking potential farmland into account, but still leaving aside Amazonia, each person in Brazil could have 10 acres. Instead 4.5 per cent of Brazil's landowners own 81 per cent of the country's farmland and 70 per cent of rural households are landless."

The large areas of undisturbed forest still left in the Amazon have led many to the view that deforestation is of minor concern and unlikely to reach significant proportions within the foreseeable future. However the results from the Landsat survey should themselves be ground for concern inasmuch as the observed increase in cleared areas in the Legal Amazon between the three years 1975 to 1978, from 28,595.25 to 77,171.75 km² implies an exponential growth rate of 33,093 per cent per year, and a doubling time of only 2.09 years. In Rondonia, for instance, Landsat imagery showed that the cleared areas rose more than six fold, from 1216.5 km² in 1975 to 7579.3 km² five years later in 1980. Hence from 0.5 per cent of the State cleared in 1975 to more than 3 per cent gone by 1980. Again Fearnside remarks that the true picture of clearance is much worse than than depicted in the satellite image.

TABLE 1

Observed Cumulative Cleared Areas for Brazilian Amazon[(a)]

Federal Territory	Observed Cumulative Cleared Areas (Km^2)			% Deforestation of State or Territory.	Clearing Rate for Exponential Increase[(b)]	Clearing Rate for Linear Increase[(c)]
(FD)	Area (km^2	1975	1978		(% yr − 1)	(% yr − 1)
Amapa (FD)	139,068	152.50	170.50	0.122	3.719	0.0043
Para	1,227,530	8,654.00	22,445.25	1.828	31.769	0.37
Roraima	243,004	55.00	143.75	0.059	32.025	0.012
Maranhâo*	257,451	2,904.75	7,334.00	2.848	30.462	0.57
Goias*	285,793	3,307.25	10,288.50	3.600	35.873	0.81
Acre	152,589	1,165.50	2,464.50	1.615	24.961	0.28
Rondônia	230,104	1,216.50	4,184.50	1.818	41.180	0.43
Mato Grosso	881,001	10,124.25	28,255.00	3.218	34.211	0.69
Amazonas	1,558,987	779.50	1,785.75	0.114	27.631	0.022
Legal Amazon	4,975,527	28,595.25	77,171.75	1.551	33.093	0.33

(a) after Parada *et al* (1981) except for (b) which is from Fearnside (1982) and in which the increase is expressed in terms of the exponential rate coefficient, r, given in Equation (2) and (c) which is the calculated linear rate of deforestation of the total area.

*The area of the state is not totally included in the Legal Amazon.

Each year the pressures on tropical rain forests are becoming more intense; and the obvious consequences are greater and greater deforestation. Governments of countries with tropical rainforests tend if anything to underestimate the extent of the problem, coming up with figures that are considerably less than those derived from satellite remote sensing. And remote sensing, as we have seen, cannot pick up the difference between degraded forest and primary forest. Meanwhile, on the ground, the changes to be seen after the forest has gone are all too evident; the soil becomes compacted, especially when bulldozers and heavy machinery have been used to clear the forest, any minerals in the soil are rapidly leached away and in general the denuded land becomes covered in unpalatable grasses such as Imperata. To sustain any kind of fertility necessitates a large input of fertilisers most of which either become locked up in the acidic aluminium-rich soils or are leached away in the first rains.

Ecology of the Rainforest

In utter contrast to the barren, simplistic transformations of the forest at the hands of man the tropical forest is a miracle of biological ingenuity. The incredible diversity of the climax rain forest, with its hundreds of thousands of species of plant and more than a million species of animal is not simply the response to greater solar radiation and rainfall compared with more temperate zones, it is the end product of many millions of years of evolution during which the flora and fauna have gradually moulded the environment to suit their own requirements. The humidity of the forest, the relative coolness of the forest floor, the extraordinary rapidity with which nutrients are absorbed back into the living system so that virtually none leaches away, the mechanisms by which the vegetation ensures its survival and propagation are the result of intricately linked factors, all of which disappear when the forest is gone.

Biologists have only managed to unravel a few of the linkages between species, but invariably find that, like a delicate watch mechanism, the disruption of one apparently insignificant part of the system can have totally unforeseen circumstances. Because there is little wind beneath the canopy, and because different members of the same species tend to be widely dispersed in the forest, many tropical trees depend on animals for pollination and for seed dispersal. And because of the lack of available nutrients from the soil in many parts of the tropics, many trees have developed large, nutritionally rich seeds that can provide the seedling with enough of a head start to get established once germination is underway. Hence the extraordinary variety of succulent fruits from the rainforest and the oversize seeds compared to wind pollinated and wind dispersed seeds of temperate trees.

Since many of the animals involved in pollination and seed dispersal need more than one species of tree for their survival, it has sometimes proved difficult to establish plantations of tropical trees for their fruits and nuts, moreover it is becoming clear that the integrity of the primary forest may require that very large areas are left intact. Judy Rankin, a botanist working in the Amazon, has found that isolated patches of primary forest of 10, 100 or even of 1,000 hectares cannot sustain themselves. Within a couple of years, of the forest being cleared, the remaining patches showed distinct signs of degradation, particularly at the edges of the plots trees were uprooted because of penetrating winds. Undoubtedly too the general drying out of the forest was a potent factor in its disintigration.

Scott Mori and Ghillean Prance who have spent many years in the rainforest collecting specimens for the New York Botanical Garden, believe that the disturbance of flowering and fruiting may be a first step in the extinction of plants and of the animals which co-exist with them and are an integral part of their life cycles. They have studied the Lecythidaceae, a family of small to very large trees found in the tropics of both hemispheres.

The Lecythidaceae are trees of lowland moist forests, with few species of the savannah. In general they are trees of the terra firme, but some species have successfully invaded the periodically inundated varzea. Species of Lecythidaceae in general do not colonise clearings, especially if the forest is burned after felling. However, many species sprout from cut trunks and some regrowth is therefore possible if an area is not burned. Where there is a distinct dry and wet season the Lecythidacea tend to flower in the dry season and fruit at the beginning of the wet season. The pattern of flowering and successful fruiting can easily be upset by abnormal weather conditions, whether too dry or too wet.

In fact, the principal pollinators of neotropical Lecythidaceae are euglossine bees which obtain differentiated pollen and nectar. The pollen from the hood which is collected by the bee does not germinate, whereas that from the stamenal ring sticks to the back and head of the bee in the right position to be transferred to the stigma of the next flower visited.

As Mori and Prance state: "The maintainance of these relationships is dependent upon the maintenance of climatic and other environmental conditions that favour lowland moist forests. Attempts at growing Brazil nuts in plantations is a good example of man's failure to recreate the environmental conditions necessary for the survival of a species. Once this species is placed under plantation cultivation fruit production is drastically reduced, probably because pollinators are not present in quantities necessary for adequate cross pollination."

The Vulnerability of Tropical Soils

As those who have tried to establish permanent agriculture in the rainforest have discovered to their cost, the soil, once the forest has been cleared away, is

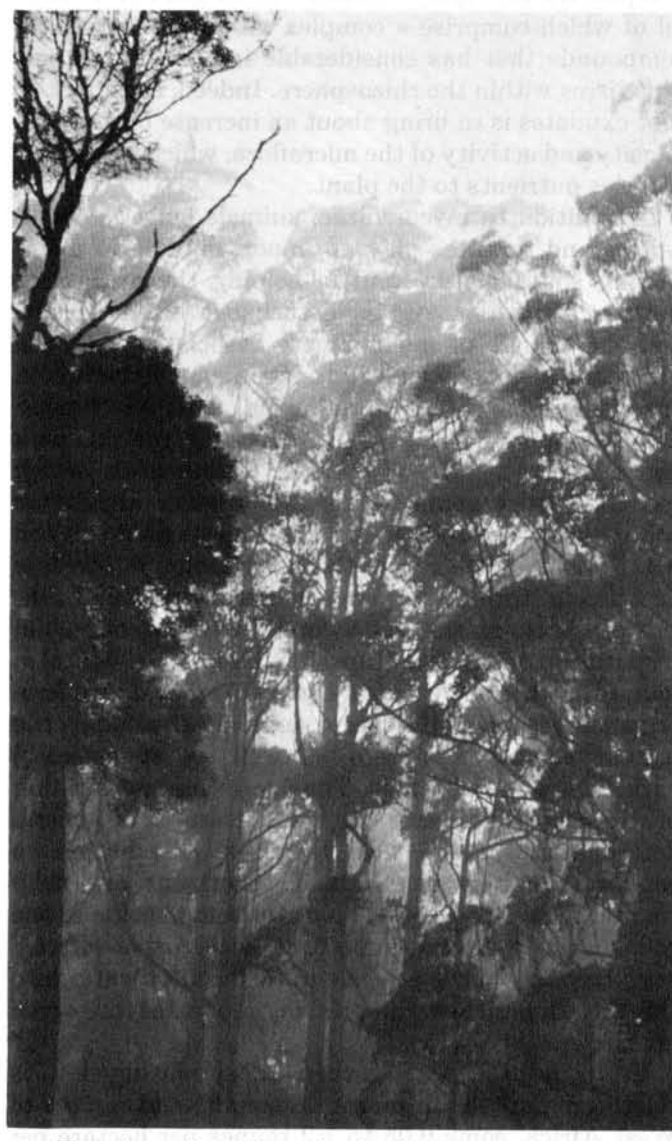


PHOTO: E CRICHTON

The primary forest is a miracle of biological ingenuity.

practically worthless. Indeed most of the richness of the rainforest is carried in the vegetation itself which over millions of years of evolution has developed unique mechanisms for recycling nutrients. In the Amazonian rainforest at San Carlo de Rio Negro in Venezuela where the soils are poorest tropical podzols, the biologist Rafael Herrera has found that as much as 92 per cent of magnesium, 90 per cent of potassium, 74 per cent of calcium, 66 per cent of phosphorus and more than 60 per cent of nitrogen are carried in the plant biomass. The recycling of nutrients in tropical soils is rapid, particularly in those with the poorest soils. Indeed measurements of the root biomass can give a good indication of the nutrient status of tropical soils, the values found ranging from 48 tonnes to the hectare to 255 tonnes in poorer soils, thus constituting 8.7 and 60 per cent respectively of total plant biomass. In forests with very low nutrient status the roots may form a thick 30 centimetre root mat which functions as a filter that prevents nutrient leaching. Such mats are associated with abundant mycorrhizae that make a bridge between the root and the dead leaf, thus ensuring a direct cycling from the leaf to the root. As much as 90 per cent of the root biomass may be concentrated in the upper 20 cm of soil. Living roots produce exudates, including assimilable organic compounds, mucopolysaccharides and growth factors, all of which comprise a complex mixture of energetic compounds that has considerable impact on the soil organisms within the rhizosphere. Indeed, the effect of root exudates is to bring about an increase both in the density and activity of the microflora, which in its turn recycles nutrients to the plant.

In addition to mycorrhizae, animals such as earthworms and termites play an important role in maintaining soil structure and in helping the process of nutrient recycling. Again disturbance of the forest, and the change of microclimate associated with the vanishing of cover, can lead to significant reduction in the activities of soil organisms, and to further deterioration of the soil. For instance the common endogeic earthworm, *Pontosolex corethrurus*, which feeds on soil organic matter, adds water and water soluble organic matter to ingested soil which raises soil pH. Patrick Lavelle, from the Laboratoire de Zoologie de L'Ecole Normale Superieure, Paris, has found that the presence of the earthworm increases microbial respiratory activity by up to 8 times. He has also found that the activities of earthworms and of microorganisms in tropical soils are seriously affected by the use of soluble fertilisers as well as of chemical herbicides and pesticides. Thus conventional farming of tropical soils leads to compaction and general deterioration of the soil. Termites, in addition to earthworms, also help mix soil horizons and help counteract the progressive natural compression of the soil. "This is a very important anti-erosive effect," says Lavelle, "since an easy infiltration of water into the soil diminishes run-off, an important factor of erosion".

In a natural, undisturbed ecosytem erosion is relatively limited. In many savannahs and forests of West Africa, some 0.05 to 1.2 tonnes per hectare per year may be lost, while data from a wide range of tropical soils indicate that up to 3 tonnes of soil per hectare per year may be lost naturally. Cultivation leads to a dramatic increase in soil loss, on average some 54 tonnes per hectare per year being lost, and at worst some 334 tonnes per hectare per year.

PHOTO: UNEP

"Deforestation today is drought tomorrow and famine the day after." Laurent Fabius, Prime Minister of France.

The Forest and Climate

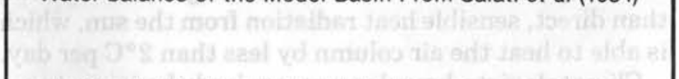
For a climatologist one of the major concerns is what overall effect eradication of the rainforest will have on local rainfall insofar as that will have repercussions on other parts of the globe. But first he has to know what happens over the undisturbed rainforest, and not just the total rainfall over the year, but how much gets back into the atmosphere through evapotranspiration as well as how much runs off into ground water and into the river systems.

To get some answers a joint Anglo-Brazilian team of scientists, involving the British Institute of Hydrology, the Natural Environment Research Council and the British Council in collaboration with the Brazilian National Research Council, the Brazilian Company for Agricultural Research (EMBRAPA) and the University of Amazonas, have constructed a 45 metre high tower which thrusts up through the canopy on a site some 25 kilometres to the northeast of Manaus in a primary forest reserve. One of the main findings is that 70 per cent of the radiation from the sun goes into evaporating water leaving just 30 per cent to heat up the air and general surroundings. Clearly evapotranspiration is an important cooling mechanism within the forest.

All investigations to date indicate that a considerable proportion of the rainfall over the forest ultimately finds its way back into the atmosphere through evapotranspiration. The tower experiments show that 17 per cent of precipitation is intercepted by the canopy and evaporated before ever reaching the ground, while more than 30 per cent of rainfall is drawn back into the atmosphere through plant transpiration. The remaining 50 per cent runs off.

Eneas Salati, director of the Brazilian Centre of Nuclear Energy for Agriculture, from research carried out in the 1970s, believes that the proportion of rainfall getting back into the atmosphere may be considerably higher than the results from Manaus suggest. He estimates that as much as 75 per cent of the year's rain returns from the forest direct to the atmosphere, 25 per cent through interception, and 50 per cent through plant transpiration. Overall he concludes that the Amazon Basin, encompassing 5 million square kilometres, receives 12×10^{12} tonnes of rain over a year, losing 6.43×10^{12} tonnes through evapotranspiration and 5.45×10^{12} tonnes through discharge into the river system that drains the Amazon Basin.

Water balance of the Model Basin From Salati *et al* (1984)



The forest thus feeds the atmosphere with water, which in the turbulent conditions over the forest forms cumulus clouds, and so the rain is returned again. For the system to be self-generating the rain that drains through the forest and back to the Atlantic Ocean will have to be made up by water brought in with the north and south Trade winds which have had the entire width of the Atlantic to become saturated with water. Water, in fact, carries its own tracer in the form of naturally occurring stable isotopes of oxygen—^{16}O, ^{17}O and ^{18}O. Because it is the heaviest ^{18}O tends to be left behind during evaporation with the result that seawater is found to have an ^{18}O concentration which is some 8 per cent higher than that in the water vapour above it. Conversely when the water vapour condenses over land the heavier ^{18}O water molecules tend to precipitate first so that as the rains pass westward over the Amazon they should become increasingly depleted in ^{18}O. However, Salati and his co-workers have discovered that the rains are less depleted than expected on the basis of simple fall out of ^{18}O water, the reason for the departure from expectation being the make-up of water through evapotranspiration. They are now developing models with which they hope to be able to put precise numbers as to the provenance of water over the Amazon.

The Water Balance after Felling

As Salati points out, the secondary forest—known as capoeira—which regenerates after tribal Indians have abandoned their small garden plots, will, given sufficient time, re-establish itself as primary forest with all the composite variety of flora and fauna found in virgin areas. But when large areas are deforested, regeneration to the original state may take as long as 300 or even 1000 years, especially when heavy erosion has taken place.

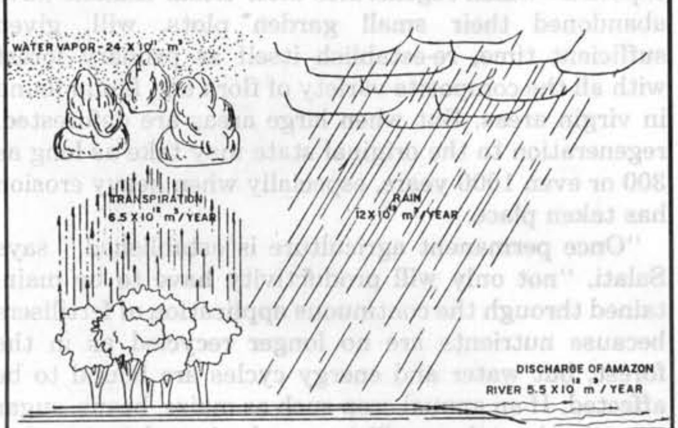
"Once permanent agriculture is established," says Salati, "not only will productivity have to be maintained through the continuous application of fertilisers because nutrients are no longer recycled as in the forest, but water and energy cycles are bound to be affected. If an annual crop such as maize, beans, sugar cane, is planted we will have substituted just one or two plant species for the thousands existing in the primary forest. This change in the flora will in turn imply gross alterations in the fauna as well as in microflora and with changes in the microflora we are bound to affect the properties of the soil.

"Thus not only are we likely to get much greater surface run-off, because much less water is retained by the plants, we are also likely to compact the soil, reducing its permeability. The overall result will be an increase in the amount of water drained off through the *igarape* during rainfall, especially during the heavier rains, and a decrease in the amount of water available for evaporation and transpiration. With less water available for evapotranspiration, the relative air humidity will decrease which *per se* will alter the energy balance, and the incident solar energy, instead of being used for water evaporation will be used for heating the air." Salati adds that the change in vegetation cover will also change the albedo, which in itself will have some bearing on the energy balance.

Already some evidence exists that deforestation in the Upper Amazonian region of Ecuador and Peru has resulted in greater surface run-off. For instance at Iquitos in Peru the height of the annual crest of the Amazon has been greater than 26 metres since the 1970s, whereas prior to 1970 it had never reached that mark.

Discrepancies in the Climate Models

Ann Henderson-Sellers, from the University of Liverpool, remarks, few climate modellers are agreed as to the precise effects on climate of land-use changes in the humid tropics. Even the background data is suspect with large variations in estimates of the extent of deforestation which has already taken place. Nevertheless most of the global climate models indicate that a change of vegetation, from forest to grassland, will lead to some drying out and a decrease in precipitation. For instance use of the UK Meteorological Office Model showed that in Amazonia such changes to vegetation would lead to a decrease in precipitation of between 1 and 5 mm per day during the wet season and less than 2 mm per day in the dry season with an overall fall in evaporation of between 0.5 and 5 mm per day.



Water balance and storage of water vapour in the Amazon Basin From: Salati *et al* (1984)

In another simulation experiment Henderson-Sellers and V. Gornitz looked at the possible effects on climate of deforestation at the current rate over the next 35-50 years. Thus approximately 5 million square kilometres were replaced by grassland, with a surface albedo increase from 11 to 17 per cent. They found a decrease in average rainfall of 0.5 to 0.7 mm per day, hence some 250 mm over the year, and less than 10 per cent of total rainfall today. The local temperature did not change significantly because the diminished cooling effect brought about through evapotranspiration was counteracted by the increase surface to space radiation resulting from increased albedo. As Henderson-Sellers points out, global climate models tend to use highly simplified information, rainfall for example is generally assumed to fill the soil with water, with any excess disappearing from the computational scheme in a 'run-off' term; the entire scheme being termed a bucket hydrological model. Many models like the UK Meteorological Office GCM, still retain a single soil layer, neglecting that different soil layers retain moisture and heat. The models also tend to underestimate rainfall, sometimes by as much as 50 per cent of that actually observed to fall. Hence their results must be suspect. Nor can the models indicate what kind of changes are likely to take place in precipitation patterns. For instance, large-scale deforestation in Malaysia was found to leave rainfall totals more or less unaffected; yet more precise information revealed that the rains had become fewer in number but with considerably greater intensity.

Latent Heat in Air Circulation

The energies involved in evapotranspiration of water over the Amazon Basin are enormous, indeed the lifting of 6.5 million million tonnes of water over the year is equivalent to the explosion of 5 million atomic bombs each day. Conversely when rain precipitates from clouds, latent heat is released and becomes available for heating the atmosphere. Professor Jan Peagle, from the Department of Meteorology, the University of Utah, points out that the quantities of energy released in heavy rainfall can be considerable, just two centimetres of rain—hence less than one inch—being sufficient to warm the entire trophosphere by some 6°C. Over the tropics, local rainfall rates in excess of 4 cm per day are not uncommon for weekly periods and much larger rates for short periods have been known. The latent heat released in 4 cm of rain heats the cloud layer by 10°C. And during peak rainfall with rates exceeding 6 cm per day, the heat released is sufficient to warm the trophospheric column of air above the earth by as much as 20°C per day. Thus latent heat release through precipitation is more important as a factor in warming the air column than direct, sensible heat radiation from the sun, which is able to heat the air column by less than 2°C per day.

Climatologists have long recognised the importance of latent heat as a means by which solar energy received in the tropics can be distributed over the higher latitudes, thus evening out the surface temperature of the earth. The eighteenth century scientist, Hadley, realised that if the earth's surface were homogeneous and the planet were not rotating, the larger input of heat at the tropics, some 2½ times that of the poles, would result in a single circulation cell in each hemisphere, with the upward limb at the equator and the downward one at the respective pole. In fact, the earth rotates, deflecting the circulation and thereby hindering the transfer of energy from the equator to the respective poles.

Thus the moisture-laden air rising from the tropics is pulled towards the north-east in the northern hemisphere, and like a mirror image to the south-east in the southern hemisphere. The winds generated by this movement of air are known as the westerlies. They are counteracted, to their south and north respectively, according to hemisphere, by the easterly trade winds, which by their movement towards the tropics complete the circulation. The entire system of air currents from the equator up to higher latitudes and then back again constitutes what has come to be called the Hadley Cell Circulation. This circulation is of critical importance in the transfer of energy, most of it in the form of latent heat of evaporation, from the warm tropics to the colder regions to the north and south. Quite clearly a change in the total quantities of water carried in this circulating system, as might result from deforestation of the tropics, will affect the transfer of heat from the equator polewards. It might also have some bearing on the expansion of deserts in the sub-tropics of both hemispheres.

Deforestation and Deserts

A tropical rainforest has a relatively low albedo—11 per cent—and therefore absorbs much of the sun's radiative energy, except when covered in cloud. Deserts, meanwhile, have albedos in the range of 30 to 40 per cent and just under half of the solar radiation they receive is reflected back from the surface into space. Thus the dry, cloudless air over deserts carries much less energy compared to the moist air arising over the tropics. The net result is that more radiation is lost from subtropical desert regions than is gained from solar radiation and deficit is made up by air from the downward limb of the Hadley Cell as it turns and heads back to the equator as part of the trade winds. Thus the air that descends into the deserts originally rose near the equator.

When the air mass sinks over the desert it tends to warm up simply through adiabatic (pressure) changes, resulting in low relative humidities and clear skies. The climatologist, J Charney, has suggested that a positive feedback principle is involved with desertification, overgrazing for example, leading to albedo changes which themselves lead to a further drying out and therefore to a spreading of arid conditions. Indeed a change in albedo from 15 to 30 per cent, hence from vegetated to non-vegetated conditions, would, according to his model, increase substantially the movement of air passing down to the desert in the returning limb of the Hadley Cell. An increase in such circulation over the desert would lead to sharp reductions in cloudiness and therefore of rainfall.

Further confirmation of man-induced changes leading to desertification has come from Carl Sagan and his colleagues. As they point out in *Science* (1979: 206, 1363-8), a change from savannah to desert brings about an increase in albedo from 16 to 35 per cent, while a change from tropical forest to pasture or savannah increases the albedo from aproximately 10 per cent to 16 per cent. They calculate that the spread of deserts over the past millennia may have raised the global average albedo sufficiently to be responsible for a 1°C average cooling of the earth. Meanwhile, over the past 25 years, man's activities may have led to global albedo increase of one-tenth of a per cent, the most significant part of that change occurring in the tropics and subtropics through deforestation (35 per cent) and through desertification (65 per cent) where the effect on the solar radiation balance is considerably greater than over higher latitudes. The global mean temperature has fallen some 0.2°C since 1940, despite the incease in carbon dioxide, and it may well be that mankind has unwittingly counteracted the greenhouse effect of carbon dioxide increase with a raising of the earth's albedo.

Gaia as Regulator of Climate

Climatologists have become increasingly aware that climate is not something imposed on the living earth as it were from above. Living organisms in their totality form a component part of climate by affecting hydrology, surface reflectivity, and wind turbulence. The sun thus provides the energy, and living organisms have created complex interacting systems by which that energy can be controlled and its potential as a life-destroying force contained. The notion that life itself has been a major factor in the regulation of world climate has been best expressed by James Lovelock in his book *GAIA—A New Look at Life on Earth*. Indeed, without life on earth, says Lovelock, because of the sun's increasing luminosity the surface temperature of the earth would by now have risen beyond the point at which life, as we know it could have been sustained.

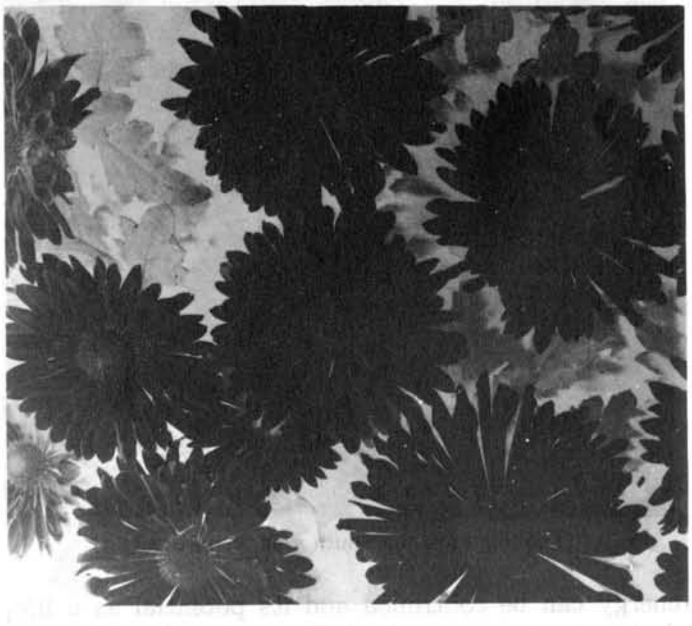

PHOTO: UNASYLVA

Loading logs in a South American Forest.

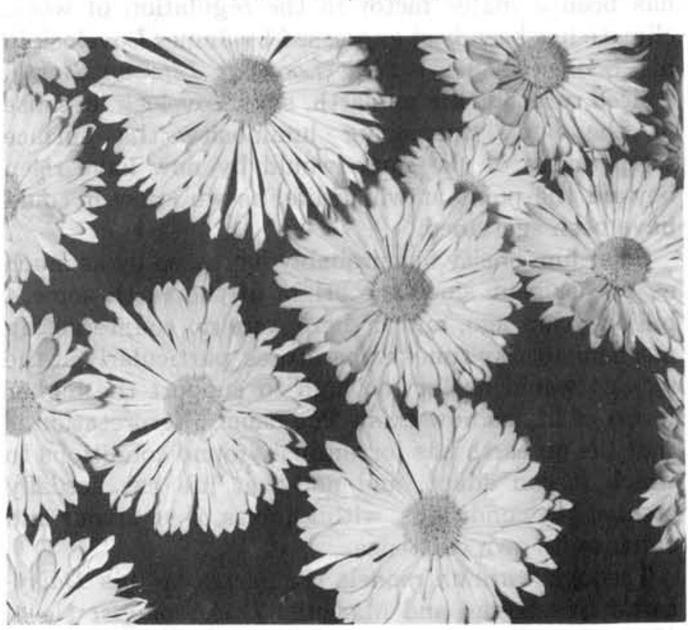
Solar luminosity has probably increased by as much as 25 per cent since the origin of the earth some 4 billion years ago, and if there were no counteracting mechanism, day-time temperatures, particularly at the tropics would be far too high to support the higher forms of life as now exist. The usual interpretation is that life on earth has fortuitously found conditions to which it can adapt, and not that life has actually created the conditions, within limits, that favour and enhance its own existence.

Through various models, in particular his *Daisyworld* (see Sagan and Margulis *The Ecologist* No 4, 1983) Lovelock has demonstrated on theoretical grounds that, simply by altering the albedo of the earth, plants—in this instance daisies—can play a role in regulating the earth's temperature, even against a sun that is ever getting hotter. In more elaborate daisyworld models which include rabbits that feed on the daisies, and foxes that prey on the rabbits, Lovelock shows that the system exhibits a strong tendency to homeostasis and stability. Ultimately the sun gets too hot for the total system and it flips out of control and becomes a dead planet.

In coming closer to the real world Lovelock has shown how plants may have used the properties of carbon dioxide as a greenhouse gas to regulate the earth's temperature. His model is based on an earlier one of J. C. J. Walker and his colleagues who claimed that life was able to begin on earth and get a grip despite a cooler sun because of the high concentration of carbon dioxide in the atmosphere at that time. Indeed carbon dioxide is thought to have comprised between 10 and 30 per cent of the atmospheric composition.



Lovelock's Daisy World Model



"As the sun evolves and increases its flux of radiation," says Lovelock "the temperature is kept nearly constant by a progressive decrease of CO_2. The process of CO_2 removal is the weathering of calcium silicate rocks and the model assumes that the rate of this process is directly related to the plant biomass. If conditions are too hot or too cold the rate of weathering declines and as a consequence of the constant input of CO_2 by degassing the earth's interior the CO_2 partial pressure rises."

Lovelock believes his model may cast some light on the periodic changes of CO_2 and climate that characterise the onset of glaciation and equally on the sudden and simultaneous rise of CO_2 and temperature at the end of cold periods that leads once again to a new warmer steady state. As he points out, "The rise in both CO_2 and temperature 12,000 years ago took place in 100 years or less and cannot be explained by geophysical or geochemical theory. It requires a change in the biota: most probably the sudden death of a substantial proportion of the marine phytoplankta."

Climate and Carbon Dioxide

Lovelock has described carbon dioxide as a 'blanket' which kept the earth warm when the sun was much cooler than it is today, and temperature-wise at least, enabled life to get a grip. Today, with a warmer sun, the equilibrium temperature of the earth at the top of the earth's atmosphere is found to be approximately 267K or—16°C. Yet the average temperature at the surface is 288K or 15°C, which is more than 30°C warmer. The difference is brought about through there being gases in the atmosphere, in particular carbon dioxide, which absorb infrared radiation that would otherwise escape to space and cool the earth down.

Although carbon dioxide levels have been coming down steadily since green plants began pumping the gas out of the atmosphere, there have been marked fluctuations, some of them coinciding apparently with ice ages. Estimates indicate that carbon dioxide levels during the last ice age some 18,000 years ago dropped as low as 180 parts per million (ppm), the evidence coming from the concentrations of carbon dioxide found in air bubbles trapped in polar ice. For more recent atmospheric concentrations, the evidence is drawn from the ratios of different carbon isotopes found in tree rings. The records for the past 150 years show that the ratios of both carbon-14 and carbon-13 to carbon-12 in the atmosphere have been decreasing. Because of their age, fossil fuels contain virtually no carbon-14; hence with the increased burning of fossil fuels that has taken place since the beginning of the industrial revolution, atmospheric concentrations of ^{14}C relative to ^{12}C would be expected to fall. That decrease in the relative ^{14}C to ^{12}C ratio as found in tree rings is known as the Seuss Effect, and the extent to which the effect has grown fits well with data on fossil fuel burning and on the rates at which carbon dioxide is deposited in such sinks as the oceans.

Meanwhile plants prefer carbon-12 to carbon-13, thereby leaving the atmosphere slightly rich in the heavier isotope. The burning of fossil fuels would therefore tend to balance out any such effect, since such fuels, originating from plants would tend also to be richer in carbon-12. However unlike the record of carbon-14 to carbon-12 ratios, the decrease in the carbon-13 to carbon-12 ratio does not entirely match up to fossil fuel burning, and the suggestion is that the discrepancy is the result of massive biomass changes brought about through deforestation, including biomass burning and the oxidation of soil humus after the soil has been exposed. The evidence suggests that man's agricultural activities over the past 150 years have contributed an amount of carbon dioxide to the atmosphere that is comparable to the total emissions from fossil fuel combustion. Clearly the accelerated deforestation of the tropical rain forest is having a marked effect on atmospheric CO_2 levels.

In essence the isotope ratios indicate that CO_2 concentrations increased from some 260 ppmv early in the 1800s to 290 ppmv by the end of the 19th century. The present day annual mean concentration of carbon dioxide as measured at the Mauna Loa Observatory in Hawaii is 340 ppmv, suggesting a 30 per cent increase since 1800, most of it the result of fossil fuel burning.

The atmosphere contains some 750 gigatonnes of carbon in the form of its dioxide (1 Gt = 10^{15}g), which is reckoned to be of the same magnitude as the carbon contained in the living biosphere, and as in the upper 100 metres of the ocean. The soil, meanwhile, probably contains twice the amount in the atmosphere, but the biggest sink of all is in the deep oceans and in the fossil fuel reserves, each of which contains one or two orders of magnitude more than does the atmosphere.

Because of relatively poor mixing, the oceans absorb no more than one half of each year's fossil fuel burning. The present level of fossil fuel emissions is estimated at some 5 gigatonnes per year, which is approximately equivalent to the seasonal variations in carbon dioxide resulting from changes in plant activity.

The growth rate in fossil fuel consumption has fallen since 1973, nevertheless based on more modest projections of economic growth than those being bandied around ten years ago, the burning of fossil fuels is likely to lead to a doubling of CO_2 concentrations by the end of the next century. The problem too, is that unlike sulphur which can be captured through such devices as flue gas desulphurisation, the capture of CO_2 emissions would involve the energy from one power plant to remove most of the gas from another. Undoubtedly too CO_2 emissions will become relatively worse per unit of useful energy once synthetic fuel production gets underway, in which, for instance, coal is converted into either gases or liquids to substitute for the dwindling reserves of petroleum.

A doubling of Atmospheric Carbon Dioxide

Various climatologists have attempted to predict the effects upon climate of a doubling of carbon dioxide concentrations. Using a general circulation model, Manabe and Wetherall come to the conclusion that a doubling of CO_2 may lead to a 2 to 3°C increase in the globally averaged surface air temperature. The warming, moreover, would be several times greater in higher latitudes compared with more equatorial latitudes. One of the results obtained from their model indicates that rainfall will tend to shift polewards, leaving mid-latitudes and therefore the arid subtropics drier. A doubling of the CO_2 content of the atmosphere, leads to an extra one and a half per cent of solar radiation to the earth being trapped—hence equivalent to placing a 15 watt light bulb every four square metres over the surface of the earth. Equally significant, the effect of doubling CO_2 on the global energy balance is some 80 times greater than the heat generated by the burning of the fossil fuels that has given rise to the CO_2 in the first place. Together, the changes in the Hadley Cell circulation brought about through deforestation, the eradication of vegetation at the margins of deserts and increased CO_2 are likely to accelerate the expansion of deserts towards the equator. With the deserts spreading as they are at the present time, there can be no room for complacency.

The Atmospheric Gases

Just as the tropics are important in the forming of climate, they are equally so when it comes to atmospheric chemistry. As Paul Crutzen of the Max Planck Institute for Chemistry points out, the tropical atmosphere generates a highly reactive chemical radical, which although present in minute quantities (2 x 10^{-14}) is responsible for the removal of many trace gases from the atmosphere, that if left would undoubtedly cause the atmosphere to change significantly from its present state. The radical—hydroxyl—is produced by the photolysis of ozone through the absorption of ultraviolet radiation, the electronically excited oxygen atom then interacting with water vapour. According to Crutzen, the presence of hydroxyl in the atmosphere provides the only conceivable explanation for the observed short lifetime of many compounds in the atmosphere, gases such as carbon monoxide, hydrogen sulphide, the nitrogen oxides and almost all organic gases. All these, after reacting with hydroxyl form highly soluble products that are efficiently scavenged by rainfall.

Man's activities in the tropics are having a significant effect on atmospheric chemistry. In particular the chopping down of the trees and their burning is increasing the burden of both carbon monoxide and dioxide in the atmosphere, while increased rice production is adding substantially to the amount of methane being liberated from the soil. Cattle production as well as termite activity are also responsible for methane production. Both gases, carbon monoxide and methane, interact with hydroxyl, the result of such interactions over the tropics being a loss of both hydroxyl and of ozone. Consequently, through man's activities in the tropics, the atmosphere is gradually, but perceptibly, losing its ability to cleanse itself of trace gases.

Measurements of methane in the atmosphere indicate that its concentration is increasing worldwide at the rate of 1½ per cent per year. That increase in itself should be of some concern since methane, like carbon dioxide, is a greenhouse gas and will therefore contribute to the general warming up of the earth's surface.

Two colleagues of Crutzen, at the Max-Planck Institute, W. Seiler and R. Conrad, have measured methane production rates from rice paddy in different parts of the world. Italian rice paddies, for example, release as much as 0.4 to 0.5 grams of methane per square metre per day. When those results are extrapolated to account for global rice production in 1979, then up to 170 teragrams (10^{12}g) of methane are released from rice paddies each year, most of it from tropical regions in the Far East.

The amount of paddy in the world meanwhile increased from 900,000 square kilometres in 1950 to just under 1½ million square kilometres by 1979, an increase of two thirds.

Methane, in fact, is released from soils under anaerobic conditions, through the activities of methanogenic bacteria. Thus, by increasing rice paddy, mankind is putting more soils into an anaerobic state. Seiler and Conrad estimate that methane production from rice paddies is probably on a par with the production of methane from the world's remaining swamps and marshes, which according to them, cover some 2 million square kilometres, three quarters of which are to be found in the tropics. Cattle production is probably adding 60 teragrams to the total. Thus global anthropogenic sources of methane amount to approximately 250 Tg/year and natural sources to 150 Tg, giving a total generation of 400 Tg of methane. Paul Crutzen estimates that 320 Tg of methane are destroyed each year in the reaction with hydroxyl, leaving some 80 Tg to add to the growing methane content of the atmosphere.

The reactions between hydroxyl on the one hand and carbon monoxide and methane on the other depend on whether nitric oxide (NO) is present in significant concentrations or not. Overall, nitric oxide formed in the tropics, mostly through lightning discharges, is quickly removed from the atmosphere through reacting with ozone which oxidises it to nitrogen dioxide which itself is oxidised by hydroxyl to form nitric acid. In the tropics the oxides of nitrogen last in the atmosphere less than one day. In more temperate

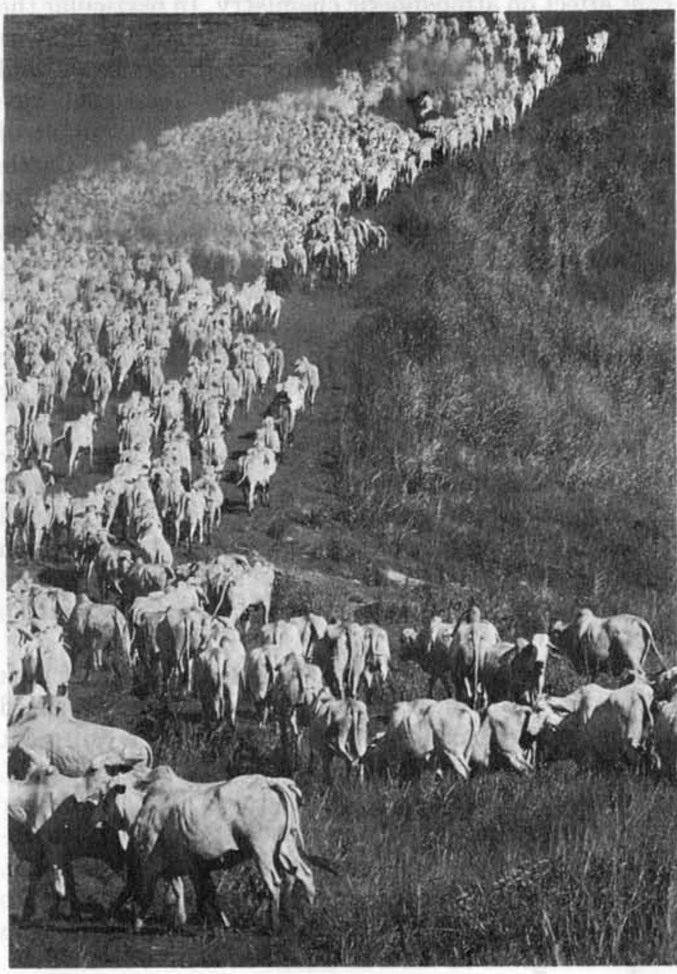


PHOTO: ICARO

Brazil aims to become the world's largest producer of beef.

zones, on the other hand, the oxides of nitrogen may have much longer lifetimes.

In the presence of nitric oxide, carbon monoxide reacts with hydroxyl to form carbon dioxide and ozone, while methane reacts with hydroxl to form formaldehyde and ozone, the formaldehyde then being oxidised further to carbon monoxide and ozone. Since such reactions take place with no net loss of hydroxyl, nor of nitric oxide, those compounds act as true catalysts in the reaction cycle. Crutzen estimates that the oxidation of each molecule of methane to formaldehyde, of formaldehyde to carbon monoxide and of carbon monoxide to carbon dioxide in the presence of sufficient amounts of nitric oxide actually yields a net gain of up to 5 ozone molecules and 2 hydroxyl radicals.

On the other hand, when little nitric oxide is present, the oxidation of methane to formaldehyde and on to carbon dioxide leads to a net loss of three ozone molecules for each methane molecule oxidised as well as to the loss of hydroxyl. "In the absence of sufficient quantities of nitric oxide, hence the situation prevailing in the tropics, it is quite conceivable," says Crutzen, "that altogether about three hydrogen radicals are lost for each methane molecule which is oxidised in the oceanic, tropical lower trophosphere—which is probably the most important sink region for atmospheric methane."

A disturbed Atmospheric Chemistry

What are the implications of increasing methane in the atmosphere? First, an increase in atmospheric methane under conditions in which there is little nitrogen oxides, leads to a corresponding reduction in hydroxyl concentration and consequently to a loss in the oxidative power of the atmosphere. As a result various gases, including methyl chloroform and methyl chloride, which otherwise get cleaned out of the atmosphere, will increasingly be able to transfer to the stratosphere where they serve as precursors for chlorine.

Second, methane appears to be increasing exponentially and the imbalance between hydroxyl production from the ultraviolet photolysis of ozone and its destruction by methane will accentuate. On the other hand, methane destruction may increasingly take place in higher latitudes where the NO concentration is higher because of man's industrial activities. Thus there may be an increasing tendency to lose ozone in clean, tropical atmospheres and generate it in polluted areas, creating a greater polarity with regard to ozone concentrations between the two hemispheres.

Active chlorine radicals, such as may increasingly find their way into the upper stratosphere in tropical regions, will contribute significantly to the destruction of ozone there. Methane oxidation leads to water production, which further enhances the action of active radicals such as chlorine.

Acid Rain

Over the northern hemisphere, the oxidation of methane as well as of carbon monoxide takes place in the presence of the oxides of nitrogen, and both ozone and hydroxyl are generated instead of being consumed, as they are over the tropics. Hence the atmosphere over the northern hemisphere is gaining greater oxidative powers, with the result that any sulphurous and nitrogenous gases in the atmosphere will be oxidised more effectively, forming nitrates and sulphates which are then scavenged from the atmosphere by rain and fall-out as acid. Although the burning of fossil fuels in the northern hemisphere is a major source of sulphur compounds in the atmosphere, it is probably dwarfed by the production of dimethyl-sulphide from sulphur bacteria living in the sea over the continental shelf. Nitrate run-off from agricultural activities as well as sewage discharge are likely to be important promoters of bacterial activity in the sea, so that dimethyl-sulphide production may have increased substantially over the past centry.

Thus acid rain is probably the net result of desparate processes which can be summarised as follows:

Creating a better environment?
Destruction of one jungle to manufacture another.

CREDIT: AKTE STROHALM

1. Tropical agriculture, in particular rice paddy and cattle production, as well as destruction of the rain forest, are leading to an increasing burden of methane and carbon monoxide in the atmosphere. The oxidation of both those gases in the presence of nitrogen oxides leads to a considerable increase in the oxidative powers of the atmosphere through the generation of ozone and hydroxyl.
2. Both sulphur and nitrogen compounds are increasing in concentration over the northern hemisphere because of man's industrial activities. Fossil burning is a major source, but agriculture and sewage disposal are another, particularly because of their role in promoting dimethyl-sulphide production from marine bacteria.
3. The greater oxidative powers of the northern hemisphere together with the growing concentrations of reduced sulphur and nitrogen gases are leading to a considerable increase in the production of acid. Acid fall out is now swamping soil buffering mechanisms and is generating the problems now associated with 'acid rain'.

The oxides of nitrogen play a double role in the generation of acid rain, acting both as catalysts in the formation of ozone and hydroxyl, and as precursors for nitric acid.

To curb our Actions before it is too Late

Phenomena such as acid rain and the damage to temperate forests, probably from increased ozone levels, are the result of complex atmospheric reactions, some of which may have their origins in the tropics. Man's activities in all parts of the globe are thus altering atmospheric chemistry and disturbing balances which have been elaborated through millions of years of evolution.

The tropical rain forest, and because of its size particularly that of the Amazon, plays an important part in the global energy balance and in the transfer of energy from the Tropics to higher latitudes in both hemispheres. That one cannot at this stage predict precisely what the consequences will be of transforming the rainforest into an industrialised zone, or of degrading it to poor agricultural land, is no exuse for letting the process continue or of shrugging it off as someone else's problem. The world, now beset with a host of environmental problems from desertification to acid rain, can ill afford to destroy what is undoubtedly a most important natural system. It is a vexed point too, how much of the forest can be cleared without causing irreversible damage to the entire ecosystem; as James Lovelock points out, it is a little like trying to predict on theoretical grounds how much of a victim's skin can be burnt before death is inevitable. But while we can learn from burn cases we cannot afford to be empirical in our approach to tropical forest clearance; we must be ultra cautious.

In the past various suggestions have been raised as to how to protect the rainforest. Both the World Ecological Areas Programme (WEAP) published in *The Ecologist* in 1980 and Ira Rubinoff's proposal for an International Tropical Moist Forest Reserve System (*The Ecologist*, 1982, No 6) indicated ways in which the international community could share responsibility for protecting the world's remaining heritage of tropical rainforests by compensating those countries with such forests for leaving them alone. If developed countries with a per capita gross national product in excess of 1500 dollars per annum paid a small per capita tax to a central international fund, as much as three billion dollars could be collected annually. Such funding would serve not only as compensation, but as a timely reminder that the tropical forests need protection. Indeed, as has become manifestly clear through a number of studies, including Shelton Davis' *Victims of the Miracle* (Cambridge University Press 1977) we in the developed countries are largely responsible for the destruction of tropical forests, not only because of our need for the timber and minerals that come from its soils, but also because we have set those countries with tropical forests on the road to a pattern of development that we ourselves have established. If they see fit to convert their forests into pastureland for millions of head of cattle to capture the world's growing appetite for beef, or to flood thousands of square kilometres of forest to generate electricity so that industry can manufacture products for our use, we should hardly be surprised. In the end we must look to our own lifestyles and what we are doing to the world, if we wish to save the tropical forests and prevent climatic catastrophes.

Acknowledgement:
I am grateful to the United Nations and to the Ecological Foundation for supporting my participation in the Brazil Conference.

The following papers were submitted at the UNU Conference:

Philip Fearnside—Human Use Systems and the Causes of Deforestation in the Brazilian Amazon.
Patrick Lavelle—The Importance of Soil in the Tropics
Luiz Molion—The Micrometeorology of an Amazonian Rain Forest
Jesus Marden dos Santos—Climate and Vegetation in Amazonia—An Overview
Jan Peagle—Interactions between Convective and Large-Scale Motions over Amazonia
S A Mori—Plant Animal Interactions in the Humid Tropics
James Lovelock—Geophysiology: A New Look at Earth Science
Jeffrey Richey—Biogeochemistry of the Amazon River; An Update
B S Shuman & R Lal—Effects of Deforestation and Land Use on Soil, Hydrology and Microclimate at Okumu, South Nigeria.
Rafael Herrera—Amazon Rain Forest Fires
J Shukla—General Circulation Modelling and the Tropics
P Sellers—Modelling the Effects of Vegetation on Climate
Paul Crutzen—The Role of the Tropics in Atmospheric Chemistry
W Conrad—Exchange of Atmospheric Trace Gases with Anoxic and Oxic Tropical Ecosystems
Ann Henderson-Sellers—Effects of Change in Land-Use on Climate in the Humid Tropics
Eneas Salati—The Forest and the Hydrological Cycle
Peter Bunyard—Dam-Building in the Tropics, Some Environmental and Social Consequences

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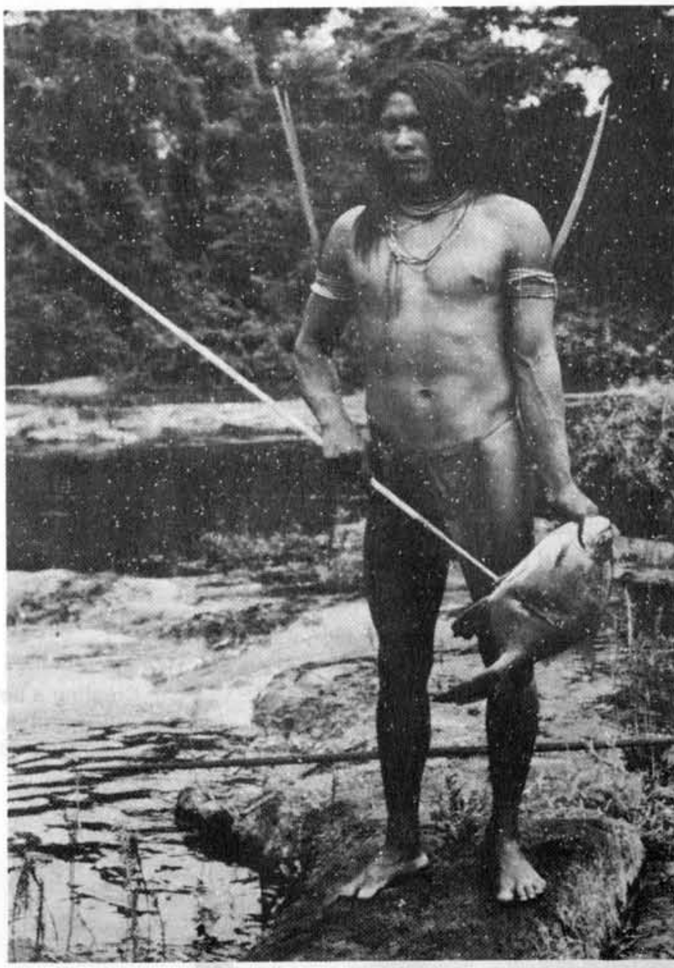
PHOTO: WHO

Rainforest Amerindian. His is not the only way of life threatened.

The Grass Roots approach to Malaria Control in Sri Lanka

The massive anti-malarial DDT spraying programme in Sri Lanka failed once mosquitos had become resistant to DDT. Mosquitos will soon develop resistance against malathion with which the country is at present being sprayed. The stage will then be set for a serious epidemic. The only way to prevent it is to adopt a "grass roots" approach, and hope that "in the war against the malarial mosquito man will prove himself superior to malathion."

Malaria has been endemic in tropical Asia since ancient times. In a paper read before the Ceylon branch of the British Medical Association in 1905, Sir Henry Blake (who was then the British Governor of Ceylon) drew attention to the fact that ancient Indian physicians had attributed malarial fever to the bites of mosquitoes.[1] He quoted in Sanskrit an extract from *Susruta Samhita* which was written over three thousand years ago; this accurately described the clinical features of malaria.

In Europe during the Middle Ages the disease was thought to be caused by foul air (from the Italian *mala* = bad and *aria* = air). This was probably due to malaria being associated with the foul-smelling swamps in which mosquitoes breed. Today, malaria affects about 200 million people in the world, mainly in the tropical regions of Asia, Africa, the Pacific and America south of the Equator.

The protozoan parasite responsible for malaria belongs to the *Plasmodium* species, and is injected into the human body by the bite of an infected mosquito. Introduction of *Plasmodia* into the blood produces attacks of fever with chills and shivering. The parasite destroys red blood cells, thus causing chronic anaemia, kidney failure and even death.

Many species of mosquitoes can transmit malaria parasites—but in Sri Lanka only one, *Anopheles culicifacies*, is known to do so. This particular mosquito has specific breeding requirements; the females lay their eggs only in shallow pools of stagnant, clear water.

Prior to the Second World War, the colonial health authorities attempted to stamp out malaria utilising their knowledge of its peculiar breeding habits; all their efforts were aimed at water management. In the late 1940s, following the introduction of DDT, the government's Antimalaria Campaign used this insecticide exclusively.

At first, insecticide spraying appeared effective, and in 1963 the total number of cases detected in Sri Lanka was only 18. This was in sharp contrast to the disastrous epidemic of 1935, when 50,000 people actually died of malaria. Ceylon therefore congratulated herself in 1963 on having conquered malaria—and from 1964 began to phase out the routine spraying of DDT.

In 1967, 3,500 cases of malaria were seen; 1968 saw an epidemic which left 1.5 million stricken. A major ecological disaster has occurred—a situation which was simultaneously facing many other countries.

During the years of spraying, however, the *Anopheles* mosquito had developed considerable resistance to DDT. Once insecticide spraying was curtailed, the mosquitoes resurfaced with a vengeance. Far from having eradicated the disease, Ceylon was faced with a resurgence of malaria. In 1967, 3,500 cases of malaria were seen; 1968 saw an epidemic which left 1.5 million stricken.[2] A major ecological disaster had occurred—a situation which was simultaneously facing many other countries.

To cope with the epidemic, the nation's Antimalaria Campaign began using the newer Malathion—a more powerful organophosphate which at the time was effective even against the mosquitoes that were resistant to DDT. Malathion however costs far more per unit than did DDT. Annually about £5 million are required—at a cost which Third World countries can ill afford.[3]

For the present, it appears that malaria is on the decline—from 262,000 cases recorded in 1977 to 20,000 in 1982. This state of affairs is no cause for complacency. Just as mosquitoes developed resistance to DDT, they are likely to do so to Malathion—and already there are signs of that happening. In the same way, the parasite *Plasmodium* can itself become resistant to the widely used antimalarial drugs like Chloroquine.[4] The stage would then be set for another epidemic—with the very agents available for dealing with such an epidemic being no longer effective. This sort of situation appears to be now taking place in India, where mosquitoes have become resistant to many of the available insecticides in spite of more than US $200 million being used for malaria control.[5,6]

Today Ceylon—or the Republic of Sri Lanka as it is now known—is undertaking a three-year programme to establish whether malaria can be successfully controlled by mobilising the Third World's greatest resource—the people themselves. Sri Lanka is an ideal nation for employing such a grass roots approach, because in spite of her relative poverty she has an intelligent, educated population. Her literacy rate, for example, is over 85 per cent, one of the highest in Asia. Moreover, there is in the country an active rural self-help organisation, the Sarvodaya Movement.

Dr Sanjiva Wijesinha *trained in Colombo and Oxford, and is currently working for the Ministry of Health in Sri Lanka.*

Founded in 1961 by A.T. Ariyaratne, this non-political movement for social and economic upliftment has established its influence in more than 3,000 villages throughout the island nation.[7] The infrastructure for conducting an ecologically sound, people-based antimalaria programme is therefore already available.

Assisting the government and Sarvodaya in this project (which is supported by several organisations such as WHO and Oxfam) is a team from America's Harvard School of Public Health. The team, which includes Professor of Tropical Public Health, Andrew Spielman, and Senior Lecturer of Population Studies, John Wuon, is led by Sri Lanka epidemiologist, Sarath Ruberu. The aim of the programme will be to mobilise the people living in malaria-infested areas to work together and eliminate the breeding sites of *Anopheles* mosquitoes.

During Sri Lanka's dry season, her rivers tend to puddle in their beds, and the land is covered with innumerable shallow pools of clear stagnant water—ideal for female *Anopheles* mosquitoes to lay their eggs. In some countries, introducing fish that eat mosquito larvae into the breeding sites has proved effective—but in Sri Lanka the breeding sites are neither large nor stable enough to support biological controls like these fish. Breeding can be controlled by eliminating the pools —either by filling them with soil, draining them, or fouling them with decaying organic matter.

The three-pronged project envisages bringing together an understanding of malaria transmission with the Sarvodaya Movement's potential to train the villagers to reduce the breeding of mosquitoes. Initially, a controlled study will be made, employing twenty villages along selected waterways, to determine whether the prevalence of malaria can in fact be reduced by such apparently simple methods. In all the villages selected, the regular efforts of the government's Antimalaria Campaign will continue, and will be supported. The population in half the villages will be taught how to eliminate mosquito breeding sites near their homes; in effect, the villagers will be motivated to take the responsibility for their health

Mosquitos have become resistant to many of the available insecticides in spite of more than US $200 million being used for malaria control.

into their own hands. The other ten villages will act as controls.

In all twenty villages, trained local personnel will make door-to-door visits once a fortnight to record 'mosquito counts' and to detect and treat any cases of malaria. Qualified staff will measure the prevalence of antimalarial immunity in both groups, thus providing an assessment of the efficacy of the control programme.

The team has found that much of the basic knowledge and techniques required can be learned and applied by non-specialists. The principles of mapping breeding sites, sampling larval populations and identifying *Anopheles* larvae were learnt by the local residents with great enthusiasm and accuracy.

Should this community participation project result in a reduction of malaria in the test areas, Sri Lanka plans to expand the programme on an island-wide basis.

It can only be hoped that, in the war against the malarial mosquito, Man will prove himself superior to Malathion.

Sanjiva Wijesinha

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Books

Understanding tropical Ecosystems

ECOLOGY OF TROPICAL PLANTS. Margret L Vickery. John Wiley & Sons. 1984.

This is a short textbook—an adaptation, as the author indicates, for tropical regions, of R F Daubenmire's Plants and Environment—*"A textbook of Autecology."*

Margaret Vickery regards it as important that people understand the functioning of tropical ecosystems for "It is only through the study of such systems by ecologists and bio-geographers", she writes, "that the effects of this interference can be predicted and, hopefully, steps taken to minimise the irreversible destruction which is now taking place in many areas of the tropics, mainly, she notes as a result of "forest clearance, overcultivation, and over-grazing."

The first question which many readers will ask is the meaning of the word "autecology". Dr Vickery rightly tells us "that the basic functional unit of ecology is the *ecosystem.*" Yet she regards ecology as being concerned with the study of communities and populations; why not of 'ecosystems'? Of course, ecology has, in recent years, become increasingly reductionistic, which it had to do, in order to become scientifically respectable. 'Autecology' is particularly reductionistic, since its field of study is apparently the relationship of the *individual organism with its ecosystem.*

The book is divided up into ten chapters, the first being an introduction, the others dealing respectively with plants and soil, plants and water, plants and radiation, plants and the atmosphere, tropical vegetation, interactions between plants, plants and animals, plants and man and the last being an investigation into the environment by Dr John Hall of the University of Dar-es-Salaam, Tanzania.

The book is perfectly straight-forward, full of useful data, well written and non-controversial. It should serve as a useful little textbook for students studying this subject.

One criticism is that it does not sufficiently accentuate the very critical differences between the functioning of temperate and tropical ecosystems. More specifically it does not really explain the functioning of the latter in such a way as to enable people to predict the consequences of the human interference she refers to, so as to enable them to take the necessary steps "to minimise the irreversible destruction which is now taking place in many areas of the tropics."

Edward Goldsmith

Colonising the Plant World

INSECTS ON PLANTS: Community Patterns and Mechanisms, D R Strong PhD, J H Lawton PhD, Sir Richard Southwood PhD, DSc, FRS. Blackwell Scientific Publications. 1984. Price not indicated.

The authors consider that the study of how various phytophagous (plant eating) insects colonise different plants under different ecological conditions will cast light on three questions which they say "dominate ecommunity ecology at the present time." These are "how predictable are natural communities? How important is competition between component species in determining community structure?" and "what proportion of co-existing species in contemporary communities are co-evolved."

That such a study is important seems clear if one considers the sheer diversity of phytophagous insects, there are at least a third of a million species, a figure which is all the more impressive if one realises that there are only 8,500 species of birds and 4,500 species of mammals. As the authors point out there are nearly ten times more species of butterflies and moths than of all birds and mammals combined. Beetles— which make up one of the nine orders of insects—also come "in a bewildering variety of shapes and forms.", so much so that when the great biologist J B S Haldane was asked by a clergyman what his studies had taught him about the Lord, he answered "his inordinate fondness for beetles." In addition, "for every species of phytophagous insects there is also approximately one predatory parasitic or saprophagous insect species."

The authors describe how plants "have fundamentally influenced the evolution of phytophagous insects." This must clearly be so for if the millions of different species of phytophagous insects had not learnt over the ages to become efficient predators or parasites of the plants on which they depended for their sustenance, they could not have survived. The authors also point to the perhaps less obvious principle that "phytophagous insects have probably played a very important part in the evolution of plants." They consider that it is likely "that phytophagous insects had a strong hand in generating the bewildering biochemical diversity and the rich variety of growth forms, leaf shapes and seasonal phenologies of modern land plants." This they regard as only a 'guess' but to me it seems to be quite obvious.

For this extraordinary diversity of plant life to have survived it must clearly have learned to limit the impact on it of its predators. These we know it has succeeded in doing in all sorts of ways, some of them are extremely ingenious.

Further on in the text the authors state what would seem to be the co-evolution principle quite emphatically. "Reciprocal adaptation and counteradaptation between plants and insect phytophages has been an important mechanism driving a steady increase in plant and insect diversity over the broad sweep of the fossil record."

An interesting section of the book, Chapter 3, deals with the way in which the diversity of the insects living off a plant species increases as the latter becomes better established in a particular ecosystem. Thus the authors consider "biochemically unusual species of introduced trees such as *Eucalyptus spp* in Europe and North America and *Quercus spp* in South Africa, Australia and New Zealand, present formidable barriers to colonisation by unadapted phytophages and in consequence have impoverished faunas. The authors however do not consider that this factor is all that important in determining insect diversity. More important is "the size of the geographic range of the host plant". Widespread species of plants, they consider, are hosts for more species of insects than rare plants. The reason seems clear.

"Widespread species of plants grow in more habitats and over a wider range of climatic zones than rare plants. Hence different species of insects are found in different parts of the ranges of widespread plants. Secondly, widespread plants present more conspicuous 'targets' for colonising organisms. Thirdly, small populations on plants with restricted ranges may be more prone to extinction."

Thus as the range of a plant

expands, there is a tendency for the number of insects it supports to increase. This is illustrated by the recent history of the rosebay willowherb (fireweed) *Chamerion angustifolium* in Britain. It was formerly a rare plant, growing in certain localities only but its range has undergone a massive expansion since the First World War. At the same time the number of insect species living off it has increased since 1919 from 13 to 30.

This information is obviously of practical value. One can expect introduced trees to remain immune to attack by local insects for a long time. Slowly, however, local insects, previously feeding on other trees will learn to colonise it. Thus "in Britain, the North American ornamental cypresses (Chamaecyparis, Cupressacae) have recruited one of the two native species of mirid bug found on the native co-familial juniper, and one of the two native species of shield bug (the second shield bug is probably extinct in Britain). Similarly, Nothofagus species (southern beech, Fagaceae) introduced into Britain from South America and Australia have acquired breeding populations of at least six species of Typhlocybinae (leafhoppers), all of which normally feed on related native British trees in the same family (Fagus (beech) and Quercus (oak)).

The authors then use this information as an argument against the ecological view of the ecosystem as a natural system that evolves according to set rules by orderly stages (succession) towards a situation which maximises overall stability (the climax). This was the view of early ecologists at the turn of the century, (Clements, Shelford, Phillips etc) a view which has unfortunately gone out of fashion since the fifties when ecology was systematically transformed into a hard science so as to make it scientifically respectable and to make its teachings conform with the world view of modernism. In this way ecology ceased to be holistic and became as reductionistic as any other scientific discipline.

Significantly too, in this respect the authors tell us "plants recruit insects from a variety of hosts, spanning the full gamut from close relatives to those with no obvious structural or biochemical affinities but merely close physical proximity. The result is a fauna on most plants that is a pot-pourri of the co-evolved, the preadapted and the opportunistic in varied and at present unpredictable proportions." In this way they make clear their opposition to the old Clementsian idea of the ecosystem as a sort of superorganism with a definite structure and function.

The authors, keen to accentuate the importance of the individual component of the plant community as opposed to that of the community itself are necessarily committed (as are the neo-Darwinists who seek to explain evolution in terms of the same reductionistic and mechanistic world view) to accentuate the importance of competition as a determinant of what community structure they accept, and to under-playing cooperation in all its various forms.

They are however honest enough to admit that competitive interactions between phytophagous insects do not appear to have played as important a role in determining insect diversity, as they had previously thought. This, however does not invalidate the thesis that competition is the most important factor involved. This they justify in the following way. "Failure to detect significant interspecific interactions in contemporary communities" they write "does not necessarily mean that competition has no part to play in structuring that community. It may instead have left its mark in 'the ghost of competition past' " to use Connell's phrase.

This sort of argument makes nonsense of the principle of empirical verification which is supposed to underlie scientific method.

Another important section deals with the question of coevolution which the authors describe as "reciprocal evolutionary change in interacting species." We have seen that they have already accepted the principle as being paramount but in Chapter 7 they purposefully seek to underplay its importance. (See Table.)

The authors admit that this model appears plausible but they intimate that it is probably untrue. It may be true in certain cases, but these may be the exception rather than the rule. They then quote Caughley and Lawton and also Monro who "divided grazing systems into two types, representing the end points of a continuum: there are *non-interactive* systems, where the herbivores have no measurable impact on the performance of their food plants, and *interactive* systems where they do." They then tell us that rare species fall into the former category. However, one can give the authors of this book a dose of their own medicine and suggest that the fact that these insects have "no measurable impact on the performance of their food plants" does not mean that they do not interact. The interaction may simply not be of the sort that is measurable by the crude equipment at present available or of a type whose effects are subtle and only discernable over a long period—(The Ghost of interaction past).

The contrived nature of the arguments used by the authors to underplay the importance of coevolution shows to what extent they have been imbued with the narrow scientific world-view of which reductionism is a necessary feature. Thus they tell us in general, co-evolution cannot occur because the removal of herbivores appears to have immediate beneficial effects on the plants on which they live. To quote them "Over and above the effects imposed by single species of herbivores", they write "several recent experiments have shown that if entire suites of herbivores attacking a plant are removed, plant performance markedly improves." Also "The effect of eliminating or markedly reducing herbivores has been well shown by Waloff and Richards' (1977) study on scotch broom (*Sarothamnus scoparius*), a shrub that lives for up to about a decade. Bushes protected by insecticides had higher reproductive rates and, beyond five years of age, survived better than those exposed to

Model of plant phytophage coevolution, elaborated from Ehrlich and Raven (1964) and Berenbaum (1983).

1 Many plant taxa manufacture a prototypical phytochemical that is mildly noxious to phytophages and that may have an autecological or physiological function in the plant (Harbourne 1982; Seigler & Price 1976; Robinson 1974; see also Section 2.1.4).

2 Some insect taxa feed upon plants with only this and other, similarly mild, phytochemicals, thus reducing plant fitness.

3 Plant mutation and recombination cause novel, more noxious phytochemicals to appear in the plants. The same chemical can appear independently in distantly related plant groups.

4 Insect feeding is reduced because of toxic or repellent properties of the novel phytochemical; thus plants with increasingly noxious chemicals are selected for by the pressure of insect herbivory.

5 The plant, 'protected from the attacks of phytophagous animals, would in a sense have entered a new adaptive zone. Evolutionary radiation of the plants might follow, . . .' (Ehrlich & Raven 1964, p 602).

6 Insects evolve tolerance of, or even attraction to and utilisation of, the novel compound and the plant producing it. An insect can specialise in feeding upon plants with the novel compound; 'here it would be free to diversify largely in the absence of competition from other phytophagous animals' (Ehrlich & Raven 1964, p 602).

7 The cycle may be repeated, resulting in more phytochemicals and further specialisation of insects.

the natural level of herbivory." Another argument equally illustrates their reductionistic approach. Thus they tell us that "When groups of herbivores act in concert in this way, tight reciprocal coevolution between the host plant and one or two species of phytophagous insects seems particularly unlikely. As soon as plant performance is influenced by several herbivore species, conflicting selection pressures may be generated that restrict or prevent coevolution."

It is clear that the authors are accustomed to considering inter-relationships between a single predator or parasite and a single prey or host species at a time. In a real ecosystem as opposed to a highly simplistic mathematical model of an ecosystem, adaptation must inevitably occur to the ecosystem as a whole—composed, as it is likely to be, of a large diversity of biotic factors or a-biotic factors rather than to a single component of the ecosystem such as an individual species whatever might appear to be the latter's importance to the life cycle of the species adapting to it.

There is no reason whatsoever why adaptation to an ecosystem as a whole should provide the optimum adaptation to any of the eco-system's individual components. In fact it almost certainly will not and it is for this reason that the argument provided by the authors is so totally unacceptable.

The unacceptability of other arguments proposed by the authors to underplay the importance of coevolution becomes apparent as soon as adaptation is used holistically. Their conclusion that "the insect fauna of plants is a pot pourri of the co-evolved, the pre-adapted and the opportunistic in varied and unpredictable proportions" simply reflects the extent to which they have been imbued with the paradigm of modernism and hence refuse to see an ecosystem as a highly organised natural system capable of coordinated self regulatory behaviour. Their statement that "coevolution most certainly does not provide a general mechanism to explain the contemporary structure of phytophagous insect communities" reflects the same set of prejudices. Only those committed to an extreme reductionistic approach can consider evolution as being anything else than a vast co-evolutionary enterprise. A species cannot evolve by itself in a biotic and climatic vacuum, it can only coevolve as an integral part of an ecosystem, and for the purpose (a term that would make Southwood shudder) of contributing to the latter's stability.

Edward Goldsmith

A Cap that does not Fit

WETLAND DRAINAGE IN EUROPE: THE EFFECTS OF AGRICULTURAL POLICY IN FOUR EEC COUNTRIES, David Baldock. A joint publication by the Institute for Environment and Development and the Institute for European Environmental Policy. £5. Obtainable from 10, Percy Street, London.

No reader of *The Ecologist* needs to be told of the threat to the remaining wetlands of the EEC countries. The introductory section to this book gives an admirable account of the history of the wetlands in France, Ireland, the Netherlands and the UK; it describes the different kinds of drainage and their relation to each other and how they are funded. It surveys the international importance of wetlands as wildlife habitats (especially as transit stations for wild fowl) and summarises the international conventions that have attempted to protect them with very partial success. The perspective given to us by this knowledge enables us to interpret the significance of the detailed accounts of how each of the four countries manages its wetlands. There is an inevitable clash of interests in all problems of land management; but it is easy to see on the evidence here displayed that the agricultural interest in all four countries has a priority that is unduly damaging to other interests.

Although each country is treated separately, they are all studied within the framework of the Common Agricultural Policy (CAP) and we soon recognise that this cap deforms the natural body which it is supposed to protect. The book arises from a research project undertaken by the two institutes that are its joint publishers. Packed with information, it is not the kind of book one can sit down and read straight through and there is inevitably a certain amount of overlapping as each country has many of the same problems. Yet without a book of this kind it would be impossible to create a comprehensive pattern of ecological control over the European countryside. It is well written and an invaluable source of reference.

How much damage?

"It is difficult" says David Baldock "to quantify the loss of wetlands in a remotely satisfactory way. In the UK it has been estimated that about half the lowland Fens and the valleys and basin mires have been significantly destroyed or damaged since the end of the last war, with the prime causes being drainage, reclamation for agriculture and chemical enrichment of the drainage water." Drainage, of course, removes a major barrier to agricultural intensification with all its destructive effects such as eutrophication, pesticide run-off and so on. To give some idea of how the Water Authorities think, I quote:

"The Severn-Trent Water Authority, the largest in Britain, has conducted a survey of its area as required by the Water Act of 1973 that covers both main and non-main rivers and has found 1,600 problems relating to drainage and has so far identified over 300 cost effective arterial schemes, likely to cost £92 million in 1982 prices. If adopted the programme would keep river engineers occupied well into the 21st century and it is notable that most Water Authorities forsee the need for a great deal more drainage work." Evidently the water engineers anticipate a field day—or should one say a field epoch!

The whole complex organisation by which drainage decisions are made without any formal representation by conservation interests reads like an account of rotten boroughs and it is hard to believe that in a democratic society they can continue unreformed for long. One has the feeling that before long there will not be a river or stream left that meanders in a natural way.

In France, which has had the good fortune to be 'backward' in imposing grandiose drainage schemes, a report in 1979 (the Sabin Report) from the powerful Conseil Economique et Social suggests that there is an urgent need to drain 3 million hectares and scope for draining up to 10 million hectares. As in other European countries drainage is firmly in the hands of the agricultural authorities and one shudders to think what may happen to marvellous wetlands like the Carmargue. The Marais des Echets—once a site of international importance for wildfowl— has already been drained with the aid of a subsidy from FEOGA despite vociferous protests from scientists and opposition from the Ministry of the Environment.

Political Sources of Mismanagement

Although the wetland drainage which is proceeding at such a pace is sustained by the policies of CAP, the main source of funding is national governments; but governments would hesitate to provide the funds were it not for EEC subsidies—notably high guaranteed prices for arable crops, export subsidies and levies on imports, assistance to 'Less Favoured Areas' and contributions to farm development schemes. If all these were removed, there would not be much point in the home governments providing so much capital for drainage in unsuitable places.

However we do not know how long it will take for CAP and the EEC to be reformed. Restraints on drainage schemes which do not conform to social and ecological criteria are therefore urgent. There is also an urgent need for research into the effects of large scale drainage, which is at present undertaken with no reliable knowledge of the consequences. Cost/benefit analyses almost invariably leave out social and ecological costs even though these may reduce profits. Agricultural research is so organised that these effects are excluded from its objectives and it concentrates almost exclusively on productivity. Until this over simple outlook is broadened no further large-scale drainage projects should be allowed.

Human Rights versus Property Rights

One realises after reading this book that society is presented with a conflict between property rights and human rights in its efforts to preserve the diversity of nature. Underlying the actions of authority, there is an assumption that the owner of property has the right to do what he likes within his own domain and any suggestion that others have rights over it is an arrogant interference with freedom and natural law. It follows from this assumption that if an owner is not allowed to exploit his possessions for his financial benefit, he must be generously compensated for as long as he owns the land—to a degree in fact that we know the state could not indefinitely fund. The level of compensation is necessarily related to the guaranteed price levels fixed by CAP. If these should drop to international market prices both the economic benefit of drainage and the level of compensation would be reduced to a point where it would not be worthwhile to drain most wetlands. In other words, the money at present set aside for conservation projects is being exhausted by compensating farmers and paying the administrative and manpower cost involved.

The assumption of the inviolable rights of private property explains why efforts to protect and conserve the countryside, despite innumerable Royal Commissions and other official reports and studies like this one, and despite a chain of Acts of Parliament, have failed in so much of their purpose. The latest Wild Life and Countryside Act is enfeebled because it shirks this issue. It can only request the landowner to respect conservation; it dare not demand that he does, for this would infringe on his 'natural' rights as a property owner. The control of land drainage is a vital part of the Act but until property rights are brought into balance with human rights (the right of human beings to have a satisfactory landscape to inhabit) the objectives of the Act can never be realised. It was recognised in urban planning after a struggle that the property owner has not the right to compensation for development plans that are vetoed by the local authority. Without that concession rational urban planning would have been impossible. But this is not so in agriculture.

Two things, therefore, are necessary to save our remaining wetlands: the first is that The Wild Life and Countryside Act should be amended so that it is no longer a Highwayman's Act—' Your money or your landscape'—but gives legal backing to human rights; the second is that the provisions of CAP should be *reconstructed* so as to provide a framework for conservation and development; the farmer would then be given incentives for conservation and good husbandry instead of the present negative attitude for compensation. The present regulations of CAP do not fit an agriculture that can be sustained. As I said at the beginning it deforms the body it is supposed to protect. One example of this has not been noted: the emphasis on productivity has resulted in monocultural practices that cause a hard pan beneath the surface of the soil so that the water does not drain away adequately. A permeable soil needs a considerable humus content. As a consequence of this bad husbandry more drains have to be laid than would otherwise be necessary. Reading this book, I was left with the feeling that the sooner the CAP bankrupts the EEC the better; otherwise the Attilas of Production with their army of ploughs, dredgers, bulldozers and chain saws will drive out all the good farmers.

Robert Waller

Poisoning our Food

MODERN MEAT ANTIBIOTICS, HORMONES AND THE PHARMACEUTICAL FARM Orville Schell, Random House, New York $17.95.

After reading the first few pages of this book a British farmer, scientist, food technologist, business man or some other kind of interested person would be tempted to regard it as an amusing chunk of American reporter's hooey, heavily tinged with Upton Sinclair's, *The Jungle.* However, after the first chapter or so it would be realised that here is an American farmer/journalist who is telling the truth as he found it about certain aspects of the US agri-chemimech industry.

His theme chiefly concerns the rearing of animals for human consumption and the effects of the drugs used; also, to a somewhat lesser extent, the influence of the feeds and the chemical residues they may contain. However, the main focus is on the real live people concerned, as he saw them from the farm gate and the garbage bin, to the slaughterhouse and right on up to the White House in Washington, DC.

Ground Floor Approach

It seems that what really matters is not so much how all these widely differing people are *supposed* to operate, but what they actually do and how they think and why—in that order, the ground floor approach. It will come as no surprise to any environmentalist to learn that in many instances, at every level, a wide gap was found between what was said, what was written, and what, in fact, actually happened.

Time and again this book shows us that truth in action is stranger than the fiction of words in any form. Consequently, having become used to the racy-readable journalistic style, the reader is likely to become fascinated. Sure, all the time the author is playing to the environmental gallery—there is no such thing as a free breakfast—but here we have a genuine show-on-the-road act as the author experienced it.

From time to time, most environmentalists may say how much they would like to ask a few well chosen questions of the Big Business Men, or the top researchers, the Government officials, or the employees at the receiving end much further down the line in the agrichemimech jungle. But, few, if any, can take time off, and be sufficiently financially independent, or have the temerity and expertise to interview such people on their own home ground.

Orville Schell did just that. Fortunately, he obtained a financial grant which enabled him to take the best part of three years making an epic journey through the US quietly confronting such people. He recorded what kind of people they were, how they dressed and what they looked like; how they reacted to his questioning; how their wives or colleagues struck him; what they were doing at the time and where they were doing it.

His interviews ranged from a small man with 200 acres and 40 head of cattle, to the Texan Director of a super feedlot fattening outfit dealing with up to 400,000 head at one time; from the dusty would-be foreman unemployed because he 'spilt the beans' regarding the illegal use of hormones, to the Super Pharmaceutical Executive in the ultra modern, air conditioned, potted-palmed office block; from the harassed farm inspector who had to let things pass despite the law being knowingly flouted, to the highly-placed bureaucratic FDA official ultimately responsible for such legislation which looks so good on paper but which he knows is impossible to enforce to any effective degree.

The five sections of the book are sequentially headed Antibiotics (120 pages), Feed Technologies (60 p), Hormones (120 p), Inspection (18 p) and Conclusion (4 p). To get into the book the Non-American reader might find it easier first to absorb the last five pages and then proceed to the penultimate eighteen pages, by which time the style will have worked its magic and the rest will have become compulsive reading.

Remembering that the object was chiefly to see and talk to people about some of the many facets of meat production, the quote index is high. The results, at all levels, for and against, are very revealing, viz, "I think you'd have to say that recently we have seen an epidemic of people using drugs (on animals) in a careless and lawless manner."—Lester Crawford, Bureau of Veterinary Medicine (page 325).

"If I see a sick-looking animal or one that shows any sign of contamination, I'll tag it (on the hoof). Then, when its carcass arrives at my inspection station I'll probably take a tissue sample. You know, it could be a drug, a pesticide or something completely unrelated to agriculture, like the PCB's that sometimes get into feed."—Thomas Harris, Meat Inspector, McDermott Meat Co (Page 317).

Referring to the overuse of hormones in chicken meat and the detection of premature puberty in Puerto Rican children:—"Since December, 1982, the number of children coming through my office has dropped dramatically. I recently learned that last year over half a million pounds of local chicken were sold to the school lunch programme. The chickens all weighed about 3½ to 4lbs. Then a curious thing happened. I learned from a friend of one of my patients who worked as a distributor, that locally produced chickens suddenly began to go to market weighing 1 to 1½lbs less than previously. This made me wonder if the publicity hadn't scared the growers from adding to their feed whatever it was they were using."—Dr Carman A Saenz, De Diego Hospital, San Juan (page 293).

An Executive Summary states, "Potential problems resulting from frequent applications of insecticides are contamination of meat, milk, eggs and the environment, and the development of insecticide resistance. Current methods of livestock insect control are often inefficient and certainly expensive because of poor application methodology, improper timing and lack of understanding of pest biology,"—Proc Nat Workshop in Insect Pest Man. 1979 (page 152).

Cardboard, Pork Queen and Porkettes

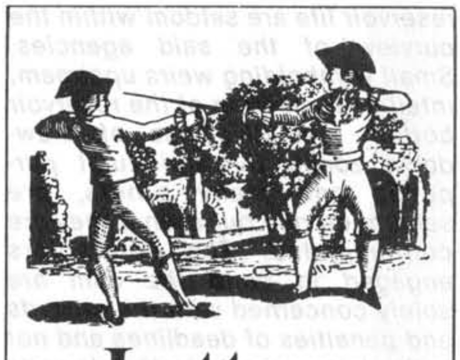
Bruce and Vi Boyd are owners and operators of B/V By-Products Inc, a company that specialises in reclaiming waste products and converting them into what Bruce calls 'exotic feeds' for beef and dairy cattle. "We've marketed cardboard as a cattle feed for eight years. There's not a damn thing wrong with it. We've even tried marketing sawdust and bark, but we can't get a cheap and steady supply." (page 139). "Me and Vi did an experiment once. We fed three head of cattle on ground cardboard and grapefruit peel and I want to tell you they dressed out real good. The taste of those guys was terrific. They were lean and they made the best burgers I ever ate." (page 141). "The nutritional value of waste paper such as newsprint, computer paper, brown shopping bags, and corrugated boxes varies with source . caused by pulping treatment, source of wood, and additives such as glue, ink, clay and plastic."—Dr A H Peavey et al. (page 141).

Richard Norvick: "Antibiotics have been and still are given for everything from headaches to ingrown toenails: they are swallowed, injected and smeared; they are painted on cuts, dumped into wounds, fed to chickens and pigs, and sprayed on the floors of hospital wards . . . Through a characteristically human combination of greed and ignorance, we are now well on the way to negating totally the usefulness of antibiotics."—Director Public Health Research Institute, City of New York. (Page 29).

This Pilgrim, no Progress

And many others said so much more. The book cover states, "Orville Schell, in a superb job of investigative journalism, cites chapter and verse. A dietary sequal to *Silent Spring*." Not quite, perhaps, but, in its way, just as pungent. If ever there was a Pilgrim who made no Progress here is one, but he has set the scene for the underside picture of his journey through Uncle Sam's pharmaceutical farming. You must read all about it.

A. Harry Walters



Letters

Do they really want to know?

Dear Sir,

I read the Ecologist *and I enjoy it; often I reflect on the articles I should have written and never got around to, as I could bring something to the debate.*

There is a faint, lingering thought that efforts should be directed at doing and then reporting on it: this is to say that one day there should be a long one! on Development Alternatives in Delhi and its karmic lessons.

Meanwhile a short note on your Reflections over Tasmanian Dam (Vol 14, No 4, 1984).

As to the question of "the environmental damage caused by not building the dam . . ." this is a nth order question which tends to obscure the main issues as it appears to provide a balanced viewpoint. Most feasibility studies are promoted by single-purpose agencies although under a cloak of multi-purpose objectives. For anybody who knows this decision-making process, it is self-evident that in spite of overt and unarguable good will to that effect, a government agency is simply unable to sustain anything but its own departmental loyalty, inter-departmental committees notwithstanding. The private promoters of the project base their cost-benefit analyses (itself a ghastly self-serving device that should be banned except in the most carefully monitorable circumstances) on SDRs and IRRs that are completely unrealistic: not only are the time horizons for dam-silting consistently overestimated because of their high impact on the claims to financial profitability, but because the mitigating and even the remedial measures which could be taken to extend the *reservoir life are seldom within the purview of the said agencies. Small withholding weirs upstream, intelligent clearing of the reservoir bottom, selective use of draw-down zones for agricltural purposes and many others, are seldom carried out even if they are contemplated. The contractors engaged to build the dam are solely concerned with the rewards and penalties of deadlines and not with giving access to the damsite road (usually the only one that could reach the "hinterland") to anybody else but their max. speed 30 ton haulers.*

Many have spoken of building small retaining weirs and dams with sufficient power (micro-hydels) to support not only local communities but also reasonable-sized industries that would involve the locals in "development" rather than have them evicted (even compensated): after all, what do they know about the support skills for a 9,000 Megawatt operation such as was planned for PNG's Purari 10 years ago! Such "developments" demand uranium enrichment or aluminium refining plants to justify the cost effectiveness of the investments, with their cortege of economic enclaves, tax privileges, social unrest and many other defects which turn out to become structural disasters.

Upsets in the habits of river-run migratory fish populations have repercussions in most of the other rivers and streams of the basin affected, all the way up to riparian villages who will never know the dam, but will see the loss of their rituals and of their food supply, down to the estuaries and impacts such as the shifting of saltwater interface: mangroves, shrimp farms, coastal villages water supplies are only a few of the resources affected. And where else to build the industries which will use the power and ship its exports?

It is easy enough to conjure up these discouraging images since most of the dams planned, under construction or built show such critical defects. Admittedly some of these are only apparent to those willing or trained to see them and this never seems to include the major role-players, steeped as they are in reductionist and single-minded logic, hypocritically offset by the tired old chestnut: you can't make omelets without breaking eggs! It is clearly time for the guardians of society's virtue to ensure that your broken eggs will guarantee you at least a piece of the omelet.

Environmental impact statements only come in when the project has already commited expenditures beyond the point of "no return" which in turn necessitates that the myths of progress, of development, of self-determination be raised to the level of sacrosanct rationality.

Modern computing techniques attached to sound information systems management can now tackle the complexity required for realistic problem-solving, on cybernetic principles. But do the "decision-makers" really want to? There is so much financial slack available in loose super-projects that it may be as unrealistic to expect desistment, as it would be to prevent land speculation and rezoning, a favourite provider of unconscionable profits. etc., etc., ... ad nauseam! Video Meliora, proboque, sed deteriora sequor.

Yours faithfully,
Christian de Laet
Canadian Plains Research Centre, Canada

The Judeo Christian Tradition is not to blame

Dear Sir,

With reference to Nigel Pollard's article about the early Israelites and their adaptations to the environment (Vol 14, no. 3), he is probably quite right, but shouldn't have to show that the blame for our environmental destruction has been misplaced.

Throughout the last 20 years there have been many articles written about the Judaeo-Christian tradition and its great influence on man's irresponsible, exploitive approach in his use of the natural environment.

The major beliefs in these religions which have supposedly created this perception, have been those of the separation of man from nature: the idea that the natural environment is there for man to exploit and to dominate for his own use.

As a result of this causal theory, we have been led to believe that it is only the Judaeo-Christian cultures on this planet that have exploited, or led to the exploiting of, the natural environment. But what about the continual destruction of land in Africa through over-population, combined with deforestation for more pasture land, homes and firewood; unsuitable agricultural practices, the expanding deserts or the deteriorating land and water resources in China which they are only now attempting to reverse and the similar situations in India, and elsewhere, outside the Judaeo-Christian cultural influence? Are we to believe that all these people followed the Judaeo-Christian example? Or is it that the industrial society first emerged within the Judaeo-Christian culture and had carried with it, in its world-wide proliferation, this negative Judaeo-Christian belief of man against nature?

This sort of speculation, however, is only theory but unfortunately we humans seem to have a great penchant for accepting theories as fact, only to have our "flat earth theories" eventually disintegrated before our eyes. Surely it is an absurd waste of time and energy, and also counter-productive, to continue to blame the misuse of our planet on either the Judaeo-Christian or other beliefs.

Let's once and for all time accept our responsibility! It matters not where the blame lies! We are human beings and it is obvious that we are the dominant life form on this planet. Let's accept this fact! We alone have the ability to completely destroy or to improve the environment of our planet Earth.

We must also be aware that our dominance cannot continue to be of an irresponsible exploitative nature. Without the sustenance that this planet provides us, we would all rapidly perish.

We must now develop a symbiotic relationship with the natural environment by enhancing and protecting our planet home in return for an assurance of a high-quality human survival. It can be none other than a responsible, benevolent, caring dominance, used in a creative, enhancing and protecting manner.

Yours faithfully,
Bill Trotter
Chief, Environmental Analysis Division, Environmental Design Directorate. Ottawa, Canada

Classified