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Man, Culture and Biodiversity

Understanding Interdependencies

Edited by

Gertrude Hauser, Michael Little
and Derek F. Roberts

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Man, Culture and Biodiversity

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Report of a Workshop held on April 2, 1994
Denver, Colorado, USA

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CONTENTS

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Introduction

by

G. Hauser

The most recent in the series of IUBS International Research Programs is that on Biodiversity, developed jointly with UNESCO and SCOPE. When the proposal was first made, the 23rd IUBS General Assembly in Canberra in 1988 recommended a feasibility study. Following a number of small exploratory workshops and discussions which culminated in a research agenda set out in the little book *From Genes to Ecosystems* (ed. O.T. Solbrig, 1991), the General Assembly in Amsterdam in 1991 endorsed the program. It recognised the comprehensiveness of the term Biodiversity and selected three themes for consideration:

1. The ecosystem function of Biodiversity, a theme which has led to the design of an experimental research programme.

2. The origins, maintenance and loss of Biodiversity, which is concerned with processes.

3. Inventorying and monitoring, aimed at measuring changes of Biodiversity over space and time.

Human studies are of immediate relevance to each of these. However even the seminal book by Solbrig (1991), which draws attention to the extent of Biodiversity, ranging from molecules to complex organisms, from morphology to ecological dynamics, while it does not explicitly exclude the potential contributions that the science of human biology can make, gives then little direct attention,

Following the discussion at the Amsterdam assembly entitled Biodiversity and Global Change, it seemed to me curious that so little attention was being paid to the human element in the Biota/Environment equation. Everyone seemed to accept that the human role was restricted to that of the destroyer of Biodiversity. This point was drawn to the attention of the Amsterdam General Assembly, and as a result a specific request was inserted in the minutes of the scientific committee "... attention should also be paid to the need to recognise that humans are an integral part of ecosystems, and to include this dimension where appropriate; a workshop on this subject is suggested for consideration by the Coordinating Committee". This was the object of the Denver meeting, to consider possible contributions of human studies to the aims of the Biodiversity programme and if thought appropriate to make recommendations to IUBS for topics for inclusion.

The Denver programme was designed as an endeavour to escape from the concept of humans solely as the wilful destroyers of Biodiversity, to examine other ways in which we and our biotic environment have interacted. These would range from our evolutionarily-patterned involvement like that of any other instinct-driven animal, through the varying effects of cultures at different levels of economic complexity, to intentional creation of Biodiversity through application of modern genetic technologies.

With that object in mind a small international nucleus of colleagues was selected, representing different fields of Human Sciences, but known for the broadness of their perspective, and their multifaceted approach to their specialities. These invited participants were requested to prepare papers drawing from their various disciplines material that would illustrate these interactions, and so provide the basis for the day's discussion. Papers were presented by the following (in the order of presentation):

P.W. Stahl, Binghamton University, New York, USA
M. Monasterio, Universidad de los Andes, Venezuela
R.M. Garruto, NIH, Bethesda, USA
M.A. Little, Binghamton University, New York, USA
G. Forstenpointner, University of Vienna, Austria — read *in absentia*
O.T. Solbrig, Harvard University, USA — ..
G.F. De Stefano, University of Rome "Tor Vergata", Italy
D.F. Roberts, University of Newcastle upon Tyne, England.

Other interested colleagues who attended, contributed to the discussion, and extended the range of expertise available were (in alphabetical order): M.H. Crawford, University of Kansas, USA; P.B. Eveleth, NIH Washington, USA; T.B. Gage, State University of New York at Albany, USA; B. Kaplan, Wayne State University, USA; S.H. Katz, University of Pennsylvania, USA; G.W. Lasker, Wayne State University, USA.

The papers presented by these invited participants are published in this volume. In planning the programme it was thought appropriate to start by enquiring into the duration of Man's influence on his biological environment, seeking evidence from those early periods when it is thought that human populations, at their then stage of cultural development, were not large enough to inflict permanent harm on coexisting species and their environment. This would lead to an examination of how recent and contemporary simple cultures with their close relationship to their environment have helped to maintain biodiversity. The third topic, man's role in increasing biodiversity in present times, would cover intentional increase of variation, for example by today's genetic engineering and by yesterday's introduction of new species by human immigrants. There would also be covered unintentional diversifying processes such as the response of micro-organisms to new modern drugs. In the fourth topic the effects on man of changing Biodiversity would be examined, and so these papers remind ourselves of why biodiversity is important to man.

The discussion to which those papers gave rise and the contributions from the others who attended formed the basis for the proposals and recommendations set out at the end of this volume to which attention should be given in the biodiversity programme.

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The Significance of Anthropogenic Landscapes in Prehistoric South America to Studies of Biodiversity

by

P.W. Stahl

With increasing alarm, the scientific community hastily records and assesses the dramatic transformations currently under way in our global biotic heritage. Most recently, world attention has focused on the frightening escalation of contemporary tropical forest degradation, as various media daily chronicle the nature and extent of devastation. At least one recent estimate has given the global rate of moist and dry tropical forest destruction at an astonishing 40 hectares per minute (Myers, 1991). Contemporary observations not only enable the scientific community to monitor and even predict rates of environmental degradation, but they also help us to understand better the complex human variables which are immediately implicated. Road building, land speculation, indiscriminate logging, mining, creation of extensive pasturage, and the rapid expansion of agricultural activities all stand out as major culprits. These more visible offenders, however, are themselves underlain by population pressure, chronic poverty, inequitable land distribution, governmental mismanagement, overall failure of development policies, global economics and burdensome national debts (e.g. Bedoya, 1990; Moran, 1993; Myers, 1991; Repetto, 1990; Southgate & Whitaker, 1992).

Today, the vast forested expanses of tropical South America are important settings for observing and studying contemporary environmental transformations. Moreover some time dimensions can be added to these phenomena through historic observations. The written accounts of one contemporary event suggest that the current situation is a more recent, albeit dramatic, portion of a continuum extending back at least to earliest European contact. Profound transformations were inevitable as the old world collided with the new. These included a wide range of introductions, from deadly pathogens to new forms of plant and animal life, as well as contrasting extractive technologies to exploit both indigenous and imported resources (e.g. Butzer, 1992; Crosby, 1986; Hemming, 1978).

Human-induced environmental transformations often affect biodiversity measures in a similar way. Although anthropogenic environments may create new niche opportunities, the overall richness of species categories tends to diminish. This is particularly dramatic in forest clearance, when the habitat complexity created through vertical stratification is eliminated. Fewer plant and animal species can be packed into the same amount of space. Coincidentally, overall species evenness is also affected, as the spectra of plant and animal taxa are increasingly dominated by certain forms. Overall species homogeneity can find its most extreme expression in landscapes altered for agricultural production, where emphasis is necessarily placed on increasing the abundance of culturally useful taxa at the expense of others.

Relationships between anthropogenic landscapes and biodiversity measures can be empirically derived and deductible modelled from contemporary, and to a more limited extent historic, observations. Nonetheless, we must critically consider the baseline we use for comparing these relationships. What exactly do we mean by "fewer species" or "increased homogeneity"? Fewer and less complex than what? When contemporary activities remove forest overstory, exactly what is our baseline for understanding change in biodiversity: the forest that existed two minutes, two years, or two thousand years prior to removal? I do not mean to trivialise this point; however, I would suggest that we often, to some degree or other, simply assume that Precolumbian America is the initial baseline from which to draw our comparisons.

The 'Pristine' Americas

Is it reasonable to assume that the environmental backdrop of native America was somehow 'natural' or 'pristine'? This and related questions have found renewed popularity in the scholarly literature (e.g. Balée, 1989; Denevan, 1992a; Redford, 1991; Smith, 1980; Sponsel, 1986; Wilson, 1992). The geographer William Denevan (1992a) has raised two issues that compel us to reconsider any notion of an 'original' biodiversity in prehistoric America.

The first involves Precolumbian population size in the western hemisphere. Retrodicting population estimates is a risky business at best; however, it is important to avoid underestimating the stunning rate of human depopulation, particularly through the introduction of foreign diseases. Recent estimates conservatively guess a minimum of 40 million inhabitants in the New World at the time of Columbus; upwards of 20 million may have inhabited the South American continent alone (Denevan, 1992b). European notions of an undefiled landscape may be derived from historic observations of once intensively manipulated environments which had already been recovering for hundreds of years after native depopulation (Denevan, 1992a).

The second point to consider is the cumulative effect of millennia of human occupation in the Americas. The timing and nature of the earliest peopling of the western hemisphere is a contentious issue in archaeology which is certainly open to debate (Whitley & Dorn, 1993). However, even if we disregarded the compelling evidence from South America for a considerably early colonisation, the most conservative estimates would still oblige us to consider a human legacy spanning roughly 12,000 years (Lynch, 1990).

The 'Long' View of Archaeology and Anthropogenic Landscapes

How are we to understand the timing, extent, and nature of anthropogenic landscape modifications in the absence of recorded observation? These perspectives are obtained inferentially through archaeology and allied disciplines which recover and scrutinise the spatial and temporal contexts of past human endeavours whose imprint survives in the buried records. From an archaeological perspective, uncritical acceptance of an unchanged indigenous landscape is similar to what one prehistorian has termed the "flat view of native history" (Trigger, 1989). The surviving material legacy of Precolumbian America provides many examples of environmental transformation, which clearly indicate the significant impact of human occupation. Evidence from the earliest colonisation of South America is as yet too scant and equivocal to detail any sound inferences regarding ecosystemic transformations; however, the material legacy accumulation after the earliest known appearance of indigenous horticulture is extensive and at time awe-inspiring. The remainder of this presentation will begin with the appearance of early agriculture, and illustrate some subsequent examples of profound anthropogenic landscape modification.

Available evidence from certain mid-altitude Andean valleys suggests that early South Americans were already relying on plant cultivars by at least 10,000 BP (Pearsall, 1992). It is important to contemplate how prehistoric agriculture in the forested lowlands was tackled without steel axes and machetes. House gardening, intensive swiddening in disturbed areas, and unintentional or managed agroforestry may have been pursued (Denevan, 1992c). What the archaeological record does tell us, is that seed cultivation appears in association with forest clearance throughout northern South America at least as early as 7,000 years ago. Pollen and phytolith evidence from Panama indicate an early presence of maize, arrowroot, and economically useful trees (Piperno, 1994). The maize data are also corroborated by stable carbon and nitrogen isotopic evidence from human bone (Norr, 1994). Furthermore, provocative data from lake core microfossils reveal an increased presence of particulate carbon and forest gap species, which suggest human-induced forest disturbance as early as 11,000 years ago. Within three thousand years, areas seem to have been severely deforested, with resurgence appearing only at the time of European arrival, which also coincided with a severe decline in native population (Piperno, 1994).

Early maize is found in a pollen core from the Calima region in the western Cordillera of Colombia soon after 5000 B.C. By the time of Christ, massive episodes of forest clearance appear along with dwellings, cemeteries, roads and drained field systems. Forest regeneration appears only during the Colonial period which witnessed dramatic population loss; a situation repeated in the Colombian Andes as well (Bray, 1994). Further south in Ecuador, the archaeological record for maize is also ancient. Phytolith data from the western lowlands support an early presence dated between 6000 and 5000 B.C. (Pearsall & Piperno, 1990). Available evidence from the eastern lowlands indicates an initial appearance of maize between 7000 and 5300 BP, with subsequent periods of intensive cultivation lasting up to shortly before Conquest (Piperno, 1990). Study areas in the Upper Río Negro of Venezuela again point to an early 6260 BP appearance of particulate carbon (Sanford et al., 1985). A long core sequence from Lake Geral near Prainha, Brazil, also indicates the sudden increase of particulate carbon, and phytoliths from grass and Heliconia as early as 5800 B.P.; a pattern which continues for the next several thousand years (Piperno, 1994).

Some of these long palynological sequences from tropical lowland forest settings raise a number of critical concerns.

1. The evidence for burning, forest clearance and seed agriculture is very early. It can precede the standard evidence of relatively durable ceramics or stone tools from prehistoric human occupation. Here, we must also remember that important root crops generally do not produce durable pollen or phytolith structures; therefore, their signatures may be mute.

2. Often intensive and long-term episodes of human use follow the initial onset of forest clearance. Geographers have long suspected the anthropogenic origin, or at least great extension, of habitats like neotropical savannas (Sauer, 1958). In addition to agriculture, the burning of forest overstory can also be motivated by the creation of secondary conditions for attracting specific game animals. Mammalian biomass in llanos and second growth forest habitats is dominated by terrestrial herbivores (Eisenberg et al., 1979). Potential maximum diversity can be achieved where second growth and mature forest intermesh (Eisenberg, 1989).
Significantly, these settings include landscapes of anthropogenic origin (Stahl, 1994). Similarly, areas of burned forest may be replaced by managed stands of tree crops (Balée, 1989; Sponsel, 1986). Botanist William Balée (1989) recently reviewed the nature and extent of various anthropogenic forest stands throughout the Brazilian Amazon. Due to ongoing environmental transformations of remnant Palm, Bamboo, Brazil Nut, Caatinga, Island and Liana forests, he conservatively suggested that over 11% of Brazilian Amazonian terra firme is in fact anthropogenic in origin (Balée, 1989).

3. Provocatively, certain records for forest regeneration do not indicate a significant return to arboreal conditions until around European contact. Long ago, Le Roy Gordon (1957) mapped the historic distribution of savannas in northern Colombia, noting that large areas away from human settlement became reforested only during the early historic period. In some areas, contemporary native societies continue to exploit stands of anthropogenic forest created by their ancient predecessors (Balée, 1989).

From the early, yet highly significant, beginnings of anthropogenic forest clearance, subsequent native South Americans radically altered many landscapes, leaving highly visible signatures throughout widely dispersed areas. Denevan (1992a) has mapped the distribution of numerous prehistoric New World cultural features within the limits of effective agriculture. Clearly the cumulative impression of these surviving remnants indicates a significant impact. Perhaps the most spectacular examples involve the well-known raised field complexes found throughout various altitudinal contexts within Surinam, Venezuela, Colombia, Ecuador, Perú, and Bolivia. Native agriculturalists understood that the simultaneous raising of a planting surface and excavation of surrounding water channels conveyed certain agronomic benefits. Growing conditions are improved, especially through enhancing soil qualities, while surrounding ditches ameliorate cultivation microclimates, improve nutrient capture, production and recycling, and provide important substrates for aquaculture (Erickson, 1994). Denevan (1982) has further provided some tentative calculations which enable us to grasp the enormous magnitude of landscape alterations involved. For the South American complexes of Barinas (Venezuela), San Jorge (Colombia), Guayas (Ecuador), Mojos (Bolivia), and Titicaca (Perú/Bolivia), he estimates over 100,000 ha of surface area, representing over one billion cubic meters of moved earth. We must also remember that these estimates are probably very conservative (Denevan, 1982). It is again important to caution against acceptance of a 'flat view' of raised field history. We can not automatically assume that entire raised field complexes were constructed, used and/or abandoned simultaneously. Archaeologist Clark Erickson has persuasively argued against the necessity for centralised state authority to generate synchronically the raised fields of Titicaca. Rather, "these landscapes represent the results of thousands of years of evolving local and regional farming systems and the gradual accumulation of landscape capital or landscape infrastructure by both communities and states" (Erickson, 1993). It is, nevertheless, a profound legacy of accumulated landscape capital which we must seriously consider.

The prehistoric nature and geographic extent of raised field gardening is of course but one class of larger-scale native South American agricultural activity to ponder. Extensive highland areas between 800 and 5700 meters were intensively terraced from Venezuela south to Northern Chile and Northwest Argentina, beginning long before the time of Christ (Donkin, 1979). In Perú alone, the total extent of once terraced land has been estimated at around one million hectares, or nearly 40% of all land under cultivation (Denevan, 1987). We must also not forget the massive canal irrigation projects which modified huge portions of arid lands to the west of the Andes. One system alone, interconnected seven river basins extending across several degrees of latitude (Moseley, 1983). It is also important to consider the movement of animal domesticates and the creation of necessary conditions for their propagation. Archaeological evidence thus far suggests the domestication of native camelids in the Central Andean highlands around 5000 B.C., with their subsequent introduction into coastal areas as early as 2500 B.C., and eventually north and south through Ecuador to Colombia, and Chile respectively (Stahl, 1988; Wing, 1986). It is also important to contemplate the longer distance relocation of smaller, portable domesticates as dogs and cavies between far-flung areas of pre-colombia America (e.g. Cordy-Collins, 1994; Stahl & Norton, 1987).

The impact of anthropogenic activities is of course not limited to agricultural remnants alone. One need only think of the <u>terra preta do índio</u> or "indian black earth" of Amazonian, which is so pervasive in riverine and interfluvial settings that it is recognised as an official soil type (Smith, 1980). When we add to this list of already impressive native South American achievements, the ancient material legacy of human settlements ranging from temporary encampments with connecting trails, to imperial capitals with formal roads, the overall extent of anthropogenic landscape modification is enormous (Denevan, 1992a; Trombold, 1991). In the words of one biologist, "Precontact Indians were not 'ecosystem men;' they were not just another species of animals, largely incapable of altering the environment" (Redford, 1991).

The Contribution of Archaeology to Studies of Biodiversity

The 'long' view of archaeology can provide crucial contributions to the study of global biodiversity issues. Continuing advances in archaeological techniques and methodologies enable us to recover and analyse materials directly applicable to understanding ancient and long-term relationships between humans and their surroundings. This long-term perspective enable us to examine critically, and reject, a static normative viewpoint of cultural/biological interrelationships, especially that which considers Native American peoples as passive participants in their landscape. It emphasises the legacy of Native American achievements, and the active, transforming, role played by humans in their environment. It emphasises the dynamic nature of evolution and co-evolution.

The long view of archaeology offers a potentially valuable perspective which is broader and more encompassing than even the most protracted and expensive longitudinal study. This archaeological window can document cultural landscape modification in time and space, as well as responses to short term natural phenomena like volcanic blasts, earthquakes, floods and El Niño events, and longer term perspectives of global climatic change. Despite a relatively blunt chronological control, archaeology can nevertheless provide rough estimations on the rate of forest recovery after clearance. Detailed sequences may also enable us to document and compare how succession and regeneration took place, and potentially provide clues as to why it did or didn't. Longer term archaeological records can also document multiple episodes of cultural clearance, occupation, and post-abandonment regeneration, as well as repeated environmental responses to natural cyclical perturbations, all of which enable us to appreciate better the dynamism of landscape evolution.

One exciting and practical avenue which archaeology can provide to issues of biodiversity lies within the application of 'appropriate technologies'. The experimental reactivation of raised fields in Titicaca (Erickson, 1985), Mojos (Erickson, 1994), and Guayas (Muse & Quintero, 1987) have all provided highly encouraging results in terms of productivity and efficiency. Root and seed crops appear to flourish, generally far exceeding current agronomic returns. Fields remain productive even under drought and flood conditions. Initial start-up costs are labour expensive, but entirely practical on a local level. After field construction, maintenance costs remain relatively inexpensive. In certain areas, ancient technologies have been successfully resurrected and introduced on the local level (Erickson, 1992, 1994). And finally, we must also consider the relevance of archaeology's long view to an understanding of why certain prehispanic technologies failed. Archaeology can not only document failure and abandonment in time and space, but also potentially provide clues as to why this happened. These lessons can be of vital importance to issues of 'development' and biodiversity maintenance on a global scale.

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I thank the IUBS Biodiversity Program and Dr. Gertrud Hauser for inviting me to participate in this workshop. Thanks are also extended to Dr. Michael Little for his kind interest, and for originally suggesting my participation in this project. I owe a great debt to my good friends and colleagues Clark Erickson, Mike Muse, Ann Stahl and Jim Zeidler for references, slide material and critical input. I alone remain responsible for any inaccuracies or misrepresentations.

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Traditional Prehispanic Ecotechnologies for the Management of Biodiversity in Latin America

by

M. Monasterio

In Latin America the pre-Hispanic cultures managed complex ecotechnological systems which through an extended historical process of cultural adaptation reached a surprising degree of stability. Examples, are the elaborate agrarian systems that evolved in the Mesoamerican and Andean highlands; the grazing systems involving native *Camelidae* in the Punas; the quite complex lacustrine agricultural systems of the Mexican "Chinampas"; the Zenú hydraulic society in the Caribbean lowlands of Colombia. Moreover, in the shifting cultivation systems in the tropical rainforest regions, cycles of utilisation and succession-regeneration allowed the maintenance of the forest ecosystems (Amazonia, Lacandona Maya forest in México and Guatemala, etc.).

In many cases the diverse cultures produced "surpluses" recognised as heritages of great value for humanity, for they were manifested in architectural monuments, works of art, feats of engineering, technological inventions, and scientific creativity; in this last case affecting through ecotechnological processes the management of biodiversity, biotechnology, genetic improvement and the regeneration of the ecosystems. Today this knowledge persists in the indigenous peasant communities where however it has been integrated through the process of cultural mixture.

This discussion will show the importance of a fundamental investigation which will lead us to understand, rescue and revalue the complex processes involved in the traditional systems, and to transfer them to the management of biodiversity for sustainable development, thereby enriching the development of the present ecotechnology.

This study was carried out within the conceptual framework of the Tropical Mountains Programme, IUBS/MAB-UNESCO, and the Network of Mountain Biodiversity of Iberoamérica of CYTED.

Biological and Cultural Diversity

The meeting of Rio-92 showed that on a world scale biodiversity is not only of biological concern, a problem which can be tackled with the tools of the natural sciences, but that it has unsuspected socio-economic and cultural connotations, which relate to the past, present and future of humanity. The maintenance, and even the possible enrichment, of biodiversity is a process opposed to the modern tendency to simplify natural systems. To understand this process it is necessary to take into account the development of pre-Hispanic cultures, colonial models and the homogenising Western culture which prevails today.

The total territory of Latin America, supracontinental in scale, contains the greatest ecological and biological diversity of the planet, mainly concentrated in the vast inter-tropical regions. In the plains, large areas occupied by forests, woods, savannas, wetlands and deserts are juxtaposed, and these contain an immense biological diversity, constituting potential strategic resources. Many of these have only recently begun to be recognised by the dominant culture, but have been used and managed by the indigenous cultures during a long historical process of adaptation to and interaction with the environment.

Likewise the tropical and subtropical mountains of the Americas include the greatest biological and cultural diversity to be found in any mountain system. This mountain system stretches from the subtropical Andes (north of Argentina-Chile) to the subtropical mountains and high plateaux of México, forming a continuous backbone in the three Americas. Similarly there is lengthwise diversity in the altitudinal gradients, which give rise to ecological zonation and thus to differences in the use of the land and the human occupation over short distances.

The mountain zones, with their succession of high plateaux levels, were the seat of the great civilisations in America: the High Andean cultures in the Central Andes and the Mesoamerican cultures. The relationships between the natural biodiversity (genetic, population, species, ecosystem) and the cultural development which occurred in these zones are an outstanding model of cultural and environmental interaction.

One example of the scientific and technical evolution of these civilisations is provided in the complex and great richness of domestication of plants (Toledo et al., 1985; Solbrig and Solbrig, 1994). Maize and potato stand out amongst these plants which, through a long process of selection and genetic improvement, developed a huge variety of cultivars which acclimatised and adapted to a wide range of contrasting environments across the altitudinal and horizontal gradients. Another example worth mentioning is the domestication and genetic diversification of the camelids (llama, alpaca, vicuña) in the central Andes, a process which required complex techniques for the management of both the animal populations and the dynamics of the pasture grasses at high altitude.

In these cases the ecological diversity promoted the spread of the plant cultivars and animal populations and their adaptation to a diversity of agroecological and rangeland niches. This process of biodiversification would not have been possible in more homogeneous environments, such as those which characterise the temperate highlands.

In the marshy tablelands of Mesoamerica another example is the "Chinampas" agriculture (Toledo et al., 1985) which, by taking advantage of the organic soils and the aquatic plants of the lakes, gave rise to one of the most original and productive ecological systems in the world. Coe (1964) and Venegas (1978), from ecological and agronomical studies, considered that this pre-Hispanic agroecosystem integrated the management of water, soil, solar energy, wild and cultivated plants, animals, manure etc. It achieved in small areas high levels of yield and diversification, being able to integrate agriculture, horticulture, fish-farming and today intensive cattle-farming.

In contrast to what has succeeded it, the indigenous experience must be reconsidered. It is necessary to re-evaluate the importance of lakes, temporary pools and other water bodies as the basis of efficient systems for sustainable development and intensive diversification of food production, as is the case in the "Chinampas", (Toledo et al., 1985).

Turning to the fourth example, the indigenous agroforestry management is perhaps the best-known: fallow-succession-regeneration of the tropical forest allowed the continuing co-existence of the population with the most diverse and structurally complex ecosystem of the planet. The capacity of the indigenous populations to utilise and manage their territories in the vast Amazonian areas, and in the lowlands of Mesoamerica (Central America and México), is the result of knowledge and understanding transmitted from generation to generation. No later model of rainforest management, in the Americas, has been capable of utilising the resources, recognising the potential uses, and transforming them to satisfy subsistence, magic, ritual and other cultural needs.

With respect to the pre-Hispanic civilising processes, the 16th century brought a disruption in the prevailing cultural and agroecological developments in the Americas and, in our particular case, in the management of biodiversity.

Five hundred years ago Europe did not have technological models for the management of the vast land, sea, coastal and island areas of the tropical and subtropical regions of the American continents. The West did not have solutions to the basic problems that faced it in devising economic and social measures which would lead to the harmonious development of its colonies. It did not have the technical resources or the economic strategies adequate to cope with the tropical forest or the high Andean plateaux, which presented conditions not previously encountered. Therefore the West left vast areas which were almost impenetrable and above all unmanageable: the tropical forests, the Andean plateaux and the deserts. These areas became refuge zones for the indigenous populations and high diversity was maintained there.

The independence and the development of new republics brought still more westernisation in the name of progress. Today's so-called ecological crisis and the biotechnological potential contained in the American tropics offer an incipient space to draw together and re-evaluate the reserve of knowledge of the indigenous and peasant populations of America that still remains. As a basic premise it is necessary to evaluate economically that knowledge, incorporating it in their capacity for self-management. For sustainable development it is necessary to rescue scientifically their agroecological practices and to know the biological processes involved in their systems of production.

Figure 1 summarises our approach in this research. The American pre-Hispanic societies (top left) contributed to a rich technological heritage through the invention of agriculture, its adaptation to a wide variety of natural environments, domestication of many plant and animal species, invention of an irrigation technology with quite elaborate engineering works, development of original technologies for food conservation. On the right side, from 1492 onwards, many mestizo cultures arose from the cultural hybridisation of aboriginal and mediterranean traditions, incorporating new crops, animals, tools and agricultural practices.

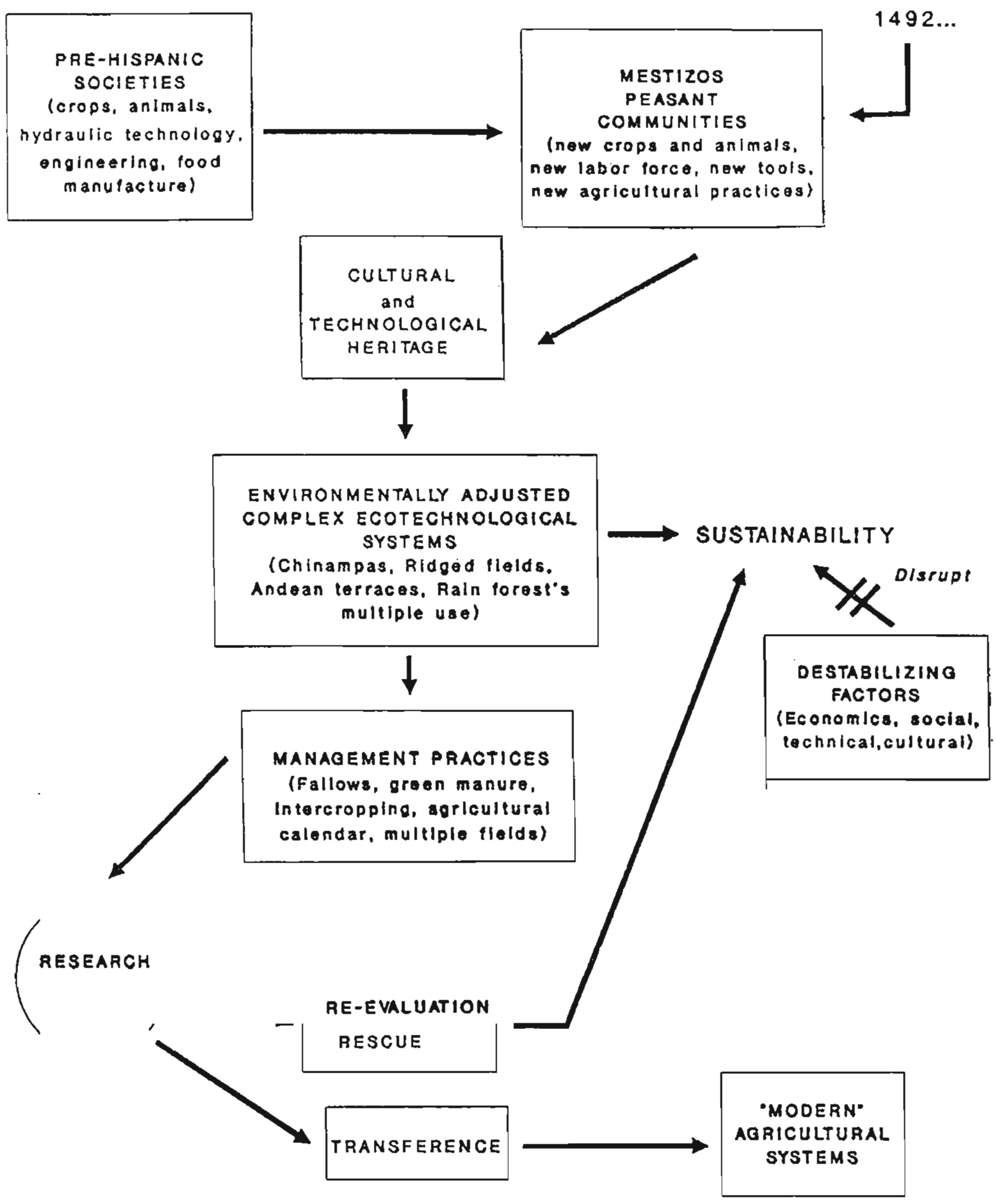

Figure 1. **Re-evaluating traditional prehispanic ecotechnologies for the management of biodiversity in Latin America.**

This cultural heritage, either pre-Hispanic or mestizo, gradually gave rise to complex ecotechnological systems, adjusted to different environments, such as the Chinampas of the valley of México, or the raised fields of the Caribbean lowlands, or some agriculture and pastoral systems in the Andes. These systems were sustainable under certain conditions, but destabilising factors acted upon them over 5 centuries of colonisation and formation of the Latin American national states.

Our approach to the traditional knowledge is centred on the management practices of the indigenous and peasant agricultural systems, the scientific analysis of each of the cultural practices, and rescue of those evidencing an ecological and socio-economic rationality. Eventually this knowledge may be transferred to the neighbouring "modern" agriculture. This approach is the opposite of the research philosophy aiming solely at a unidirectional technological transference from modern to traditional systems.

The Andes as a Management Model

Of the several pre-Hispanic systems briefly touched upon, the Andean can be taken as an example of management. Its apogee occurred in the central Andes from which it spread out to the northern and southern mountain ranges. Among its outstanding features were the territorial organisation, the complementary management of many contrasting environments, the hydraulic and soil conservation engineering works on a regional scale, the dense communication network, biotechnological inventions affecting management of resources, genetic diversification and the advancement of the limits of agriculture into the high Andean zones of recurrent frosts.

From this complex list the key points can be picked out for interpreting the strategies employed in the management of the diversity in the different zones of climate, place and time, and which were the basis of their functioning and development.

Territorial Organisation and Regional Planning

The strategy of ecological complementarity, that is to say, the simultaneous control by one group of people of diverse and separate territories located in different ecological areas, constituted one of the principal bases of the sustained development of the high Andean civilisations before the European conquest in 1532 (Murra, 1975). In this pattern of regional land use along altitudinal and hydrothermic gradients, called "complementarity in terrestrial archipelagoes" (Murra, 1985), the main centre of occupation, control of power and greatest human density was found in the high plateaux above an altitude of 3200m. This apparent paradox of intensive occupation of the high Andean plateaux in cold tropical environments, considered by Europeans unfavourable for human beings and the development of agriculture, is understandable because there was in fact a climate adequate to allow sustained development throughout thousands of years, which culminated in the formation of an empire. The Inca Empire was then later disrupted by European invasion. This central control of the diversity of territories is similar to that which evolved in other complex societies elsewhere which enabled the utilisation of multiple resources and the development of the social complexity.

This control exercised from the cold high plains, extended over occupation zones situated on both sides of the Andes, that is to say on the Western slopes down to the Pacific coast and on the Eastern slopes to the Amazonian borders. The extent of these zones was of great importance for they incorporated belts of transverse complementarity which succeeded each other throughout the length of the Central Andes (Murra, 1992). It was on the solidarity and control created by these interrelationships, that the social unification of the central Andes was mainly founded.

The capacity for environmental management of this culture was surprising; it allowed the exploitation of all the ecological levels from the highest peaks to the Pacific with its coastal and maritime potential in the West, and to the slopes which descend to the Amazonian forests on the East.

Thus, on to the integration achieved in the zones of transverse complementarity, managed from the highlands, was superimposed a process of superintegration in the longitudinal Andean axis, which allowed unification of the transverse zones which were relatively isolated ethnically, and totally isolated socio-politically. These ecological and socio-economic bases were the foundation for the constitution of the great political structures, Wari, Tiwanaku, which culminated in Tawantinsuyo, the Inca Empire.

Andean Agroecology

It was in these conditions of the high Puna plateaux, apparently unfavourable in European eyes, that the inhabitants of these cold tropics very early utilised the daily cycles of freezing and thawing to develop the technique of dehydration of tubers (chuñu) and of meat (ch'arki), (Troll, 1968), which allowed their storage for long periods of time. The massive storage of these key easily transportable foods was the basis for an important macro-economic development and not merely the generation and persistence of peasant societies (Murra, 1992).

The societies of the high Andes made use of the constant diurnal rhythms of the mountain tropics - night freezing and daytime thawing combined with high insolation - to create a complex technology of food preservation, the biochemical processes of which have still not been measured or interpreted by modern science.

In the contrasting rainfall conditions of the Puna, with cycles of rain and drought, the tubers only develop in the wet season of the year. The Andean societies found a method to preserve the tubers and reduce their weight, which is an additional advantage for their transport to other altitudinal levels of secondary occupation, or over the long distances travelled by the Inca armies which colonised and integrated the territories.

The manufacture of chuñu (using potatoes and other tubers) can be carried out in the open country. The tubers are spread out during the night on straw in small depressions in the surface of the soil, exposed to the night frost. In the morning they are soaked with running water. This process is repeated over several weeks. This great invention of using the diurnal microclimatic cycle of the tropical Andes was of enormous advantage in establishing human settlements at high altitudes, where many tubers are found and there are recurrent frosts.

Permanent settlements at high altitudes only became possible after the development of this process of food preservation. Formerly these were areas where tubers were only produced during the wet season (three to six months per year in the Punas). Another important advantage for settlements at high altitude was the presence of wild camelids in the pastures above the level of the Punas. Once domesticated, the application of the same principles and technical processes to the preservation of the meat brought enormous advantages, diversifying the diet and complementing its protein value.

In the total strategy of the Andes the notable points include: the capacity to utilise space and time variation to make use of the ecological and biological diversity; the management of multiple environments, with their annual precipitation cycles and daily microclimatic cycles, which enabled the development of techniques to preserve food. Another notable fact was the experimentation and genetic improvement which brought about the acclimatisation of Amazonian plants, such as coca, to the "Yungas" (wet valleys), and the adaptation of many potato varieties to altitudes over 4.000m. These potatoes were grown in the plots of the temporary residences of the puna shepherds who stayed at great heights during the season when the mountain ranges were snow-free and the pastures provided good feeding for their flocks.

We have not emphasised the hydraulic engineering works, such as dams and canals, nor the many anti-erosion techniques employed on the steep mountain slopes, such as the huge system of terraces which characterises the Andean mountains by their impressive appearance. It would take too long to detail all the infrastructure and the conservation practices which were elaborated for the control and management of water and soils. Here we have only given a brief idea of the aspects related to the utilisation of biodiversity and the sustained development, the combined organisation of space and time, and the political and ecological significance of land use. But it is important to stress the technological and biological innovations arising from the relationship between these human societies and nature, which allowed exploitation of raw materials in the high Andes, associated with a genetic diversification and a wider distribution of Andean tuber cultures to agro-ecological niches which are more extreme in temperature than those found in the intertropical zone.

The Current Situation

Following pressures exerted in the Andean region during the colonial and republican regimes that tore apart the Inca organisation, it is necessary to reflect on the present-day situation:

> What now remains of the complementary use of resources in the mountain ranges?
>
> What is left of the territorial planning of the pre-Colombian archipelagoes?

Today even though disorganised, in the schemes of the ancient archipelagoes adjustments have been made so that in many cases parts continue to be used of the complementarity of the diversity in the Pacific-Andean-Amazonian regions. There still persists in a large part of the indigenous societies and Andean peasantry a complementary localisation of their plots in different ecological areas, often at a distance of many days' walk from their principal high altitude residence.

There remain various examples of groups of people living at altitude who still utilise higher and lower levels, reaching them on foot. One of the most notable cases is that of the Q'ero indigenous communities (Flores et al., 1989) who control an altitudinal range of 4000m. This stretches from the level of the "Yungas" (wet valleys) at 1500m where they cultivate coca plants, fruit trees and now coffee; across the intermediate mountain levels where maize cultivation predominates and the high valleys with tuber cultures; to the high levels with pasture grasses and camelids over 5000m. Above these altitudes they still communally run the salt-mines.

In the situation found today, the complementarity of the agricultural cycles in the successive seasons of the year takes on a new fundamental importance, now that many areas are utilised by the same groups of people who journey from one ecological level to another during the year; this is the situation in the Q'ero indigenous farming people. Due to the extreme isolation and inaccessibility of the Q'ero, they have been able to resist the powerful pressures towards destroying the system of multiple use of gradients.

Ecological complementarity does not only persist in peasant communities, but also it is practised by owners of large "haciendas" who controlled, until quite recently, several altitudinal levels and utilised them for the production of potatoes, maize and the diverse products of the "Yungas" (Fioravanti, 1975).

The continuing presence of a dense human population in the tropical Andes from the northern to the central cordilleras (Monasterio, 1989; Morlon, 1992), is a fundamental historical fact, from the times of the local chieftains ("cacicazgos"), through the Inca Empire, the colonies and the current states. This human presence is linked to the existence of a peasantry with a strong social organisation and a profound environmental knowledge, constituting a strong mesh of forces which has resisted all the destabilising pressures and the large emigration to urban centres, and which has been maintained.

The density of the population permitted the construction and maintenance of a complex infrastructure of irrigation, soil conservation, management of the animal herds and pastures, and the accomplishment of the seasonal sequence of the agricultural tasks throughout the year.

What lessons can be learnt from today's peasant societies which preserve and practise the technical knowledge, carrying out the series of ecological and biological processes for utilisation of the environment yet modifying them to meet new situations. They also, unbiasedly absorb and adapt non-Andean technical elements whenever they consider it convenient and possible.

It is clearly of scientific and practical value, indeed of social, economic and political value as well, to recognise, re-evaluate, rescue and transfer all this information which still persists. Ecotechnology can play a role in the rescue and re-evaluation of traditional knowledge.

Ecotechnology, Sustainability and Equitability

What follows relates to ecotechnology, its conception and current application as used by research groups in Latin America who recognise its "traditional" origin, as a product of a long society/nature interaction. Ecotechnology may be defined as the combination of technologies which shape a system of utilisation adapted to the environmental ecological, social and cultural conditions in such a way as to satisfy the needs of a defined region and to allow the transfer of resources to areas of ecological and economic complementarity.

Ecotechnology is characterised by:

1. A holistic view of technology (including biotechnology) seen in an environmental context, cultural and ecological.

2. Technological or biotechnological solutions, or a combination of both, adapted to the management of open systems, partially self-regulated and in continual transformation, as are agro-ecosystems and natural ecosystems.

3. As a first priority, satisfaction of the needs of the local populations for resources, using optimal means of production compatible in the best possible way with the stability of their environment and sustainability of the production systems. Yet where control and self-management of key resources by local populations prevails, it is important also to be open to the requirements and needs of other regions and populations sharing the principle of global equality.

4. Selection of productive systems which minimise the ecological costs and maximise the conservation of natural resources (primary sources of production and transformation) through the understanding of the ecological processes which govern the functional dynamics, productivity transformation of the agro-ecosystems and surrounding natural ecosystems, with the objective of achieving sustainable development.

5. Evaluation, restoration, improvement and application of traditional and local knowledge, and its integration with the new knowledge from the different fields of "modern" science, in order to refine the information for the construction of productive systems and for biotechnological transformation in those in which the ecological perspective is lacking.

6. Recovery of traditional technologies and reanalysis of the present ones with the aim of offering a range of potential solutions which may be adjusted to varying ecological and cultural characteristics. This should be a participative enquiry jointly between the scientific investigators and the populations involved who know their environmental systems and are concerned in their self-management.

7. Consideration that traditional ecotechnology is adapted to local production needs, using traditional knowledge and technologies and use of native resources. This scientific and cultural store of knowledge should be assimilated to elucidate the current paradigm of sustainable development, based on the agreement on Biological Diversity, and the controversial challenge of global equality, which in turn should be based on self-management.

The Biological Diversity Convention of Rio 1992 presents a fundamental dilemma since it implicitly questions the current models of development which tend to increasing homogenisation of natural and social systems. Current management systems have been shown to be inefficient for the maintenance of biodiversity and the planning of sustainable development. In the inter-tropical regions of the American continents the greatest diversity is found in the indigenous and peasant areas where it is utilised in traditional ways. It is an urgent priority to re-evaluate their knowledge, primarily for their own benefit, and then also to provide resources shared fairly for humanity, following the objectives of the Biological Diversity Convention.

Conclusion

This survey has shown the critical importance of biodiversity to Latin American indigenous cultures, the ways which they evolved to make efficient use of it, and the great contribution so made to the development and refinement of their civilisations. It challenges the current paradigms of economic exploitation.

By implication it indicates some of the potential advantages that may accrue from the maintenance of existing biodiversity, and the salvage and restoration of that which has been partly lost, and urges development of ecotechnologies that will help to attain the objectives of the 1992 Rio Convention.

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Interactive Biotope Structures. The Enhancement of Biodiversity in Domesticated Animals by Controlled Breeding

by

G. Forstenpointner

Introduction

Human communities are integral elements of many ecosystems subject to a complex pattern of mutual dependence among all their active components. These include also the non-human forms of life and, of these, animals are taken as representatives for present purposes.

For representation of this interaction the "Ecological Triangle" is useful (Figure 1). This is principally based on the structural models of Levi-Strauss (1965, 1971) for the interpretation of integral and associative cultural elements, embodying the thesis that individual elements of a system can only be understood in relation to the other elements in that system. In the ecological triangle oppositional pairs of elements are designated on a scaled axis. Thus an individual though rather simplified triangle-diagram can be attached to every human way of life.

For instance 4 degrees are entered on the axis "Man" ranging from a stable, very conservative way of life (1) under "extreme" environmental conditions to that of a very dynamic urbanist interaction (4). The earliest preneolithic groups of human beings will fall within the way of life indicated as "1". A degree "0" or "-1" will also be required to cover those life conditions which make gradually impossible the continuing existence of a group. Examples of this last degree are the Scandinavian Greenlanders or the people of the early Sahara cultures (ca 5000-1000 B.C.).

The degrees "2" and "3" are to be regarded as intermediate levels; the human representatives gain increasing influence on the environment and the animal species they utilise, an influence which at the same time becomes less reversible. Degree "2" would apply to groups of human beings such as Bandceramic farmers, but also rain-forest dwellers. Degree "3" would refer to the traditional small scale peasant agriculture practised since the Bronze-Age (ca 3000-1000 B.C.), to ways of life as in mountain pasture agricultures and seasonal semi-nomadism. Actual nomadism, however, is to be entered in the vicinity of degree "4" on account of its immanent capacity for expansion.

The way of life indicated with degree "4" strives at total control of the environment, including all its non-human forms of life even though barely involved therein. The action-arrow in brackets refers to the - often unconscious - interaction between the changed environment (including the controlled living creatures), and the way of life of the human group concerned.

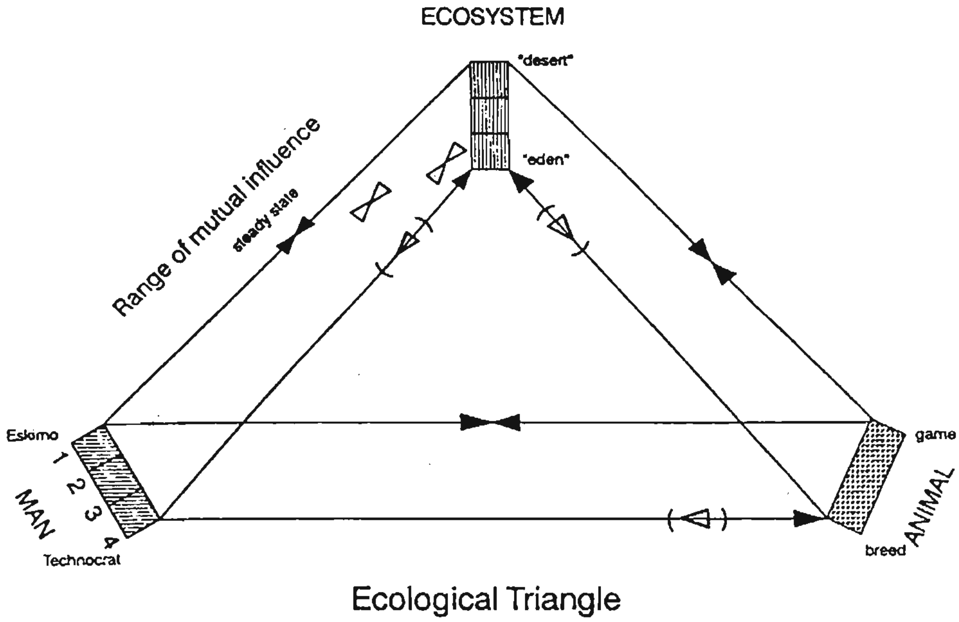

Figure 1. **The ecological triangle. A triangle-diagram, based on structural models, but modified by introduction of scalable axes, is used for representation of interactions between the elements of ecosystems.**

Influence of Cultivating Ecosystems on Biodiversities and the Archaeo-Zoological Record

The depletion of species in an ecological system resulting from modern exploitation and extractive techniques is evident and has been exhaustively dealt with in literature on the subject. Similar depletion results from the manifold modern activities, ranging from monoculture in agriculture and forestry accompanied by the soil and water changes to manipulations of landscaping on behalf of the leisure time industry and the biotic effects of various toxic emissions. The consequences of these ways of life and economy indicated as degree "4" in the ecological triangle, however, are not the subject of this contribution. Neither is the influence of human groups whose economies fall within the degrees "1" and "2" on the ecological triangle. What should be pointed out, however, is that the effects of their activities on biodiversity are usually limited, due to the small number of persons in those societies.

Degree "3", the traditional, small-scale agriculture with its quite wide range of products doubtless may be regarded as a preliminary step towards the modern, landscape-exploiting economies; its influence on biodiversity must, however, be viewed in a different way. Up to the middle of the 18th century no significant depletion of species can be established in Middle Europe, other than the - indeed spectacular - extirpation of some representatives of the larger fauna in direct competition with or threatening mankind. Up to this stage large woodlands could be preserved in their original state on the one hand and, on the other, a great number of small biotopes resulted from the various agricultural methods. Pollen-analyses have determined the maximum number of floral species in the period prior to the introduction of invasive agricultural methods (Kral & Mayer, 1976; Hauschild, 1991). What seems likely is that also the small fauna benefitted by the increased spectrum of available habitats, though analogous faunal studies do not exist as yet.

By means of archaeo-zoölogical records, however, clear indications of the life forms of these early traditionally cultivated landscapes have been furnished. As an example may be quoted the attempt to reconstruct the biotic profile of the elevated plain of Lousoi in Arcadia at Late Classic Times (4th to 2nd centuries B.C.), by means of the animal bones discovered there (Forstenpointner & Hofer, 1994). The Basin of Lousoi today at 1200m above sea level, is nowadays moderately fertile in the bottom area; the surrounding mountains are severely eroded. Specimens of extraordinarily large red deer lead to the interpretation that vast areas of the mediterranean primary forests must have existed in that period. Pasture land probably divided up by belts of shrubs and woodland must have been available in the valley bottoms. Bones of quite large cattle bear witness to the quality of these pasture lands, while bones of the bustard may be considered an indication for the dividing belts. Another reason for the high standard in cattle breeding could be the fact that at least parts of the herds were regarded as belonging to the goddess Artemis, since a temple dedicated to her was situated near the ancient village. Remains of the pelican, furthermore, suggest the presence of a lake in that period.

Massive changes in the biotic profile probably as early as the 3rd to 6th centuries A.D. may be traced back to the large-scale deforestation of the mediterranean area that then occurred, to be regarded as intentional clearance as an economic measure, as occurs in degree "4" in the Ecological Triangle. Moreover, a depopulation of the old cultural landscapes can be shown (Kolb & Kupke, 1992), and there was severe erosion correlated with the utilisation as goat pasture of what were formerly intensively cultivated soils. The drastic deterioration of man's life conditions at that time are by no means equivalent to the depletion of species in terms of biodiversities. It is due to this very fact that the mediterranean secondary biotopes remained deprived of modern agricultural utilisation and that today they generally feature a great variety of species.

Lasting changes in entire biotic profiles and landscapes, or portions thereof, which doubtless may also be caused by traditional economic structures are not necessarily connected with permanent settlement of the area concerned. Seasonal cultivation of elevated Alpine regions has led to the development of an ecological system, involving the mountain pastures, throughout the whole central European area the persistence of which is dependent on their permanent and continuing utilisation. This anthropogenic landscape indisputably qualified for preservation both on account of its extraordinary beauty, and its long tradition which makes it virtually a cultural movement. But it can only be maintained by the summer grazing. Without this, patches of bush and shrub become established. Then, during the winter, normally the heavy accumulation of snow slides off the short grasses down the hillside without damage to the vegetation. However when the bushes and shrubs appear they retain it, until it begins to slide, and then its weight drags the bushes with it and their uprooting leaves bare patches of rock, which the grasses cannot recolonise (Stahr & Dommermuth, 1993).

Mountain pasture husbandry refers only to the utilisation of plant regions predominantly above the climatic timber-line. It may be compared to a nomadism transferred from the horizontal into the vertical (Grass, 1980) plane, with, however, only a major part of the livestock of a settlement being taken up to the higher regions. Specialised shepherds are in charge of the animals. The maintenance of the Alpine pastures is mainly based on the grazing, and the variety of floral species has been crucially characterised by this (Bortenschlager, 1981; Kral, 1983). A double by-product of mountain pasture husbandry in its present-day sense is hay-production on the one hand, and the making of dairy products. The beginning of genuine pasture cultivation may be traced back to the introduction of the scythe in the Alpine region during the last few centuries B.C. (Gleirscher, 1985). Habitation sites stemming from the Bronze Age in very elevated Alpine regions (Lunz, 1981; Niederwanger, 1983) are to be regarded from the archaeozoological findings rather as remains of permanent settlements than of summer shepherd huts. Thus the existence of an actual semi-nomadism in the sense of transhumance (Dehn, 1972) can very probably be scheduled for the pre-Roman period. Similar ways of life also prevailed in various valleys in southern Switzerland up to a few decades ago, the effects on the landscape being much the same as those resulting from mountain pasture husbandry as such.

Increase in Biodiversity by Means of Differentiation of Domestic Cattle Races Under the Influence of Small-scale Traditional Farming

Influencing of biodiversity by means of human economies and ways of life does not only occur through the restructuring of ecological systems, but also through the formation of domesticated animal species. The following is an example of the indisputable increase in genetic variance resulting from domestication procedures, demonstrated by the breeding history of domesticated cattle. As substantiated by archaeological findings, cattle domestication and cattle keeping began in the Near and Middle East no later than 8-9000 years ago (e.g. Mellaart, 1967). Cattle species were domesticated independently at different places, thus populations of differing genetic stock contributed to the genetic pool of domestic cattle. The intensified reproduction of domestic cattle led to the rise of new recombinations, migrations of cattle keepers furthermore set the stage for an increase in the genotypic variation due to the blending of stationary and immigrant animal populations (Brem et al., 1990). That systematic animal breeding set in with the 4th and 3rd centuries B.C. is clearly manifested in the first illustrations and archaeozoological signs of formation of cattle races (Figure 2).

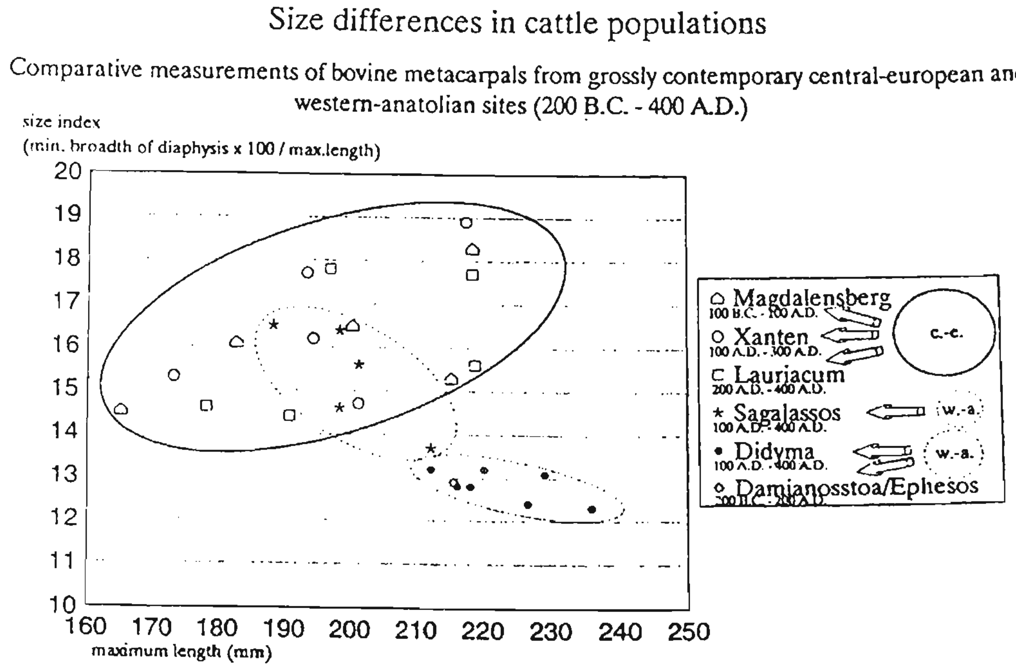

Figure 2. **Distinguishing body-shape-differences between cattle-breeds by osteometric means. Data are taken from Waldman (1966, Xanten), Hildebrandt (1966, Magdalensberg), Baas (1966, Lauriacum), Van Neer and De Cupere (1993, Sagalassos), Boessneck and Von Den Driesch (1983, Didyma) and Forstenpointner (1994, Damianosstoa).**

The term race refers to a group of animals of the same species shown to be intimately related by their specific morphological properties as well as the ways in which they are used. The term, however, is not usually employed in zoological nomenclature, but corresponds by and large to the term "subspecies". The phenotypic differences amongst domesticated animal races are often more striking than those amongst subspecies of non-domesticated species.

The worldwide distribution of domesticated cattle led to a variety of differing morphological forms of this animal species, varying according to their uses, environmental requirements and the aesthetic ideas of the cattle keepers. The range includes phenotypes capable of surviving in the wild such as the Highland cattle stemming from the Hebrides, the Spanish Lidia race, or the Hungarian White Longhorn; then the unpretentious, efficient forms such as the Central European Brown and Yellow cattle races, but also the Alpine Piebalds; and finally the highly specialised types bred for their dairy-production, such as the Jersey cattle, or for meat-production, such as the mighty Chianina race.

The range of appearance of the domesticated dog breeds is even more varied. There were miniature dogs smaller than the present-day Yorkshire terrier already in antiquity (Boessneck, 1975), but also races as large as mastiffs used for military purposes (Keller, 1909). Also the horse, domesticated considerably later than the cow and dog, shows differing forms at an early stage. The Arab race resulting from adjustment to the hot and dry climatic zone has been recorded in illustrations on monuments for over a period of 3500 years. In Middle Europe mostly slender built small horses were found during Roman times; in the Low Rhine area, however, also occurred animals with cold blood characteristics (Mennerich, 1968). At the same time Celts and Teutons were breeding a race of still smaller horses, which nevertheless is described as very efficient (Junkelmann, 1990).

Favourable factors permitting the developmental history of new races are also documented by archaeozoological records. One example relating to cattle breeding comes from the west coast of Asia Minor. Our considerations have to start with the findings from Samos (Boessneck & Von Den Driesch, 1988) and Ephesus (Riezler, 1993) dating from Archaic and late Classic days, as there are no osteometric investigations of material from older sites except for those from the Neolithic settlement of Fikirtepe (boessneck & Von Den Driesch, 1979). For the period from the seventh century to the third century B.C. the existence of a very small cattle race of slender build is deduced from the available bone material, individual animals of which are sometimes to be regarded as miniature. Findings from Dydima (Boessneck & Von Den Driesch, 1983; Boessneck & Schäffer, 1986) suggest a revolutionary change as far as cattle keeping in Hellenic days is concerned, manifested in extraordinary large, but at the same time slender built, animals differing in their appearance very significantly from the also large, but heavily built animals in the Roman sphere of influence. Boessneck and Von Den Driesch (1983) pointed out morphological similarities in Egyptian and zebu-like cattle races, but could not determine any possible relations osteologically, as no skulls allowing for exact judgements were found.

Bones of a very similar structure to those from Dydima were excavated from layers attributed to Roman Imperial times with a certain amount of discretion (Forstenpointner, 1994). The form of the horn-cores already suggests crossbreeding with oriental cattle races, and this interpretation was conclusively confirmed by the clear depiction of two humped cattle, on murals at the slope dwellings ("Hanghäuser) of Ephesus. These graffiti are also dated as Roman-Imperial. Further depictions of zebus were also found on coins and other places and are to be regarded as an indication of the breeding of these cattle in the valley-plains of the river Meander. The introduction of this race must have taken place only shortly prior to the Roman seizure of power in Asia Minor. Further studies regarding the development of cattle breeding along the Ionian coast and its influence on race formation in later centuries are in preparation. They could prove important, as there are certain morphological similarities to Eastern European races such as the Hungarian Prairie Cattle, and the importation of the stock by Turkish invaders cannot be rejected.

The heyday of race development occurred with the rise of small scale traditional agriculture. The first surveys in the early 19th century (Abel, 1978) led to initial measures for "race cleansing", i.e. the elimination of apparently undesirable animals and populations. This led to a long period of uniformity. Such race depletion with the consequent reduction in the genepool variability, and thus of biodiversity, is to be viewed in a similar way to the depletion of species in an ecological system through the practice of advanced agricultural methods. Reflection on this subject particularly as far as scientific animal breeding is concerned has developed in the last 20 years or so. The manifest problem of the decline in genetic resources in domesticated animal races spurred a series of opinions and statements by organisation concerned with the matter. Recommendations and arguments supplied by the FAO with regard to maintaining old forms of domestic cattle are quoted by Bodo et al. (1984).

Though they cannot be dealt with in detail here, the main line of argument stresses the usefulness of restoring such races on account of:

> The necessity to preserve to the full the genetic potential of domestic cattle species, in order to be able to fall back upon characteristics possibly required for future purposes, such as adaptability or resistance to diseases.
>
> The possible economic superiority of adapted races with low efficiency compared to "exotic" high efficiency races in countries of the Third World, e.g. with a nomadic pasture-system.
>
> The characteristics of old, traditional animal races as cultural monuments.

Various possibilities exist for preserving genetic information of a race without any subsequent economic utilisation (Brem et al., 1982):

> The establishment of small populations in domestic animal zoos or by private animal keepers, the unsatisfactory economic profit of which could be made up for by keeper's bonuses. Keeping can be limited to female animals provided that sufficient deep-frozen sperm are available.
>
> The exclusive storage of deep-frozen sperm without preservation of live populations. So the original genotype required can be restored satisfactorily by insemination of brood animal from present populations, and subsequent multiple crossbreeding.
>
> The storage of deep-frozen embryos and sperm without preservation of living animals. By transfer of thawed embryos, animals of the required race can be produced when desired.

All of these methods have already been implemented more or less intensely for the preservation of endangered domesticated animal races. What is to be considered, however, is that only the establishment of an embryo-bank will grant a secure possibility for the conservation of a sample of the genome of a race (Brem, 1990). Live keeping in small populations gives problems, as inbreeding and genetic drift will inevitably arise after a few generations. The exclusive storage of sperm will entail gene-loos when the genome is reactivated by means of the necessary crossbreeding procedures. Nevertheless it seems meaningful on account of its good and particularly cheap preservability, to provide also for the storage of deep-frozen sperm in addition to the installation of embryo-banks.

Summary

In summary, the influence of human activities on the extent of biodiversity in ecological systems subjected to economic utilisation is to be viewed in different ways. Modern landscape-exploiting agricultural methods lead to a massive depletion in species both of fauna and flora. Similarly, the uniformity of domestic cattle races results in the accompanying reduction of the gene pool of the animal species under consideration. Small scale, traditional agriculture, in turn makes for an increase in biodiversity, especially regarding the wide ranging diversification of domesticated animal races. Though a return to pre-industrial agricultural structures, naturally, cannot be demanded, the recollection of the utility of smaller and less standardised economic units might prove very meaningful. Kohr (1962) stated that "small is beautiful". His politico-economic recommendations are at least partly founded upon the evolutionary fact, that the rate of biodiversification corresponds to the development and maintenance of an ecosystem's inner stability and ability to survive.

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Influences of Turkana Pastoralists on Dry Savanna Biodiversity

by

M.A. Little

South Turkana Ecosystem Project

The South Turkana Ecosystem Project began in 1980 as a collaborative research programme drawing on the skills of sociocultural and biological anthropologists and rangelands ecologists. The work was to be done in a dry bushland savanna ecosystem inhabited by nomadic Túrkana pastoralists who exploited these lands by keeping several species of livestock and moving them frequently in search of forage and water. The early objective of the project was to understand and document the relationships among the people, their livestock, and other components of their savanna ecosystem. The theoretical perspectives of the scientists working on the project were based generally on systems ecology, adaptation to the environments, and biobehavioural and populational frameworks. Important assumptions made about this ecosystem were that it was highly variable both in space and in time and that the people were able to exploit successfully the environment by means of adaptive flexibility (N. Dyson-Hudson, 1972, 1980; Dyson-Hudson & Dyson-Hudson, 1980).

The research work was divided into three primary areas: systems ecology, in which modelling was an important element; sociocultural anthropology, with emphases on livestock productivity and social relations; and biological anthropology, with interests in health, demography, and adaptability. The ecologists were interested in ecosystem-level problems and the effects of the Turkana population on the savanna ecosystem. Numerous experimental and descriptive studies provided data for the ecosystem modelling. The sociocultural anthropologists were interested in how the human population is able to survive and adapt to a highly variable environment (spatially and temporally) with very limited resources. Sociocultural anthropologists focused their efforts on social units, such as the family settlement or larger social aggregates. The biological anthropologists were concerned with the effects of an arid savanna environment, a pastoral life style, and a highly mobile nomadic existence on human nutrition, child growth, disease, reproduction, physical activity, and other indicators of health and adaptability. Biological anthropologists focused on patterns of human variation within the Turkana population. Work continues, up to the present, to integrate and synthesise these different conceptual levels of scale and perspective, particularly the relations between human and livestock population dynamics (Coughenour et al., 1985; R. Dyson-Hudson, 1989; Ellis & Swift, 1988; Leslie & Fry, 1989; Little et al., 1990; Little and Leslie, 1990).

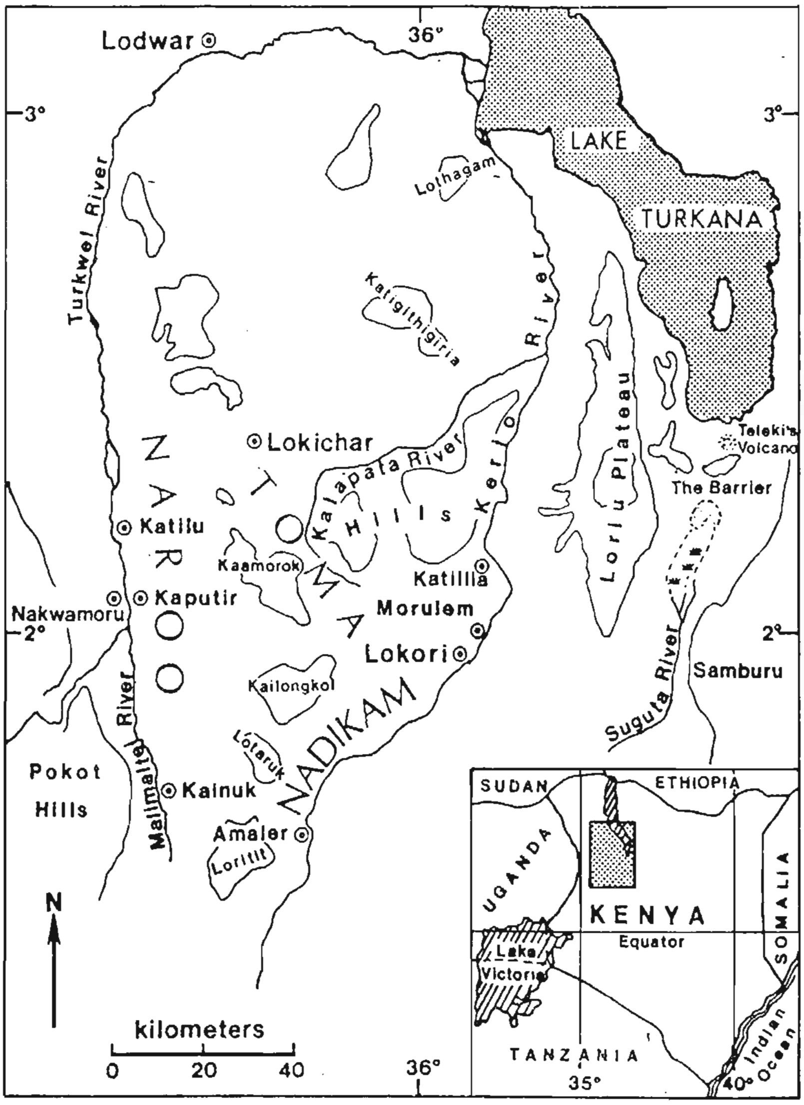

Figure 1. **Map of South Turkana.**

The Turkana People and Their Environment

The Turkana are pastoral nomads of northwest Kenya (Figure 1) who migrated to this area and expanded to fill what is now Turkana District more than 150 years ago (Lamphear, 1992). They herd species of livestock as their principal means of subsistence: dromedary camels, zebu cattle, fat-tailed sheep, goats, and donkeys. Livestock are herded largely for their milk, which is a principal component of the diets of all members of the society (Galvin, 1992). Other livestock products, such as blood and meat are consumed as food, but in much smaller amounts. This diet produces a nutritional pattern in which protein intakes are more than sufficient, but caloric or energy intakes are often deficient (Galvin, 1985).

For more than a decade,we have worked closely with the Ngisonyoka Turkana, a tribal subsection of the main population. The nomadic Ngisonyoka Turkana move frequently throughout a home territory of about 8,000-10,000km^2 in search of green forage for their livestock. Mobility and flexibility of herding strategies help buffer the nomads against seasonal and longer-term environmental fluctuations, particularly in food supply. Within the Ngisonyoka home territory, there are a number of nucleated settlements inhabited by Turkana who have given up livestock herding and have become farmers or mixed farmers and herders. Such settlements are always along one of the two main rivers, the Turkwel and the Kerio, which supply water for irrigation cultivation (see Figure 1). These settlements tend to have considerably higher population densities than in areas of nomad habitation. They are also areas of considerable woodland degradation because of the continual pressure for fuelwood for direct use and charcoal production.

The biotic environment of South Turkana is structured by rainfall that is highly seasonal (averaging about 250mm per year), and by hot equatorial temperatures (Little & Johnson, 1985). These conditions produce a semi-arid savanna that is characterised by limited vegetation appearing in the form of seasonal flushes following rainy periods. Turkana subsistence is clearly driven by these conditions of limited water and vegetation for livestock. There is, however, considerable environmental diversity in South Turkana that provides resource exploitation alternatives for the Turkana. For example: there are riverine woodlands that enclose the two major river systems; areas adjacent to rivers can be used for limited irrigation agriculture; the montane areas retain green vegetation during the long dry season and are used for grazing at these times; there is a north-south gradient in rainfall with southern areas wetter than in the north; and there is another gradient in rainfall with highland areas showing more rainfall than the lowland plains. The ecosystem of southern Turkana District, then, can be characterised as spatially patchy and temporally variable. The Turkana people exploit these conditions by means of nomadic movement, with average settlement relocation at a rate of 13 times each year.

The Ngisonyoka Turkana employ complex strategies to exploit the limited resources of this semi-arid savanna ecosystem. Nomads exploit a variety of plant species for their livestock, and maintain a high degree of mobility to move livestock quickly to seasonal flushes of vegetation. Nomads are quite skilled at exploiting a patchy ecosystem that is both spatially and temporally variable. Settled Turkana, although principally cultivators, also keep some livestock, and participate in exchange relations with nomads who may be friends or kin.

Turkana Influences on Their Environment

Although nomadic Turkana population density is only about 1 person per square kilometre, or less, the Ngisonyoka Turkana do modify and have considerable impact on their environment. For example, livestock management of their five species entails movement of livestock from place to place to exploit green vegetation. Camels and goats browse on acacia trees and shrubs, while sheep, cattle, and donkeys graze on grasses and forbs. Hence, there is not only continual pressure on the plant productivity of the ecosystem, but also a competition with wild herbivores that keeps the populations of wildlife at relatively low numbers. At the same time, and particularly during the long dry season, below-ground water reserves are tapped via wells that the Turkana dig in dry stream beds. It is not known whether the aquifers that maintain the below-ground reserves are being depleted by these practices, but it is unlikely, based on current human and livestock population densities.

Another nomadic activity that modifies the savanna environment is grassland burning. This practice is designed to burn off senescent plant growth to allow new grasses to develop during the rainy season. Rangelands burning also tends to prevent new tree growth and assists in maintaining savanna conditions. As can be seen below, however, there are advantages to promoting tree growth in such an ecosystem with limited rainfall, intense solar radiation, and high evapotranspiration.

Nucleated settlement of Turkana, in contrast to nomadism, places new stresses on the limited resources of the dry savanna. There are several settlements that are associated with irrigation cultivation along the Turkwel and Kerio Rivers in South Turkana (see Figure 1). These include the towns of Katilu and Kaputir and settlements Nakwamoru and Juluk along the Turkwel and the towns of Lokori and Morulem along the Kerio. Wells have been dug at these sites to serve the somewhat large populations, and it is almost certain that the pressure on below-ground water reserves is contributing to its depletion. Furthermore, there is heavy use of fuelwood at these sites, such that take-off of woody vegetation exceeds its replacement. These areas are heavily deforested despite the fact that they are all located in riverine woodlands.

The nomadic Turkana use wood for a variety of purposes. Some individuals manufacture charcoal for sale, although this activity is quite limited among nomads. Most of the wood that is utilised is for: making wooden vessels, watering troughs, and other items; fuelwood; and corral and hut construction (see Figure 2). In the first case the overall takeoff from the available woody vegetation is negligible. In the second case, most of the wood used for fuel is deadwood. In the third case, significant amounts of woody vegetation are used for corral and hut construction. The species most often used are *Acacia tortilis* and *Acacia recifiens*. Some values on wood use are given in Table 1 from surveys reported by Ellis and his colleagues (1984). Estimates of the total woody vegetation utilised by the Turkana nomads as a percentage of the total annual ecosystem productivity is only about five percent (Reid & Ellis, in press).

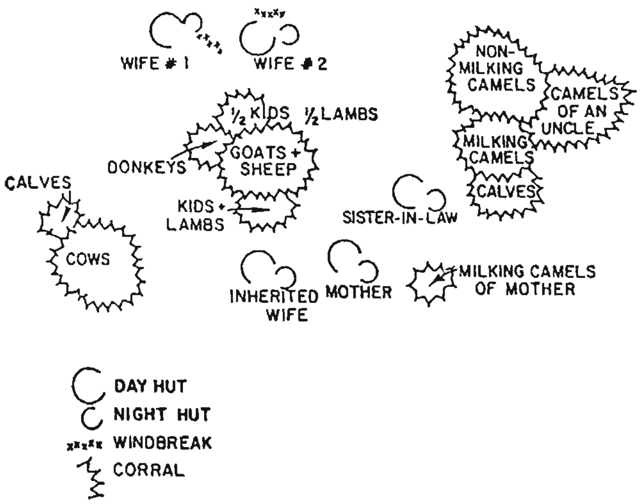

Figure 2. **Schematic diagram of a Ngisonyoka Turkana settlement (after Galvin 1985).**

Deforestation and Reforestation of the Dry Savanna

It is clear, then, that the nomadic Turkana are not contributing to deforestation through burning of rangelands or takeoff of wood resources. This is counter to arguments that have been made against dry savanna pastoralism, where it is believed that desertification in many areas is anthropogenic in nature (Lamprey, 1983). However, to pastoralists contribute to biodiversity through practices that lead to reforestation?

There is now considerable evidence for reforestation by the nomadic Ngisonyoka Turkana as the result of pioneering research by Reid and Ellis (in press; Reid, 1992) conducted in the late 1980s. Prior to this work, we had learned from Ngisonyoka Turkana informants that many sites in the home area of these informants had more vegetation than was present two or more decades ago. At the same time, clumps of young acacia trees were observed that were roughly the shape of Turkana corrals, and it was hypothesised that the dung-filled corrals were serving as inadvertent acacia-tree nurseries. When the Turkana family unit moves, only portable things are moved such as vessels, hides, clothing, and the like. Corral thorn enclosures are left intact and probably act to keep out wildlife, even after the family has moved.

Minor	Major
Herding Sticks	Fuelwood (Usually dead wood - 416 kg/yr/person)
Stools	Construction of akis, ekales, and anoks:
Milk and Other Vessels	Akis (night huts), X = 50 kg of wood
Watering Troughs	Ekales (day huts), X = 220 kg of wood
	Anoks (Corrals), X =170 kg of wood
	(1009 kg/yr/person)

Total Consumption = 1,425 kg/yr/person, and since population density of the 8,000 or 9,000 Ngisonyoka Turkana in South Turkana is about 1 person/km^2, then the wood use is about 1,500 kg/km^2/yr. This constitutes only about 5 percent of the annual woody productivity in the area (Reid and Ellis submitted).

Table 1. Wood use by the Ngisonyoka Turkana (after Ellis et al. 1984).

Trees are important in arid zones for a variety of reasons. First, their long roots tap water sources that are deep in the soil to provide green foliage even during the dry season. Camels as browsers are good milk producers throughout the dry season because they were able to feed on this arboreal foliage (Coughenour et al., 1985). Second, since this environment is hot and dry with intense sunlight, there is considerable evapotranspiration, so any shade from trees tends to promote growth and persistence of grasses and forbs that grow in the soil below the trees. Correspondingly, water tends to be retained in the soil below the tree foliage. Third, acacia tree seedpods provide a dry season high-protein food source for livestock, particularly goats (see Figure 3). Fourth, wood is needed for fuel and construction materials for huts and corrals. An finally, trees provide badly needed shade for people and livestock alike.

Robin Reid's (1992) research design to test whether corrals were promoting reforestation involved comparisons among three sites: within the abandonment corral, 100 meters from the corral, and 500 meters from the corral. Differences in many variables between the 100m and 500m sites were minimal, but there were major differences between values from within and without the corrals.

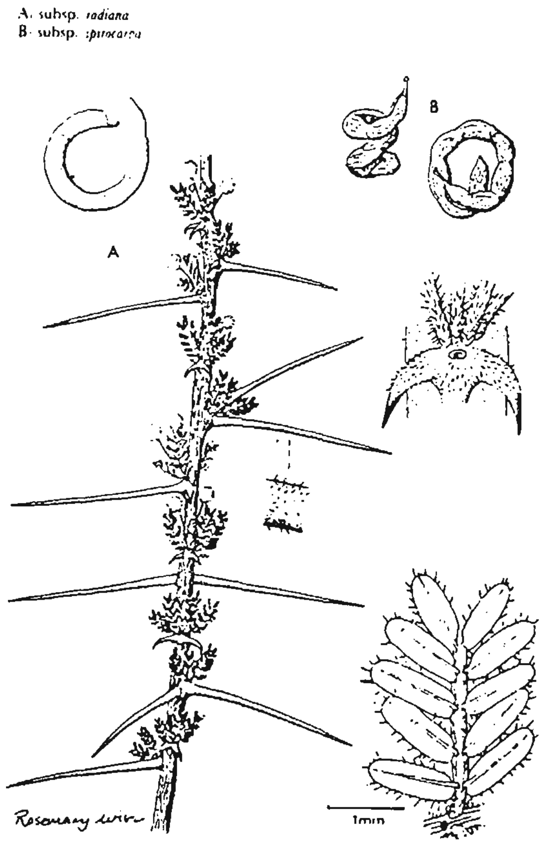

Figure 3. ***Acacia tortilis* (after Coe and Beentje 1991).**

Conditions inside the corrals were found to differ in the following ways from conditions outside of the corrals: corral soils had greater nutrients, greater moisture, and a higher *Acacia tortilis* seed density; corrals had higher seed germination, higher seedling density, and higher seedling survival during the dry season; growth rate of corral seedlings was greater only during the first six months (probably because of crowding and persistence of thorn enclosures); and the corral to non-corral density of acacia trees is more than 100,000:1 after 1 year and even after 29 years is about 40:1.

Reid's (1992) conclusions were that the evidence demonstrated unequivocally that Turkana corrals and the frequent nomadic movement were contributing substantially to *Acacia tortillis* reforestation, and hence, the biodiversity of the area.

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Influence of Human Populations on Microbial Biodiversity: Proliferation, Distribution, Evolution and Emergence of Human Diseases

by

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Introduction

Over the past decade biodiversity has come to refer to "The variety and variability among living organisms and the ecological complexes in which they occur", and is defined as the total number of living organisms taxonomically classified (OTATF, 1988). Biological diversity is represented at different levels of complexity, at a basic chemical or molecular level (nucleotide sequence differences), at a species level and even with more complexity in terms of ecosystem diversity.

What is perhaps curious is the extent to which humankind has been eliminated from the biodiversity construct. Human biodiversity seems to have been put separate and apart from the biodiversity of all other living organisms and humans are not forumated into a biodiversity scheme except in a negative sense. Mankind, in all its diversity, has an important integrative and functional role in ecosystems worldwide and its impact has been both positive and negative. The interaction between human activities and natural systems was spelled out in the 1971 Man and Biosphere Paris report as its first objective "to identify and assess the changes in the biosphere resulting from man's activities and the effects of these changes on man" (Little, 1989). While this underlies the central role of humans in the biosphere and supports the contention that humans are an integral part of the various ecosystems in which they live, the two-directional nature of the statement has been overlooked. The two directions remain far from equal with basic ecology, ecosystem management and conservation and non-human biodiversity the overriding concerns.

It is important that we recognise that humankind is a dominant and integral part of the biosphere. Indeed the contributions to species and ecosystem biodiversity was and is dependent on the wide range of human biodiversity (human populations) living at various technological levels within the biosphere, from isolated hunter-gatherer and horticulturalist groups to peasant agriculturalists, mechanised farmers and western industrialised societies. In each instance the positive and negative impacts of human populations on biodiversity are different. For example, the cultural and biological variation among isolated or semi-isolated groups from the Arctic tundra to tropical rain forests, from small island atolls to central continental plains and mountain ranges, and from rural to urban population centres probably exceeds that of genetically open, technologically advanced societies. Isolated groups are characterised by having a geographically or culturally restricted territory and the lack of travel outside it, a "simplified" ecology and fixed habitat, and a close association with flora and fauna, that usually results in a minimal impact on the external environment. The importance of such isolates to medicine, however, in elucidating the etiology, pathogenesis, ecology, and epidemiology of disease and their influence on microbial biodiversity and the emergence of human diseases is inordinately high. These relationships extend to peasant agriculturalists where culturally specific hygienic practices are important to microbial biodiversity and spread, and where reliance of 80% of the world's population on traditional medicines is found. Likewise, technologically advanced societies appear to have an overall greater global impact on the biosphere and biodiversity because of their reliance on extensive and intensive manipulation of natural systems and the development of artificial means of economic growth and survival.

Microbial Diversity

According to some accounts there may be 1,400,000 living species of all kinds of organisms on earth with approximately 4,800 species of micro-organisms other than viruses and an estimated 1,000 to 10,000 species of viruses (Table 1) (Wilson, 1988). Wilson's biological concept of species is "a population or series of populations within which free gene flow occurs under natural conditions". It seems that overall species diversity has been maintained or has increased slowly over evolutionary history. Likewise, it appears that the longevity of most species (except perhaps that of modern 20th century humans) has remained fairly constant. Thus, while it can be argued that there has been a loss of certain species by both natural means or by human events, there does not appear to be an overall decline in the number of species in the evolutionary records (Wilson, 1988). This, in part, may be due to both the positive and negative impact of humans on biodiversity, either planned or unplanned and controlled or uncontrolled.

Kingdom and Major Subdivision	Common Name	No. of Described Species[2]	Totals
Monera			
Bacteria	Bacteria	5,000	
Cyanobacteria	Blue-green bacteria	1000	
Mycoplasma	Wall-less bacteria	10,000	15,100
Virus	Viruses	1,000	1,000

[1] Adapted from Wilson (1988)
[2] Order of magnitude only

Table 1. Number of microorganisms that have been described and characterised[1].

It is obvious that numerous micro-organisms are beneficial while others may present a danger to various species. The smallest of living organisms are bacteria (including cyanobacteria), fungi (including yeast), and proteus. Along with viruses and viroids, their potential contribution to agriculture and medicine is enormous. It is also true that the concept of species as we know it for animals and plants is difficult to apply to micro-organisms and such populations and organisms, usually descended from a single cell or genomic sequence, are called strains, variants, or quasispecies. The effect of human populations on microbial diversity and evolution and the emergence of human disease in disturbed and undisturbed natural settings is the central theme of the discussion that follows. It concerns viral diseases (as examples of microbial diversity), the importance of human hosts in microbial evolution and the emergence of human diseases, including concepts of host range, virulence, host-virus interactions, genetic mutation and recombination, spread of infection, natural immunity, and drug resistance.

Natural History of Infectious Disease in Human Populations

The natural history of infectious disease in human populations represents a system of dynamic interaction. The associated factors affecting the expression of disease include: degree of isolation and contact; demographic characteristics of the population including size, density and age and sex distribution; group mobility; ecosystem stability; uniformity of food sources; physical environmental stress; close physical proximity during work and play; similar housing; culturally specific hygienic practices; degree of natural resistance and differential genetic susceptibility. The specific characteristics of the disease agent must also be considered, including virulence, persistence, and potential reactivation. The above list is not all-inclusive nor the categories clearly definitive.

Most infections do not lead to overt disease but only to subclinical infections that also confer immunity. Burnet and White (1972) offer three general considerations on the spread of infections, which can be summarised as identification of the reservoir and mode of liberation of the infectious agent from it; transmission from infected host to new susceptibles; and mode of entry into the tissues. Specific factors such as route of inoculation, number of organisms needed to produce clinical symptoms, number of persons shedding micro-organisms, duration of disease, resistance and virulence of the agents, and probability of contact with new susceptibles are also important in determining the epidemiological characteristics of infectious disease.

Infectious diseases affecting human populations can be generally divided into two categories: 1) Those that persist in a population over a long period of time, maintaining themselves in either human or nonhuman hosts, are referred to as endemic or endogenous infections. They are characterised by high incidence and low morbidity, frequently due to the large number of subclinical infections that confer natural immunity. Such infections tend to survive well in small isolated populations as they do not normally kill their hosts. 2) Those infections that produce only acute symptomatic disease and have either human or non-human hosts are referred to as epidemic or exogenous diseases that cause high morbidity and variable mortality in human populations (Garruto, 1981). This classification is somewhat arbitrary and some diseases are both endemic and epidemic.

Viral Biodiversity and Evolution

In assessing the effect of human populations on microbial biodiversity, it is perhaps interesting to consider the case of viral biodiversity because it is possibly the most complex example of biodiversity of all living organisms. This complexity is due to the intracellular "symbiosis" that takes place in a host-virus relationship and the evolutionary (and thus biodiversity) consequences, both to the virus and to the host that results from these ancient organisms. Lederberg (1993) states that while humans can deal fairly effectively with other micro-organisms, such as bacteria and proteus as human pathogens or as agricultural menaces, our only real competitors are viruses since viral nucleic acid is entangled with host nucleic acid and the fundamental machinery of the host cell. Indeed, the three examples of human viral diseases that follow in the next section give credence to this statement and indicate the ultimate creativity that biomedicine must demonstrate to protect the human species.

Current conventional thinking suggests that with the emergence from a chemical environment (Figure 1), the first biosphere consisted of replicating RNA molecules (Holland, 1993). The living organisms in today's world are DNA-based and the only RNA lifeforms are RNA viruses, with the exception perhaps of new concepts in protein evolution, replication, nucleation, and the identification of self-replicating infectious proteins (Gajdusek, 1992). RNA viruses are extremely successful due to their genetic hypervariability compared to DNA viruses which are more stable genetically and chemically. Viral evolution and subsequent viral biodiversity can proceed either through mutations (base substitutions) or through genetic recombination. Drake et al. (1969) suggest that spontaneous mutation rates in viruses and other organisms are inversely proportional to the size of their genome. Although both RNA and DNA viruses are very error prone, DNA mutational errors are correctable whereas RNA errors are not, thus allowing enormous diversity within RNA virus populations. For example, Holland (1993) estimates that in an average 10kb genome for RNA viruses, there is an estimated 1 mutation per 10 replications if the error frequency averages 10^{-5} base substitutions per nucleotide site per replication. For human immune deficiency virus (HIV), which is a retrovirus with a 10kb genome, this would be equivalent to 10^{-2} base substitutions per nucleotide site per year. By comparison the base substitution rates of higher eukaryotes average 10^{-9} base substitution per nucleotide site per year. The RNA virus rate thus exceeds at least a million-fold the average (corrected) error frequencies of animal, plant and human hosts.

We also know that high mutation rates do not necessarily mean rapid evolutionary change, because even in hypervariable viruses parts of the genome may remain very stable. The degree to which this is true is dependent on host-virus interactions which are unlikely to be greatly altered in viruses already adapted to the human host. As with any host-parasite relationship, the survival of both is often determined by the ultimate adaptability of the host and the host's immune system to evolve highly mutable immunoglobulin-gene regions as a mechanisms of natural immunity (Holland, 1993; Lederberg, 1993). Natural selection over time probably favours host resistance while at the same time the parasite often becomes less virulent; this is brought about through various mechanisms including phenotypic modification of the virus by the host with occasionally viruses incorporating host DNA sequences into their genomes and conversely viral sequences integrating into the host genome.

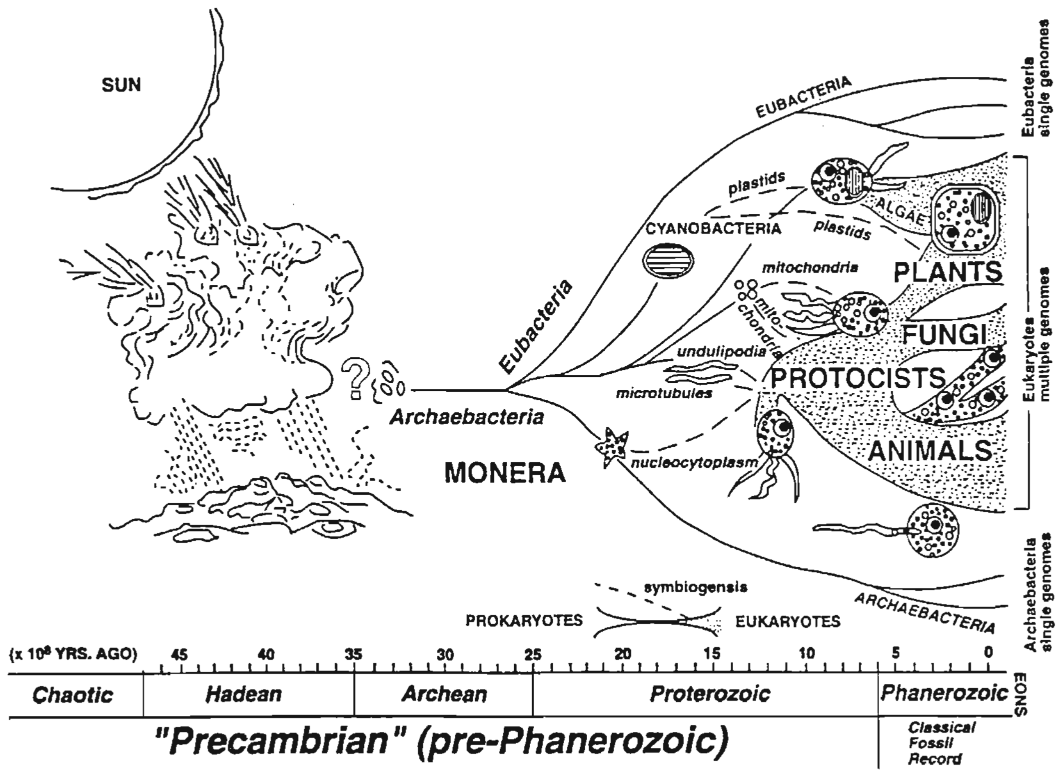

Figure 1. **Classical evolutionary record.**

Emerging Viruses and Human Diseases

In recent years there has been a renewed interest in so-called emerging viruses and emerging human diseases, three examples of which are presented below: influenza, hantavirus pulmonary syndrome, and acquired immunodeficiency syndrome (AIDS). The viruses that produce these disease are often themselves term "emerging" and are defined as newly appearing, newly recognised or rapidly increasing in numbers or geographic range. As discussed earlier, new viruses appear through mutational or recombinant change, through the introduction of an existing virus from another species, or through the dissemination of a virus from a small, perhaps more isolated population in which it is endemic, to larger populations over wide geographic areas (Morse, 1993). The examples below represent all three cases.

Influenza Viruses

Influenza is caused by an orthomyxovirus and is one of the medically most important diseases in the world today with an estimated 100 million infections annually (Murphy, 1993; Palese, 1993). It also typifies the genetic hypervariability that occurs from year to year in RNA viruses with segmented genomes. Influenza can occur epidemically and pandemically. The great influenza pandemic of 1918 produced severe morbidity and mortality with an estimated 20-40 million deaths (Murphy & Webster, 1990; Webster, 1993). In the United States influenza is the sixth most important cause of death. Historically, influenza epidemics occur periodically with a sudden onset, usually during January to April in the northern hemisphere. The epidemics often last only 2 to 3 weeks and then disappear.

In humans, the virus replicates in the respiratory tract with peak viral replication occurring 48 hours post inoculation and it is then spread by aerosol from person to person. Preschool and school-age children are major vectors in the spread of influenza which is greatly enhanced by crowding, a situation that clearly favours aerosol transmission (Garruto & Gajdusek, 1975; Kingsbury, 1990). The highest morbidity and mortality occurs among the oldest age groups and in those with chronic disease among whom secondary infections, such as bacterial pneumonia, commonly develop, There is no evidence of a persistent or latent infection in humans and we do not know what factors limit an epidemic. The minimum population size to maintain influenza transmission during non-epidemic periods is not known, but among small, isolated populations the infection can be explosive and devastating with not only medical but social repercussions as well (Garruto, 1981).

There are three major influenza serotypes classified as A, B, and C. Each has a variety of subtypes classified on the basis of their surface proteins, haemagglutinin and neuraminidase (H and N proteins) (Murphy & Webster, 1990). These proteins represent the major antigenic components of the virus to which the host's immune system responds (Webster, 1993). The most mutable of the three influenza serotypes is influenza A, which is responsible for the vast majority of human epidemics. The responsible subtypes in most human epidemics with influenza A are subtypes H1, H2, and H3 which, for example, were identified as the culprits in the 1918 pandemic (Spanish flu), the 1957 pandemic (Asian flu) and the 1968 pandemic (Hong Kong flu).

The reason for the "minor" epidemics (biennial epidemics) is thought to be mutation in the influenza viral genome while the "major" epidemics (pandemics) are due to what is called antigenic shift (Webster, 1993). This antigenic shift is linked to a major influenza reservoir in ducks and other avian species. The virus replicates in the respiratory and intestinal tracts of ducks (H1 through H13 subtypes), but does not cause disease in avian hosts. A second important reservoir is the pig which often leads to clinical disease and to swine influenza epidemics. Evolutionarily and pathogenetically what is thought to happen is cross-species infection in countries such as China where influenza viruses from aquatic species (ducks) infect pigs. In addition, human influenza virus is also known to infect pigs (Webster, 1993). Thus, the pig acts as an intermediate reservoir host for both avian and human variants of influenza virus, leading to a cross-species genetic exchange and reassortment between the avian and human virus producing a key source for new pandemics and a source of microbial biodiversity (Webster, 1993).

Haemorrhagic Fever Viruses

The haemorrhagic fevers are caused by viruses belonging to several different families, the largest of which the Bunyaviridae, consisting of more than 200 distinguishable RNA viruses (Bishop, 1990), There are four genera, all of which produce zoonotic diseases. Only rarely, if ever, is infection spread by person to person contact. The discussion here will be limited to the hantavirus genus whose representatives cause more than 100,000 cases of haemorrhagic fever with renal syndrome (HFRS) in China alone each year. The genus also represents a group of agents that cause the newly emerging, newly recognised disease called hantavirus pulmonary syndrome, first identified in the four-corners area of the southwestern United States (Hughes et al., 1993; MMWR, 1993; Nichol et al., 1993). Most descriptions of a related disease, HFRS, can be traced back to 1913 in Siberia, but the Chinese literature also has accounts that appear 1,000 years earlier (Johnson, 1993; Yanagihara & Gajdusek, 1988). The first recognition of hantavirus infection by western medicine came during the Korean War when the disease was originally known as Korean haemorrhagic fever. Although approximately 2,000 U.S. troops were infected and developed disease with a high mortality, it was not until 1976 that the causative agent (Hantaan virus) was isolated from lung tissue of the striped field mouse (*Apodemus agrarius*) captured near the Hantaan River adjacent to the demilitarised zone in South Korea (LeDuc et al., 1993; Yanagihara & Gajdusek, 1988). A second disease, originally called nephropathia epidemica, is a less severe form of HFRS found in the former Soviet Union, Scandinavia, and Europe caused by a genetically distinct hantavirus, Puumala virus, harboured by the bank vole (*Clethrionomys glarolus*). Seoul virus, a third distinct hantavirus, causes HFRS in city dwellers with the reservoir host not the mouse (*Apodemus*), as found in rural areas of Korea, but the rat (*Rattus norvegicus* and *Rattus rattus*) captured in Korean cities and world-wide (LeDuc et al., 1993).

Clinically, HFRS has a mean incubation period of 12-21 days and several clinical phases with fever, chills, headache, muscle ache, nausea, vomiting, photophobia, erythematous flushing of the face and petechiae (McCormick & Fisher-Hoch, 1990). As mentioned earlier, rodents are the principal reservoirs of hantaviruses and the virus is shed in rodent urine where it is aerosolised and so infects the respiratory tract of humans. Among the rodent species the main rodents serving as reservoirs of hantaviruses are *Apodemus agrarius* (field mouse), *Microtus pennsylvanicus* (meadow vole), *Clethrionomys glareolus* (bank vole), *Peromyscus manculatus* (deer mouse), and *Rattus norvegicus* (Norway rat) (Yanagihara & Gajdusek, 1988).

In the context of emerging human disease we need to look no further than the southwestern United States. A decade ago Lee and colleagues (1982, 1985) isolated from indigenous meadow voles in Frederick, Maryland what is now called Prospect Hill virus, one the hantaviruses. This confirmed earlier suspicions of the presence of hantaviruses in the United States that cause haemorrhagic fever, but a decade ago no known cases of haemorrhagic fever were ever reported in the United States. By the mid-1980s rats (*Rattus norvegicus*, a non-indigenous species) in Baltimore harbour and the inner city had been found to have antibody to hantavirus. Shortly thereafter, a hantavirus termed Baltimore rat virus was isolated, but again the agent was found to be unassociated with disease (LeDuc et al., 1993). Even in prospective studies of patients with possible renal problems who were screened for antibody in the Baltimore area, no cases of acute hantaviral infection were ascertained.

In May 1993, the Indian Health Service in New Mexico reported a patient suffering from an unusual respiratory illness and, within a short time, contact with other physicians in the area showed 4 more patients with similar symptoms. The disease affected healthy adults, with symptoms that included fever and muscle aches. The hallmark symptom, however, was pulmonary edema that rapidly progressed to respiratory failure and very often death (Hughes et al., 1993). What made the disease initially difficult to identify as a hantavirus infection was the development of a serious respiratory complication without any evidence of renal involvement, a hallmark symptom in other hantavirus infections. Currently there are more than 50 cases of hantavirus pulmonary syndrome thus far identified that are responsible for more than 25 deaths. New cases have now appeared in 14 different states and new reports of cases in New York City and Florida (CDC, 1994). The question being asked is how the epidemic erupted in a geographic region that never previously reported a case of hantavirus infection? The earlier identification of hantavirus in rodents native to the United States by Lee and colleagues a decade earlier, established that the agent was endemic (Lee et al., 1982, 1985). Ecologically, it is thought that heavy snows and rainfall in the four-corners areas of the southwest during the previous spring produced an abundance of piñon nuts and insects, that apparently caused an explosion in the deer mouse (*Peromyscus maniculatus*) population, an endemic reservoir for the virus (Stone, 1993). The deer mouse population expanded to 30 mice/hectare (with a 30% subclinical infection rate), but within 3 months collapsed to 20 mice/hectare for no known reason, although predators such as the fox, owl and snake are thought to be responsible. It is like that these are not the first cases of hantavirus infection to have occurred in the United States, but only the first cases recognised since the clinical expression of the disease in the United States involves primarily respiratory rather than renal involvement and thus is clinical different from that seen elsewhere in the world.

Human Immunodeficiency Viruses

Another virus group that represents the influence of human populations on microbial biodiversity through proliferation, distribution and evolution of the agent are the retroviruses. The emphasis where will be on human immunodeficiency virus (HIV), the cause of acquired immunodeficiency syndrome (AIDS). HIV is an RNA virus whose genome is hypervariable. Much has been written about the biology of HIV and the emerging disease it produces. Perhaps no other agent has been studied so extensively with a research budget from the U.S. National Institutes of Health approaching 10% of its total allocation. So much has been written about HIV and AIDS that only a truncated version of the biology of the agent, and the disease AIDS, will be presented here. Instead, an effort will be made to concentrate on the origin and evolution of the agent and the disease.

HIV is a lentivirus that infects human and nonhuman primates. The routes of transmission are through sexual contact, through contact with blood and blood products (transfusions and contaminated needles through i.v. drug use) and through perinatal transmission (Hirsch & Curran, 1990). HIV is also found in semen and vaginal secretions and both male-to-female and female-to-male transmission occurs, although the frequencies of such transmissions are probably unequal. White cells, particularly CD4 receptor T-lymphocytes are important target cells. The mean incubation period (latency) may be 8 years in adults and much less in younger individuals. The factors affecting the rate of progression to clinical disease are unclear, but nearly all HIV infected individuals eventually develop AIDS.

By 1983 several laboratories had identified and isolated HIV. The virus is 9700 nucleotides in length. Its sequence has been compared to more than 15 million bases of mammalian, plant and viral sequences with no similarities found, leading to the conclusion that HIV is recent in origin and probably a recombinant of other viruses that have yet to be characterised (Myers et al., 1993). Unlike most other diseases, we can, though retrospective studies, fairly well determine when the virus entered the United States. Through serological evaluation it is likely that HIV-1 may have appeared in the United States as early as 1968. What we now know is that around this time two pandemic centres, one in the United States and the other in Zaire, began to emerge about the same time (Myers et al., 1993). By 1991 there were an estimated 6 million HIV-positive adults in Africa alone, with some countries having prevalence greater than 10%. The spread of the virus is thought to have occurred through heterosexual contact between travellers and prostitutes from central Africa, who eventually made their way by road to Kenya (Myers et al., 1993). In addition to central Africa, a second epicentre developed in west Africa where a second virus (HIV-2) was isolated. What is at first puzzling is that the temporal separation of HIV-1 and HIV-2 in Africa occurred within a few years, with no evidence of cross-infection within either region until recently.

Evolutionarily, there seem to be two hypotheses that may explain dual African epicentres: first, that HIV-1 arose from a simian immunodeficiency virus (SIV) in African green monkeys in sub-Saharan Africa, and second, that HIV-2 arose from an SIV from sooty mangabeys in west Africa (Doolittle, 1989). It is evident that both of these hypotheses require cross-species transmission over the same timeframe and a common progenitor or ancestor to both HIV-1 and HIV-2. The argument proposed by Doolittle (1989) is strengthened by the demonstration of SIV mangabey viral sequences in an individual from rural Liberia (Hahn, 1990). This genetic evidence and related phylogenetic analysis point to the evolution of HIV during the past 50 years and that of SIV within the past several hundred years (Figure 2) (Myers et al., 1993). If true, this represents a unique recorded event of a new infectious agent arising suddenly and dramatically in modern times having a profound impact on human health worldwide. Unlike influenza virus, which is of ancient origin, yet produces new epidemics and pandemics through mutation and cross-species genetic recombination, HIV represents the evolution of a totally new virus and a new human pathogen, an agent that is thought to cause 100% mortality in humans. Today five subtypes of HIV-1 have been identified and the geographic redistribution of HIV-1 is already taking place worldwide. Because of its high mutability, new subtypes, and perhaps even new viruses (types) are expected to evolve, given that intrapatient viral genome differences as large as 6% and interpatient differences as large as 20% have been identified (Myers et al., 1993). If the interpatient viral genomic difference is increasing at an estimated rate of 1% per year, continued host-virus interaction will continue to produce further biodiversity of this micro-organism. Even now, some individuals have been found to be dually infected with HIV-1 and HIV-2 (which share only a 40% homology in their genomes). For the human species this is alarming and promises to complicate chemoprophylaxis and other intervention strategies in the future.

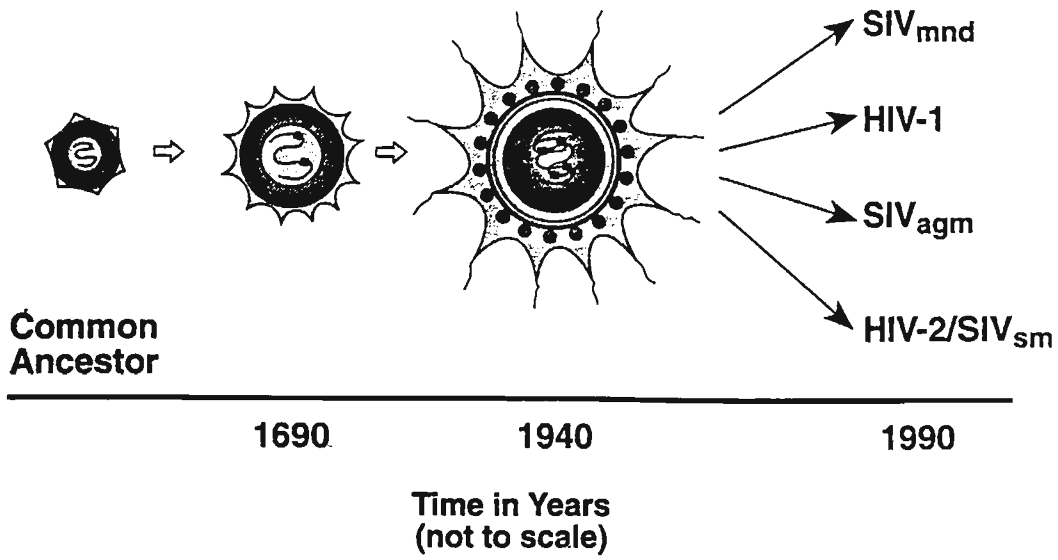

Figure 2. **The Big Bang Theory of AIDS.**

Summary

In summary, there appear to be several main mechanisms by which human populations influence microbial biodiversity. The first is a mechanism of human host-parasite interaction at the individual and cellular-molecular level across all variations in the human genome worldwide and a host-parasite interactions within a defined macro/micro ecosystem. The second involves the dissemination of the microbe to new hosts across human populations worldwide. The third mechanism (not discussed here but dealt with extensively by Hawksworth, 1990) involves agriculturally and economically important microbes that are genetically engineered and disseminated relative to some commercial or research enterprise by technologically advanced societies. These factors, combined with non-host directed mutational change and genetic recombination of the microbe, are a key to microbial biodiversity and the impact human populations have on such diversity. The examples presented here, specifically address the types of situation that occur using natural systems.

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Biology International Special Issue No 32 (1994)

Biodiversity and the World's Food Crisis

by

O.T. Solbrig *

Introduction

There is increasing anxiety among scientists and the general public about the loss of species, the transformation of ecosystems, and the reduction in the genetic diversity of crops and the effect that these losses can have on the functioning of the biosphere. These concerns arose because of the drastic transformation of natural landscapes taking place all over the world in the last fifty years, particularly in the tropics. Many scientists suspect that an extensive reduction in species diversity may lead to loss of ecosystem stability and function. The issue has been addressed from historical, economic, social, ethical, and ecological points of view (Norton, 1987; McNeely, 1988; Oelschlager, 1991; Solbrig, 1991; Wilson, 1992; Solbrig & Solbrig, 1994).

Landscape transformation and loss of biodiversity are closely tied to population growth and the increase in food production through increases in the arable surface, a continuing process. According to the United Nations the population of the world will double in the next fifty to a hundred years. If massive starvation is to be avoided food production will also have to double in that period. On paper such a challenge, although formidable, looks attainable, though its effect on biodiversity is unpredictable. Even though most suited agricultural land is being used today and there is very little room for expansion, average yields are still low and, at least in theory, with enough knowledge and capital it should be possible to double average yields in the next fifty years. The 18th and 19th centuries in Europe also saw a fast rise in population, accompanied by tremendous poverty, starvation, and human suffering. Yet the agricultural and industrial revolutions increased food production and created the industries that provided the wealth and the jobs on which our present world is based (Kennedy, 1992). A similar process could take place during the 21st century in the Third World.

During the industrial revolution, population, agricultural knowledge, and capital were all found in Europe. In today's world, population, resources, agricultural land and capital are not evenly distributed. While much of the human population is found in the tropics, the best agricultural land is concentrated in temperate areas. To increase agricultural yields special knowledge and resources are needed. Most of that knowledge and most of the financial resources are present in the industrialised world; yet most population growth is taking place in tropical countries, with limited agricultural means, traditional agricultural practices, and no capital. Because the citizens of these countries are poor, they don't have the money to purchase the agricultural surplus of the industrialised countries, and since these are engaged in a competition among themselves

* Text of a lecture presented at the University of Wageningen, The Netherlands, on the University's 75th anniversary.

for commercial supremacy, it is unlikely that they will provide much financial aid. Where the green revolution has increased production in countries such as India, much of the displaced population has not obtained alternative employment and has been relegated to the slums of large cities.

Some tropical countries are faced with the prospect of massive famines. Most of the poor are already severely undernourished, in poor health, and badly housed. These problems, could lead to civil strife as can already be seen in some African countries, and to a massive wave of migration from the tropics to the industrialised world. The vanguard of this migration is already in Europe, in the United States, and increasingly in the industrialised countries of Asia. This migration wave is likely to lead to persecution of immigrants, xenophobia, and ugly racially and culturally based confrontations. We are already seeing the beginnings of these confrontations. The pressure on land will also increase deforestation, land degradation, and biodiversity loss.

Is there anything that can be done to reverse this bleak and depressing prediction? Can we scientists use our knowledge to ameliorate the human condition? Unfortunately, no technical solution will work if the world's population does not stabilise. Demographers and social scientists tell us that population growth will stabilise only when conditions ameliorate and people can see a better future. This presents us with an apparently insoluble circular situation. Only a partnership between institutions in the industrialised and the third world can reverse this vicious circle between poverty and population growth and create a better future for the world.

In this paper I argue that if we wish to preserve some of the world's biodiversity on which we depend, our own selfish interests dictate that we engage in trying to help solve the problems of poor countries.

Agricultural Productivity and Population Growth

Most of the rich countries have a highly productive agricultural sector. Yet that sector contributes only a small fraction of the overall domestic gross product, and employs a small proportion of the population (Table 1). In the rich countries of the north most of the population is urban and is engaged in industrial or service activities. In contrast, in the poor countries of the south, most of the population is rural, and agricultural productivity is low. Rich industrialised countries have low population growth, in some cases even negative population growth, and normally the economy grows at a sufficiently fast rate to absorb population increases and enlarge living standards. Poor, mostly rural countries have high population growth and the economy grows at rates that are less than population growth, resulting in decreases in the living standard of the population. The increased population must be absorbed principally by the rural sector. Yet, this sector is running out of land. The result is a spill-over of population into marginal land, and an intensification of use of existing land. This transforms the landscape and degrades the land. Much of the deforestation (but by no means all) in the tropics and accompanying loss of biodiversity can be traced to population-driven agricultural expansion. As population expands, food production is insufficient, and

America and tropical South America, where less than 10% of the population owns over 80% of the land.

	Total	Agriculture	percent
Low Income	621 260	198 803	32 %
Middle Income	1 740 010	261 002	15 %
Industrial Market Economies	10 451 880	313 556	3 %

Table 1. Average total and agricultural gross domestic product (in US$) of countries with different income levels (source: World Bank).

Agriculture differs from most industries in that its basic resource - land - is fairly inelastic and so far no viable substitute for it has been found or is likely to be found. There is only so much suitable land, and by now most is occupied. Historically, most increases in agricultural output have come from occupying new land. Although yields have increased slightly in the historical past, only in the last two centuries, but especially in the last hundred years, have agronomists learned how to increase yields on old land by the use of improved varieties and massive additions of fertilisers, especially nitrogen and phosphorus.

Just as in other industries, increases in agricultural productivity result in a reduction in labour. In industrialised countries the excess rural labour is absorbed by manufacturing. This accounts for the high agricultural productivity and low percentage of workers in agricultural activities that is characteristic of developed countries. But in poor rural countries without a developed industrial sector capable of absorbing displaced rural labour, increased agricultural productivity through the use of labour saving inputs exacerbates existing inequalities as people are displaced from the soil and forced into the squalid existence of city slums, where the problems of under-nourishment, disease, and lack of human services, are worse than in the country-side.

To resolve this problem three aspects of the economy and the sociology of tropical countries must be addressed. One is population control. Although distasteful to many, the time may have arrived that tropical countries should consider more drastic population control measures such as were adopted by China. A second aspect is industrialisation. Unless domestic industries can be developed to employ displaced rural labour, increased rural productivity will only mean large and deteriorating urban industrialisation. Unless domestic industries can be developed to employ displaced rural labour, increased rural productivity will only mean large and deteriorating urban slums. What is needed, obviously, is a population with enough purchasing power to consume surpluses from a more efficient and productive rural sector. The third, and last aspect is new approaches to agriculture that do not rely on monocultures and the massive inputs of capital that have been so successful in temperate agriculture. Only in that way will we be able to preserve the many species of plants, animals, and microorganisms on which we rely for ecological services.

A Model of Land Use and Productivity

In 1798, at the start of the agricultural and industrial revolution of the 18th and 19th centuries, Thomas Malthus predicted that the world soon would grow out of food. He observed that the population of Europe was growing exponentially but that growth in food production was only increasing linearly. At the time that Malthus wrote this famous essay, most increases in agricultural production resulted from enlarging the arable surface. Yet as Malthus was writing, a revolution in land use was taking place, involving crop rotation, increased use of artificial fertilisers, and improved varieties, that would increase yields. With the introduction of scientific agriculture in the 19th and especially the 20th century, yields have increased dramatically especially in Europe and North America. This increase in yields transformed Malthus' predicted food shortage into a politically embarrassing and difficult to solve food surplus. The so-called "Green revolution" transferred the technology of scientific, high-input agriculture to parts of the Third World with equally spectacular results and avoided still another predicted famine, that predicted by the "Club of Rome" (Meadows et al., 1972). Yet their analysis is relevant.

Figure 1 shows the relation between agricultural yields population and land use over time. Of the total land surface of the world, only 3.2 billion hectares are suitable for agriculture. Of these, a small part, about three million hectares can be used with little additional input. Another 5-7 million hectares are suitable with some inputs, while the bulk of the potentially arable land is either too steep, too dry, or too infertile to be used as such and requires great investments in works, irrigation, or soil preparation before it can be used. If used without proper preparation marginal land degrades and can be lost totally for agriculture. To increase world agricultural production in a sustainable way requires capital inputs, be they to improve marginal land or to increase productivity on existing good agricultural land.

In figure 1 because of the limitations of the graphical representation it is assumed that all good agricultural land is used before any marginal land is used, which is not correct in a strict sense. Geographical constraints dictate that in high density countries marginal land will be occupied while there still exists good agricultural land in areas where the population is not so dense. In Figure 1, the upper line of the graph shows the actual and projected population of the world between the years 1850 and 2100. The two horizontal lines parallel to the abscissa show the total available land suitable for agriculture (upper full line) and the proportion of that land that is of good and medium various yield projections. The upper line (full dark circles) is the amount of land that is needed to be cultivated with a low yield supporting 2 persons/Ha, which was the average yield in 1850. If yields had not increased the world would have run out of agricultural land about 20 years ago. The second line of the graph (triangles, dark line) indicates a yield of 3.6 persons/Ha, the present average yield in the world. If this yield is maintained the world will run out of agricultural land around 2025. The other two lines (dark squares and open squares) indicate the land needed if average yields are doubled or tripled (7 and 10 persons/Ha respectively). As can be seen if yields are doubled the world can be easily fed with the available land. It can be seen that if we triple average yields on existing land in the next hundred years we can feed the population of the world without increasing the arable surface. Tripling yields is technically feasible, especially in the Third World where yields are still very low. Such strategy would preserve landscapes and species diversity.

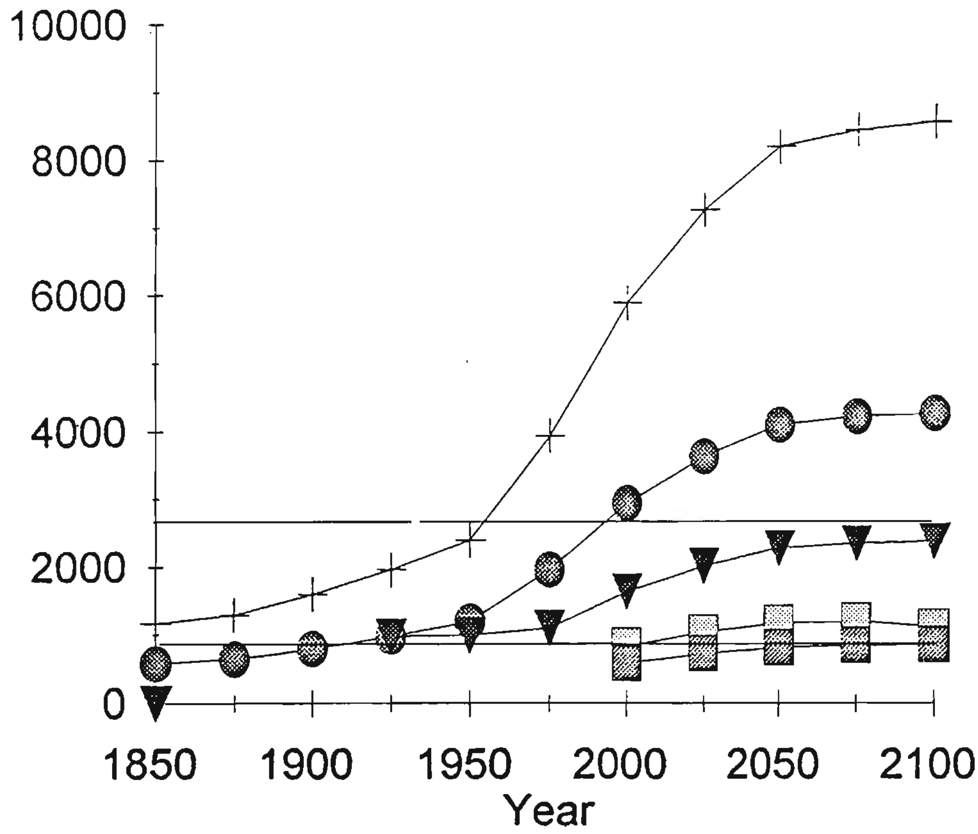

Figure 1. **The relationship between world population growth and agricultral yields. If yields are doubled the world can be fed, easily if they are trebled.**

However, although such a strategy is technically feasible using high input agriculture, it is not workable in practice because of lack of capital, and knowledge in many Third World countries. Furthermore, unless the displaced rural population were to obtain alternative employment, there would be no market for the additional food, as people would starve in the midst of plenty for lack of money with which to buy the food. This is of course already the case. Europe and North America have a food surplus that cannot be bought by scores of poor undernourished people in the tropics. Instead, they keep expanding their unproductive and environmentally inappropriate agriculture into increasingly marginal land.

Deforestation and Land Use

Deforestation in tropical countries is a critical problem. Table 2 shows the rates of deforestation in several countries according to the latest figures available. We can observe that deforestation is greatest in those countries that also have high population growth rates and low agricultural productivity. Although deforestation is not solely the result of peasants in search of new land, or firewood, both these factors are strong contributors.

In dense forests much deforestation is by organised businesses, sometimes local but more often multinational concerns, with the blessing of national governments. In the measure that deforestation creates national savings that are invested in development, and if logging is done rationally so as to minimise erosion and landscape modification, such activities are to be encouraged. In the last century the United States cut down much of their natural forests to create the capital for industrialisation. However, such is not the case in many tropical forest operations. Logging is often done with little regard to the impact on local landscapes, and multinationals usually export the profits together with the logs, and only a small group of local officials and concessionaries profit from such operations.

In dry forests and savannas deforestation is done mainly by peasants in search of firewood. In these regions, fuel shortages are critical and well documented. Some deforestation is associated with charcoal production for use by local industries, such as in the state of Minas Gerais in Brazil, where large quantities of charcoal are used in the iron and steel industry. Deforestation in dry forest and savannas degrades the land, increases erosion, and robs cattle of shade. Acute shortages of fuel-wood, especially in parts of Africa and India, are another manifestation of the reduced standard of living that the local population must endure. The very high population growth rates in some of these regions make conservation almost impossible.

Agroforestry and more rational use of the resources in dry forests and savannas, and conservation, and local control of timber in moist forests are the most promising policies to reduce deforestation. Examples of successful programs are the "Salta Forestal" program in the dry forest of northern Argentina (Whyte & Burton, 1983; Solbrig, 1983) and the programs of Malaysia and Sarawak to manage their humid tropics.

Ivory Coast	6.8	El Salvador	5.5
Brunei	3.6	Martinique	3.6
Togo	3.4	The Gambia	3.2
Nicaragua	2.8	Ecuador	2.5
Malawi	2.4	Niger	2.3
Honduras	2.2	Nigeria	2.0
Guatemala	1.9	Haiti	1.9
Philippines	1.8	Colombia	1.7
Benin	1.3	Malaysia	1.2
Mexico	1.2	Bangladesh	1.1
Madagascar	1.1	Thailand	1.0
Guinea	1.0	Uganda	0.9
Burkina Faso	0.9	Venezuela	0.9
Ghana	0.8	Mozambique	0.8
Laos	0.8	Kenya	0.8
Sudan	0.7	Panama	0.7
Somalia	0.6	Chad	0.6
South Yemen	0.6	Iraq	0.5
Sierra Leone	0.5	Mali	0.5
Jamaica	0.5	Vietnam	0.4
Brazil	0.4	Cameroon	0.4
Ethiopia	0.4	Peru	0.4
Trinidad and Tobago	0.4	Rwanda	0.4
Tanzania	0.3	Zambia	0.3
Dominican Republic	0.3	East Germany	0.2
Argentina	0.2	Zaire	0.2
Paraguay	0.2	Angola	0.2
China	0.2	Yugoslavia	0.2
The Congo	0.1	Bolivia	0.1
South Korea	0.1		

Source: Social Indicators of Development, Economics Department., International Bank for Reconstruction and Development/The World Bank, Washington, D.C.

Table 2. Deforestation rate of selected countries (net annual percent).

Conclusions

The transfer of temperate region agricultural technology to tropical regions, what is called the "green revolution" was a huge technical success, as yields in cereals increased dramatically. National output expanded in countries such as India that went from net importers to self-sufficiency. Socially, the "green revolution" was a mixed success. It brought increased wealth to those farmers with the education and the capital needed to take advantage of the new approach. On the other hand it displaced many peasant farmers who lost access to the land and were forced to move into the cities. In some sense, this parallels events during the European agrarian revolution of the 18th and 19th centuries. But while Europe was industrialising during that period and was capable of absorbing the influx of people made redundant in the rural sector, the rate of industrialisation in the Third World is too low to absorb the excess population. Furthermore at no point were the rates of population growth in Europe as high as they are in some Third World countries today.

The challenge is to increase agricultural production, reduce landscape modification and biodiversity loss, create alternative employment for the excess rural population, and reduce poverty. One scenario is the European model of development, which we have been discussing, favoured in countries such as India, China, and Brazil. It involves the use of modern, high-input techniques to increase agricultural outputs, while at the same time increasing the rate of industrialisation by state subsidies. Unless and until population growth rate stabilises, such a strategy does not produce sufficient employment, and results in massive deforestation and landscape modification. Furthermore this strategy is possible only in large countries with access to sufficient capital either through savings or borrowing.

Poor, rural countries with ineffective or corrupt governments are unable to execute such a strategy. In these countries, an alternative strategy of improving yields through the use of suitably modified traditional practices, is called for. Intercropping, agroforestry, use of green manures, crop rotation, and nomadic pastoral systems are some of the many techniques that can be used to increase yields without displacing large numbers of people. Together with these, cottage-type industries should be encouraged that can provide alternative rural employment and be the basis for savings with which to build more traditional industries. But for either strategy to succeed, population growth rates must be brought under control.

Unless the twin problems of population growth and food production are resolved, rural populations will spill over into every type of land in use for subsistence. The result will be tremendous landscape modification and loss of biodiversity to the detriment of all humankind. Furthermore, as the situation becomes more hopeless, there will be massive and unstoppable migrations from the tropics to the temperate regions. In the words of the president of Mexico, Carlos Salinas de Gortanu, either the industrialised world helps Mexico improve its economy or it will have to import its people. And not only the economy of Mexico, but that of most tropical countries.

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Biology International Special Issue No 32 (1994)

Biodiversity and Selection in Man: An Example of Biodiversity Maintenance by non-Adaptive Factors

by

G.F. De Stefano

Introduction

Natural selection undoubtedly played a leading role in shaping human evolution, as it is the most important mechanism by which inherited variations become established and distributed within a population according to their adaptive value. However, although from theoretical considerations the role of natural selection is clear in several instances, it is often extremely difficult to measure, and to assess the importance of the changes it causes relative to those due to nonadaptive changes brought about by other mechanisms. Similarly it is just as difficult to decide how far the existing variations in gene frequency among populations are maintained by selective and by nonselective forces.

Furthermore, on account of the clear limitations on experimentation in humans, and of the difficulties in reconstructing or simulating all the relevant environmental or cultural conditions, it is even more difficult to provide molecular, physiological and demographic details of the mechanisms involved in selection of man.

To overcome these difficulties the problem is usually approached indirectly. One such approach is analysis of the association between the geographical or temporal distribution of a given environmental agent and that of the genetic character under investigation. The studies on the distribution of the thalassaemia genes or those of the glucose-6-phosphate dehydrogenase (G6PD) polymorphisms in the Mediterranean malarial regions provide good examples of such an approach (Allison, 1965; Bienzle et al., 1972; Luzzatto, 1980; Luzzatto & Battistuzzi, 1985).

Nevertheless the problem of the relative importance of adaptive and nonadaptive factors remains evident even in these examples. Reduction of mortality and fertility as well as the great improvement of living conditions in Mediterranean countries during the last century has certainly reduced by a great deal the incidence and efficacy of natural selection on their populations. In some cases selection against a genotype has been specifically relaxed. Decreased mortality of haemoglobin S and thalassaemia homozygous as well as G6PD hemizygous individuals through modern medical treatment are examples of relaxed selection pressure as a result of major cultural nonadaptive achievements (Battistuzzi et al., 1991). As a consequence at present, in spite of its great theoretical interest, the problem under attention does not appear to have a clear and unique answer. A possible way to help solve this question would be to compare populations in which the general relevance of some adaptive and nonadaptive factors can be clearly envisaged.

The Indian and Black Communities of Northwestern Ecuador

One example of this approach is given by the populations living along the Cayapas river and its tributaries in the province of Esmeraldas, Northwestern Ecuador. At present, this territory of more than 2,500km^2, characterised by a typical tropical rainforest environment, is inhabited by two different populations: the Cayapa Indians and a group of blacks of African ancestry.

The Cayapa Indians, known also as Chachi, are believed to be the biologically and culturally the most isolated of the present-day native populations of Ecuador (Marson & Swanson, 1972; Carrasco, 1988; Stinson, 1989; De Stefano et al., 1992; Rickards et al., 1993). Their total number was assessed at no more than 3,000 individuals in the 1954 National Census. More recent census data based on ethnic affinity are not available, but at present their number is estimated to lie between 3,500 and 3,800 individuals (Carrasco, 1988). Loukotka (1968) includes the Cayapa language in the Chibcha linguistic stock, while Greenberg (1987) assigns it to the Chibchan-Paezan branch of the Amerind language family. Cayapa Indian origins, although widely debated, still remain an open question. Barrett (1925) and De Boer (1987) maintain that they lived initially in the Andean highlands from where they migrated to be Cayapas river rainforest lowlands at least five centuries ago because of Inca expansion pressure and the Spanish conquest. According to Barriga Lopez (1987) and Carrasco (1988), the ancestors of the Cayapa Indians were settled in the Amazonian regions from where they migrated first to the Andes and then to the Northwestern coastal areas.

The first Blacks reached the coast of Esmeraldas Province about the middle of the 16th century. They are reported as a group of 40/45 individuals, including some females, who first settled on the coast near Esmeraldas town (Morner, 1966; Alcina Franch, 1976). It is not clear when they first moved inland from this original settlement. However blacks are reported to have been settled along the Cayapas river and its tributaries since the beginning of the 18th century. Throughout this century they are thought to have received small but steady contributions by fugitive black slaves mainly from Southwestern Colombia (Jurado Noboa, 1992; Savoia, 1990). Since the beginning of the 19th century the black community of the Cayapas river and tributaries appear to have been fully settled, and can be considered as a well-defined permanent population of this area. At present their numbers are estimated as more than five thousand individuals, accounting thus for much more than half of the present total population (Martinez Labarga, 1993). The Cayapa Indians and Blacks live very close to each other, in some cases in the same villages, as in Zapallo Grande, the main community along the Cayapas river, yet there is very little intermarriage between them, and indeed this seems to have been till now highly discouraged (Erickson et al., 1966; Ortiz, 1983; Stinson. 1989; Carrasco, 1988).

Biology and Demography

Researches on these populations are still in progress, but some basic data on their genetic characteristics are already available. The principal differences in phenotype frequency observed in some blood group systems and in haemoglobin type are shown in Table 1 and those in some red cell and serum polymorphisms in Table 2.

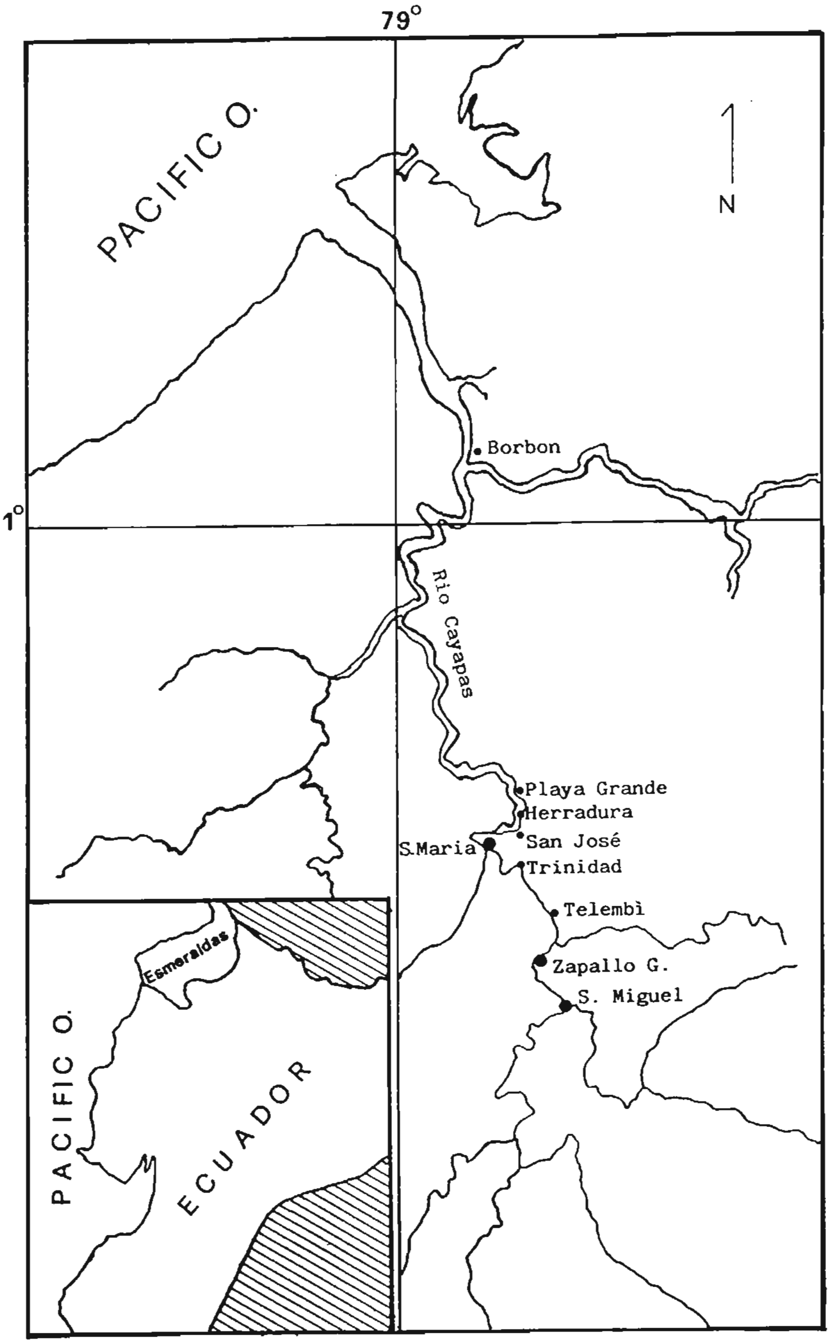

Figure 1. **Location of villages sampled.**

Blood group frequencies (Table 1) in samples from eight villages scattered along the Cayapas river (Figure 1) seem broadly to confirm the absence of intermixture between the two populations (De Stefano et al., 1992). However a wider epidemiological survey showed the presence of S haemoglobin in the Cayapa Indian communities along the Onzoles and Santiago rivers, main tributaries of the Cayapas river (Guderian et al., 1985, 1992). This finding suggests a certain degrees of intermixture although still slight and, it seems, geographically quite limited.

		Blacks (n=180)	Cayapa Indians (n=120)
A_1 A_2 B O			
	A_1	12.8	--
	B	8.3	--
	O	75.0	100.0
Fy	a + b +	7.3	39.3
	a - b -	62.6	1.3
K	+	0.5	15.7
Di	+	--	3.1
		(n=1308)	(n=640)
Hb*	AA	75.7	98.4
	AS+SS**	20.4	1.6
	AC+CC+SC	3.9	--

* From Guderian et al., 1985; De Stefano et al., 1992; Cayapa and Onzoles Rivers.

**Children below ten years.

Table 1. Main blood group and Hb differences (phenotypes %).

Cell and serum genetic polymorphisms (Table 2) show in general expected frequencies of the markers characterising Black and native Indian populations (Martinez, 1993; Guevara et al., 1991; Rickards et al., 1994). A remarkable exception is the sixth component of complement (C6) among the Cayapa Indians who have an unusually high frequency for the C6*B common allele (0.814) as well as a frequency at a polymorphic level of the C6*A21 allele previously reported to be rare in Mongoloid populations (Scacchi et al., 1994). Thus the analysis of these genetic systems clearly shows the persistence of a high degree of biological diversity between the two peoples, in spite of more than three centuries of close coexistence in the same geographic area.

	Blacks (n=196)	Cayapa Indians (n=189)
G6PD*A	14.4	--
G6PD*A-	8.8	--
G6PD*B	74.4	60.4
PGM1*1A	52.9	0.6
PGM1*2A	2.6	--
PGM1*1B	4.5	32.9
PGM1*2B	--	9.8
ACP1*A	0.6	4.3
ACP1*B	76.9	60.3
ESD1	91.0	54.3
F13B*2	45.2	--
*3	1.8	76.9
C6 Variants (A21+BA21+AA21)	--	10.9
APOC2*2	1.2	--

Table 2. **Main red cell and serum protein type differences (phenotypes %).**

At present official up-to-date records on the demography of the Cayapa Indians and Blacks of the Cayapas river basin are lacking. From an ongoing study however some preliminary observations can be summarised (Table 3). The data seem to indicate two main factors which tentatively may explain the differences in the demographic trends between the two populations. Blacks show at present a marked mobility, with considerable migratory movements in and outside their traditional residence area. The Cayapa Indians by contrast display a marked tendency to stay securely in their villages of birth. On account of their mobility these Blacks have a much wider area and choice in the selection of spouses than the Cayapa, who generally choose a partner in the same village, or one nearby. As a consequence the Cayapa are characterised by a high consanguinity rate (Carrasco, 1987; Guderian et al., 1994). There is also a clear and widely ascertained practice of polygamy among the Blacks and the opposite tendency towards monogamy by the Cayapa Indians. These differences in mobility and mating patterns may well contribute to the relative demographic success of the former.

	Cayapa Indians	**Blacks**
Population	Quite stable	Growing
Migration	Nonexistent	Active
Mating pattern	Ethnic endogamy	Tendency to ethnic exogamy
Family	Nuclear family	Open (polygamy)
Language	Cayapa	Spanish

Table 3. **Differences between the two populations.**

Conclusion

The results so far obtained in the ongoing comparative studies on the Cayapa (Chachi) Indians and Black population living in the Cayapa river basin, northwestern Ecuador, seem to indicate the following. Despite almost three centuries of close contact and existence in the same geographical area the two peoples continue to display clear differences in genetic constitution. These differences originate at least in part from the different selection outcomes of the ancestral populations in response to the biodiversity to which they were exposed in their former habitats. Helping to maintain these genetic differences is the persistence still today of deep-seated cultural patterns discouraging intergroup marriages, and the resulting absence of intermixture strongly contributes to maintaining the biological diversity between the two populations. It seems likely moreover that the two peoples are responding differently to the selective challenges of their present environments. For evidence on group differences in the prevalence of endemic environmentally-induced diseases (Guderian, 1994a,b; Guderian & Shelley, 1992; Molea et al., 1984; Jara et al., 1989) (Table 4) has been recently adduced and for at least one of these diseases a stronger genetically based immune response has been suggested for Blacks (Guderian, 1994b). However no evidence of association of this differential response with mortality or reproductive success is available, so it is not yet possible to understand the extent to which this factor may influence the differences in the demographic trends in the two populations. The extent to which the biological differences are described as well as the differential response to the environmental infectious factors may contribute to the demographic success of Blacks still remain this to be assessed. But at present it seems unquestionable that this success can largely be accounted for by the two different cultural and life-style patterns which cannot be viewed as adaptive, i.e. the clear and widely practised custom of polygamy by the Blacks and their migrational dynamism, in contrast to the marked immobility of the Cayapa Indians.

	Blacks	Cayapa Indians
P. falciparum	+	+
P. vivax	-	+
TBC	+	++
Oncocerchosys	++	+
Syphilis (GAST test)*	18.4	41.1

(*) Purpura et. al. 1992, p.c.

Table 4. Differential morbidity (from Guderian et al., 1992, p.c.).

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Biodiversity and Health

by

D.F. Roberts

Much of the discussion and many of the popular conceptions of the interrelationship between man's activities and biodiversity have been in terms of relatively straightforward effects. There are numerous examples of man's involvement, with outcomes which sometimes have been successful, but more often which have been disastrous to at least one indigenous species. There has been increase in biodiversity as a result of the deliberate introduction of a foreign species by immigrant settlers to new areas, for domestic use (e.g. rabbits, dogs) or for psychological reasons, to make the new home more reminiscent of the old (e.g. sparrows, gorse). Then in the longer term has often come decrease in biodiversity as the new species came to dominate and oust their indigenous competitors, or as the habitat of the latter was destroyed with the new patterns of land use, or as man deliberately destroyed species, for protection as with the wolf in England or for sport as with the dodo. Such introductions have not always been deliberate, and again the consequences have usually been negative. A current example is the decimation of the earth worm population in parts of England as the result of the arrival of a highly successful flat worm competitor which preys on them, and a recent example is the escape of the mink from captivity in southern England to the detriment of indigenous species of ground nesting birds.

There has been less emphasis on more complex interactions. The first example of the relevance of biodiversity to health to be discussed, the spread of a species of tsetse fly in Ankole in western Uganda (Ford, 1977), illustrates the complexity that may occur.

Glossina in Ankole

The tsetse fly, Glossina, is the principal vector of the trypanosomes, which cause sleeping sickness. There are several species and these differ in their feeding preferences. *Glossina morsitans* is found in the savanna and deciduous woodland vegetation zones across Africa from Mozambique to Senegal. This species feeds preferentially on animals, and turns less readily to man for food than do other species such as *Glossina fuscipes* which is the principal vector species for sleeping sickness in man though in some locations *Glossina tachinoides* and *G. pallidipes* are involved. These different preferences therefore mean that *G. morsitans* tends to avoid areas of extensive human settlement, preferring the less densely inhabited areas where there are more game animals on which to feed.

A principal feature of the interlacustrian plateau west of Lake Victoria is the broad north-south belt of savanna grassland, a corridor down which the cattle keeping peoples of this area migrated, bounded on the east by the great barrier of Lake Victoria and on the west by the mountain mass of Ruwenzori, and the chain of lakes extending from

Lake Albert to Lake Tanganika. Typical African savanna with its rolling grass-covered hills and sparse acacia scrub, this corridor extends from the broad grasslands of the upper Nile in the north to the plateaus of Rwanda and Tanzania in the south. In this area evolved a number of kingdoms and chiefdoms, and a relatively stable political system incorporating both the pastoralists and agriculturalists.

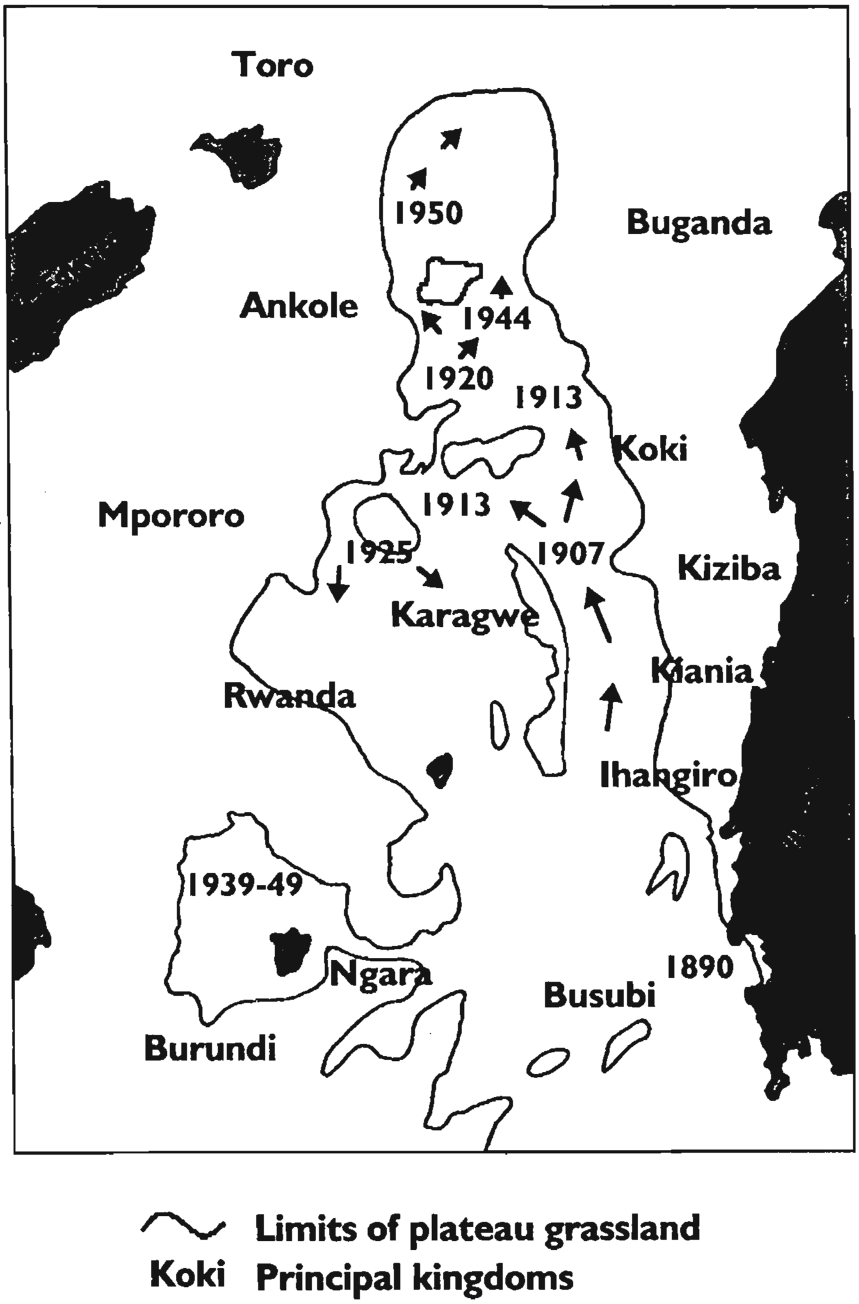

Figure 1. **Spread of Glossina morsitans in the Ankole grasslands.**

The kingdoms and tribal areas of the Lacustrian plateau each had its own territory, and these were often separated from one another by boundary wilderness areas (Grenzwildnisse). These areas were less suitable for human exploitation, but were nevertheless important for the survival of the human communities. As in much of Africa, when rains fail there come times of scarcity. In such times indigenous peoples, as elsewhere, tended to turn to areas of marginal food supply which yield less palatable foodstuffs, and so such areas provided a food reservoir in times of scarcity. They were sometimes of strategic value for defence in intertribal conflicts. They were also important in the numerous wars of succession. For in this area political power was organised through the system of divine kingship. In this system inheritance is not divided among sons but passes to one only. When the divine king died, those sons who failed to secure the kingship but still wanted it, and were prepared to fight for it, fled to these areas where they gathered their strength and from them continued to make war against their brother the new king. From the ecological point of view, these areas provided habitats for game and other undomesticated animal species. Thus this aspect of biodiversity, the retention of boundary wilderness areas, was of importance to the human societies in this region in a number of ways. Culturally they were of military value and they provided a source from which the political events (i.e. successions) could be tested from time to time; biologically they were important reservoirs of less desired food for times of scarcity and, despite the dangers of infection, provided a grazing reserve for times of stress.

In Ankole these boundary zones provided habitats for other species of tsetse fly, notably *Glossina pallidipes*, and *Glossina brevipalpis*. *Glossina morsitans* had been confined to the woodlands to the south. But then, with the social collapse that followed the European invasion, the destruction and abandonment of settlements allowed recolonisation by woodland and the animals which inhabited it which were the host species for Glossina. This permitted the distribution of the fly to expand. Whereas previously the settlements had been barriers to its expansion, for besides the species disinclination for man as a food source they had restricted the numbers of natural hosts, with the loss of the settlements the way was open for the expansion of the range of the fly. It spread rapidly. Figure 1 traces the spread of *Glossina morsitans* into the Ankole grasslands. It was by no means steady. *Glossina morsitans* began to invade the interlake area west of Lake Victoria between 1890 and 1900, starting in the south and working northwards from Busubi, reaching Karagwe in 1907, and Koki in 1913. It was halted in 1919 by a severe rinderpest epidemic that killed off most of the wild host animals.

In the meanwhile the invasion had branched west and south from Karagwe in 1913, and eventually arrived in Urundi in 1960 in spite of quite massive efforts to prevent it. The northward movement after the rinderpest epidemic began again in 1925, more slowly, until in 1940 it was a mere trickle along the western edge of the dry grass savanna of northeast Ankole, continuing to its northern limit in 1950. Then suddenly, between 1953 and 1958, about 1800 square kilometres of pasture became overrun with tsetse, which occupied the whole of the remaining dry savanna of Ankole, and began to invade what was left of the dry savanna in Buganda. Spread was rapid because the tsetse was able to occupy country already carrying natural savanna and woodland inhabited by suitable wild animal hosts.

For this rapid expansion in 1953-58 various factors were blamed. These included a newly introduced policy of grass burning, the Bahima method of pasture control, the upset of the traditional pattern of nomadic movement of the cattle keepers by the advancing tsetse flies themselves when they arrived in the southern pastures. It now appears that the principal cause was none of these. Across these grasslands, as in much of Africa, there occurred a seasonal migration of elephants following their customary routes. Elephants destroy trees, push them down, and they can then reach the palatable tips of the higher branches and succulent roots. This destruction of trees, particularly those growing alone or in small stands, made the locality less attractive to the game animals which were the tsetse hosts, and so eliminated or kept down the tsetse flies from large parts of east Africa. During the earlier years of this century the European propensity for big game hunting had been developing. The elephants migrating annually through the Ankole grasslands were an attraction, so in this area between 1930 and 1937 there was intensive slaughter of elephants The surviving herds ceased their annual migration through the Ankole grasslands in 1937. The intensive slaughter of elephants, the cessation of their migration, the subsequent absence of tree destruction, was a chain of events which released a succession of vegetation and fauna. Thus by the mid 1950s conditions had been attained in which *Glossina morsitans* suddenly found an adequate food supply and suitable habitat where it had previously found neither.

The causal chain leading to the expansion of *Glossina morsitans* in this area is therefore quite complicated. Previously the indigenous settlements, the pattern of land use, the distribution of host species, the migration of elephants, the tree destruction, had kept the species at bay. The development of big game hunting, the destruction of elephants, the consequent change in the vegetation cover and faunal associations, the change in the nomadic migration pattern, the change in the human settlement distribution, all of these interacted to allow and encourage the spread of the *Glossina morsitans*.

Direct Effects - Nutrition in Arnhemland

The complexity and indirectness of the interaction between human societies and the biodiversity of their habitat is well shown by this example of the spread of an insect species, a potential parasite vector, which may well affect human health in this region in due time. It is worth recalling a situation where the potential effect of biodiversity on health is direct, but which has not yet been fully analysed anywhere. A simple society of hunters and gatherers is dependent for its food supply, and indeed everything else, on what it can obtain from its immediate environment, the territory over which it ranges. Its territory is limited, and it rarely desires or needs to go outside it - and if it does so there is usually conflict with the adjacent society. The food that it procures has to be adequate in amount to provide the energy required for daily living, growth and reproduction. The food also has to provide the proteins, fats, carbohydrates, and all the essential nutrients and trace elements that are necessary for health.

There is little quantitative information on the numbers and amounts of different plant species consumed by such peoples, and little is known of the nutritional value. Full utilisation necessitates a detailed knowledge of the ecology of the territory, where different species are to be found and when they are available for consumption. Jones (1980) compiled a list of vegetable and fruit resources throughout the year used by the Gidjingali, aborigines of northern Arnhemland, a coastal savanna people. This list included ten fruits, differing in their seasons of availability so that all months of the year were covered, and there were 18 vegetables, of which seven were predominant providing a major carbohydrate source. Specht (1958) published a list of 85 species of plants used for foods, and 52 for making tools. This list however covered all the localities visited and included a number of different habitats, so is probably an overestimate of the number used by any one community. For an inland group data are available by White (1978) and Scarlett (1976) for Ritarrngu in eastern Arnhemland. These show the number of species (providing fruit, seed and roots for food) utilised in each month in different habitat types. The greatest number of fruit species is utilised in the monsoon forest and open forest, with 20 or more species available over more than half the year. In the freshwater swamps they are replaced by roots as the providers of the greatest number of species (over 20 for two thirds of the year). The least variety (fewer than 5 species) occurs in the mangrove forests and the tall open forests. No data are available on the total calorie content provided by the different classes of foods for such communities at different periods of the year, there is no detailed analysis of the essential nutrient and trace element content of the individual species used. But clearly the more species that are utilised the more likely it is that the range of requirements will be covered over a longer period.

It is not of course only the hunters and gatherers who make use of a variety of wild plants. Among the Ageir Dinka of the southern Sudan in November/December 1953 eleven different wild plants were included in their diet, even though most of their food intake came from their own crops and cattle.

Child Health in Yucatan

There is one recent study which attempts to examine directly the effects on health of changes in biodiversity (Murguia et al., 1990).

In Mexico the geographic characteristics of the Yucatan peninsula provided a rich and diversified environment for the Maya Indians, who traditionally used the rain forest to provide their requirements, and the cultural practices of the indigenous population helped maintain the ecosystem with its intrinsic biological diversity. With the coming of plantations the high biodiversity of the natural ecosystems has been curtailed, and in places transformed into virtual monocultures. The development programmes in the Yucatan peninsula took no account of the systemic relationships that supported the high biodiversity, and paid little attention to the characteristics of the limestone soils of the karst area of the peninsula or to the social variability of the indigenous human populations. The newly-introduced socioeconomic activities have produced a severe disequilibrium of the tropical ecosystem. The study by Murguia et al. enquires how far nutritional health status and standards have suffered as a result.

On the east coast of Yucatan there is the special biosphere reserve of Rio de Lagartos, with a protected area of 47,000 hectares, one of the internationally important wetlands. There is an offshore sand bar, and the lagoon separating it from the land is some 80km long, shallow with very slow water flow, and the resulting evaporation produces a salinity gradient increasing from 28 to 180g/l from west to east. As a result of its geographical location, the area is characterised by local microclimates since it receives both tropical and arctic air masses, while offshore the Caribbean stream transports and deposits sediment to form sand islands and coastal lagoons. The Rio de Lagartos lagoon also receives rain and underground fresh water. Soils are also highly diverse, influenced by the lagoon and marine processes, and their contents include sand, mud, stones and organic material.

The complex conditions of this area have produced a high biodiversity. There are 8 different vegetal associations: sand dunes, mangroves, short mangroves, low flood forest, deciduous low forest, subdeciduous medium forest, petenes, and high grassland, and 326 plant species have been recorded. The reserve, on a main avian migratory route, is used both for feeding and nesting, and 260 species of migratory or resident birds have been recorded. The number of insect species is as yet undetermined, there are at least ten species of mammals, and the waters of the lagoon and adjacent sea contain at least 98 fish species and 23 mollusc species. The water flow is the critical variable for the existence of the system, and for the development of human activities based on it. The life span of a lagoon is geologically short, for there is a natural tendency to disappear. Human intervention is required to sustain the system and to make possible the harmonious coexistence of the wildlife, vegetation, and human activities that modify the lagoon water flow.

Of the vegetal associations, the mangrove areas are ecologically critical, because in them take place the main processes of primary production which support the animal life, including fish. A second ecologically critical area is the barrier island with its sand dunes, because upon its existence depends the existence of the lagoon. Changes in the water flow affect directly the mangroves or the barrier island, producing changes in the nutrient content of the lagoon waters, or change in salinity level.

Man's use of Rio de Lagartos is very old, with evidence of pre-Hispanic Maya towns dedicated to fishing and salt extraction. In the reserve today there are four villages: San Felipe (1434 inhabitants), Rio Lagartos (1619), Las Colorados (779) and El Cuyo (793). Las Colorados was recently founded for the salt factory workers, and the other three villages were founded during the colonial period. These four villages, with their differing economic and local environmental features, fall into three well-defined environmental types. (a) The first, marine and estuarine, is used for fishing by all three entities. (b) The sand dune system depends on the existence of an underground water table and the sandy soil, and this is used for salt production and coconut agriculture. (c) The subevergreen tropical rain forest is the area of Indian corn production and cattle raising. Then there are two subtypes (d), the modified rain forest where the corn production is concentrated, and (c) the grasslands over limestone where the cattle predominate. The use of these ecosystems by the human entities is shown in Table 1.

A survey was made of child nutritional status as defined by WHO criteria, malnutrition status being assigned to a child below the third centile of weight for age, and risk of malnutrition to a child below the tenth centile. A nutritional index of a community was calculated as the percentage of well nourished children (i.e. above the 10th centile, based on the WHO criteria) with index values of less than 50 corresponding to an adverse situation with the children generally chronically malnourished. An assessment of the biomass was made by aerial photography, direct observation and collection of specimens, and a conservation index was calculated for each environmental entity, an index of less than 70 points meaning serious disequilibrium with possible loss of genetic material. From interview and field observation an index of condition of daily life was devised incorporating 112 variables.

The best preserved area of the reserve is San Felipe-Rio Lagartos. The main former activity of the inhabitants was fishery for home consumption, but since the 1960s there has been increasing commercially-orientated marine and lagoon fishing, directly related to the development of port and road facilities. To maintain the fisheries the natural resources require to be conserved; already today the market influence is leading to over-fishing of some species, and there is some water pollution present. The inhabitants have a high consumption of fish and other seafood, and they obtain grain and other foods from outside from marketing their catch.

In Las Colorados, the main activity is electrolytic salt production, the factory employing more than 400 workers. Salt production however requires control of lagoon water flow to increase the salinity, and this is producing serious changes in lagoon hydrodynamics. More than 900 hectares of sand dunes, 91 of mangroves, and 12km of the barrier islands, have been destroyed in the building of evaporation and crystallisation ponds, using vegetation and sand from the mangrove and coastal dune areas. The salt production means a complete transformation of the natural environment into a factory, and it is not surprising that the activities in Las Colorados have consumed half of the pre-existing biomass. Food accessibility and consumption are totally dependent on the wages that are earned.

In El Cuyo, where the main activities are cattle raising, marine fishery, and cultivation of Indian corn and the coconut, large areas of the tropical rain forest and sand dunes have been taken over by agriculture and grassland. Since fishing of the lagoon is not possible on account of its high salinity, most people engage in sea fishing. This provides food for self consumption, but the low income from marketing of the coconut and cattle products means limited availability of imported food.

The inhabitants of the three entities differ in their attitudes. The fishermen are the largest group, present in all three entities, and they are aware of the importance of management. In Las Colorados the attitude is essential industrial, and salt production is the predominant interest. In El Cuyo the non-indigenous peasant group is indifferent to the environment and so are the cattle owners.

Table 1

Population	Ecosystem				
	A	B	C	D	E
San Felipe-Rio Lagartas	++	-	-	-	-
Colorados	+	++	-	-	++
El Cuyo	++	+	+	+	++

Table 2

Population	Children's nutritional status						Total
	malnourished		at risk		well nourished		
	N	%	N	%	N	%	
San Felipe-Rio Lagartas	30	9	49	14	269	77	348
Colorados	29	20	30	20	88	60	147
El Cuyo	31	27	28	24	58	50	117

Table 3

Population	Functional indices		
	conservation	daily life	nutrition
San Felipe-Rio Lagartas	97.7	51.2	77.3
Colorados	52.3	38.1	59.9
El Cuyo	85.4	38.3	49.5

Tables 1-3. **Environments, children's nutritional status and functional indices of the Yucatan communities.**

The nutritional status of the children varies among the three entities (Table 2). San Filipe-Rio Lagartos has the greatest percentage of well nourished children, and El Cuyo the least, and conversely the first has the lowest percentage of malnourished and El Cuyo the greatest. Las Colorados lies between them, though tending more towards El Cuyo. Amongst the children, it is the females who have the greater percentage of malnourishment and who are at risk of malnutrition.

There is an interesting parallel in the indices of conservation, daily life, and child nutrition (Table 3). The quality of daily life in the best area, Sal Filipe-Rio Lagartos, is scarcely above 50%, but nutrition is better than in the other two localities. The other two show their vulnerability to social and natural change. Las Colorados has no possibility of making use of the natural resources that are lost, and the inhabitants have only one choice, the wage regime to obtain food. El Cuyo, restricted by isolation, by the hypersalinity of the lagoon water and the lack of adequate technology, has no short-term alternatives to obtain food. The Colorados people, dependent on wage earning, are in a better position when natural resources disappear, but they and El Cuyo are in a critical situation. Both are sensitive to social change, economic change, or environmental change, any of which could be detrimental to their children's health and growth.

This comparative analysis shows how the man-nature relationship defines how natural resources are utilised, and demonstrates the existence of a socio-environmental complex that governs not only the quality of daily life but also the nutritional status of the inhabitants in this region. The childhood nutritional status data show how malnutrition increases when biodiversity declines and people require more foreign products without sufficient income to obtain them.

It is difficult however to attribute these findings to the loss of biodiversity. Rather it seems that the loss of biodiversity and the adverse health effects are both outcomes of the same processes.

Conclusion

These 3 examples illustrate some of the interrelationships between biodiversity and human health, show how they vary in complexity, and give some indication of the variety of factors that may be involved. The first, tracing in detail the spread of an insect species, shows the complexity of the chain of human actions and nature's response to them. Though the species *G. morsitans* is not principally concerned in human trypanosomiasis in that region, the example was chosen because of the detailed data that are available. It would have been possible to illustrate the point in less detail on a species that is a major vector, as for example in the increase in sleeping sickness cases transmitted by *G. fuscipes* and *pallidipes* in Busoga in 1957 where change in fishing practices led to increased contact between infected people and the lakeshore vectors. Man's indirect effects on biodiversity may well lead to altered health patterns. The second example, of the reliance for their food by Aborigines on the biodiversity that exists, illustrates the direct health involvement of biodiversity through nutrition. The third example, in which again the intermediary is nutrition, recounts an attempt made in a comparative study to elucidate the effect of biodiversity on child development.

Many more examples can be found in the literature of the direct and indirect involvement of biodiversity on human health.

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Discussion

by

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In preparing for this meeting, each author was told of the background and object of the workshop and was left to draw, from his own particular area of expertise, material that would illustrate the interactions of man and his biotic environment and, hopefully, to illustrate the positive effects of human activities on biodiversity.

The first part brought a historical perspective. It is several decades since in the geological setting Erdtmann (1929) developed the technique of pollen analysis, in which microscopic examination of the virtually indestructible pollen grains of some trees, produced in large numbers, and scattered by the wind, and now recoverable from peat bogs and lake deposits, allows genera and species to be identified and the forest succession established, a method widely employed for tracing climatic changes (e.g. by Godwin (1940), and Hardy, (1939) in Britain; Granlund (1932) in Sweden). Such data provide information also on the changing biodiversity of these remote periods, and they have more recently been used for later periods to trace man's effects in the eastern Mediterranean (Bottema & Woldring, 1989; Jahns, 1990; Bottema et al., 1990). The first paper by Peter Stahl moves outside Europe to examine recent work in South America on anthropogenic landscapes and biodiversity in the pre-Columbian period. He shows that the biodiversity existing at the time of European contact was unlikely to have been the original pattern, but was the result of millennia of human occupation of the Americas by a much larger number of inhabitants than hitherto thought. He discusses ways in which inferences can be drawn on the timing, extent, and nature of human modifications of biodiversity, for only when they are available can the prehistoric pattern be estimated and the rate of change derived. He indicates how advances in archaeological techniques and methods help understand the ancient and long-term relationships between man and his environment, and moreover touches on the value of the experimental approach for examining ways of land use other than those envisaged in modern western concepts.

The second part embodied a classic geographical perspective as propounded and developed by Brunhes (1910) and Forde (1934), the interrelationship between habitat and way of life. The presentations considered the utilisation and maintenance of biodiversity, how traditional and simple ways of life help establish or maintain an equilibrium. Maximina Monasterio drew from the vast ecological diversity of south and central America to consider different examples where the traditional cultures had developed sustainable patterns of land use. The high mountain agrarian systems were based on the utilisation of the great altitudinal and horizontal variation in conditions, the development of an enormous variety of cultivated plants adapted to them, a complex technology of food storage, and an activity pattern based on the pronounced diurnal rhythm constant the year around. In the different rainfall conditions of the Puna, the response to wet and dry periods was a seasonal migration utilising different resources at different times of the year. In the Amazonian forests the indigenous pattern was that of shifting cultivation, where a plot after a short period of use was left for the vegetation and fertility to regenerate. In Chinampas there was a system of multiple use of the lacustrian plateaus. All these showed different strategies of ecological complementarity, in which a single human group simultaneously controlled territories and localities differing ecologically, which constituted one of the principal bases of the sustainable and sustained development of these ancient cultures. Their contributions to biodiversity lay in the number of varieties of domesticated crops that they developed, and the patterns of land use in which the biodiversity, and the soil fertility to support it, were maintained by areal movement and intervals between episodes of cultivation to allow regeneration.

By contrast with Dr. Monasterio's descriptive account of the relationship between the way of life and the broad features of the environment, the analysis by Michael Little is at a different level and gives an additional dimension. The Ngisonyoka Turkana like other pastoralists dependent on cattle emulate many grazing species in their migratory life which allows them to utilise the plants of different areas at different times of the year. By contrast to the few settled Turkana communities which are depleting forest and ground water reserves, the nomadic Turkana, with their frequent relocation of settlements, are doing neither. An impressive attempt at quantitative research demonstrated unequivocally that the practice of nightly corralling of cattle, and their frequent nomadic movement, contributed substantially to reforestation and hence to the biodiversity of the area. The effect of course is not intentional. For Turkana manipulation of the environment is minimal and dictated by short-term considerations - burning to induce new growth of fodder plants, sinking temporary wells in stream beds to tap briefly the water beneath. Indeed the pattern of management of the livestock derives not from externally taught procedures but from generations of experience and evolution that have produced a complex which allows survival in the face of the unpredictability of the environment. This complex involves multi-species herding; live animal productivity (blood, milk) instead of carcass meat; breeding for this productivity, disease resistance, heat tolerance, docility and other desirable qualities; techniques of disease control; and many other features as noted by Dyson Hudson (1980). The day to day decisions involved in managing this complex are of course deliberate, guided by past experience.

Intentional influence on biodiversity is brought out in Gerhard Forstenpointner's discussion which provides links both between preceding chapters and between them and the group that follows. He examines the archaeological record to show the dual effects of domestication on biodiversity, with examples from late classic and early historical times in the eastern Mediterranean. In present times he shows the key role in the maintenance of the alpine pastures played by the practice of transhumance and the seasonal grazing of cattle on them. The breeding history of domesticated cattle provides examples both of the indisputable increase in genetic variance resulting from domestication procedures, similar to that in the dog and the horse, and of the reduction in variability that occurred from time to time. It is of course not only in historic times that these considerations apply to the breeding of cattle. Vissac (1993) traced the changing pattern of cattle breeds in France from the beginning of the 19th century, when rural society was organised into small territories, each relatively homogeneous based on subsistence agriculture. Cattle breeding was integrated with other agrarian practices, so that choice of animals for reproduction depended on a wide range of uses. Different needs for draft animals soon led to a distinction between the cattle breeds of north and south France; draft animals were required in the south, but not in the north where horses were used for traction, so that northern breeding was aimed at the production of milk and meat. A result was a shift in the distribution of breeds between 1800 and today in France.

The chapter by Ralph Garruto relates to one of the most recent and fastest growing areas in human sciences, a product of the present century and especially of the development of immunology of the last two decades. It shows how basic biological mechanisms are responsible for effects of man on biodiversity at the microbial level, and the corresponding effects on him. This Dr. Garruto illustrates by viral disease, notably influenza, haemorrhagic fever, and AIDS. He identifies these basic mechanisms as the host/parasite relationship and the dissemination to new populations of new viral strains by movement of humans or other host organisms. As biological mechanisms they appear to be outside human control, and when man has deliberately tried to interfere with them, his albeit well-meaning attempts have rarely been successful. But the effects of modern lifestyles, notably the close proximity of individuals in modern urban living and the great increase in individual movement on the distribution and proliferation of microorganisms, is clearly brought out.

The final group of papers on the importance of biodiversity to man starts with that by Otto Solbrig. The responsibility for the adverse effects of man on biodiversity is solidly attributed to the rapid increase in population growth of the last century or so, and the pressures that this has placed on the natural resources for food and other requirements. The conflict between requirements and resources originally formulated by Malthus inspired Darwin to formulate the concept of natural selection but has had little practical effect in the way of limiting world population growth. The reduction in biodiversity that has occurred through the loss of species and the transformation of ecosystems, Solbrig reminds us, may lead to loss of ecosystem stability and function. It is very likely that this loss has been a factor in promoting the famines, under-nourishment, poor health, and civil strife already so apparent in many tropical countries. Traditionally, many of those of simpler cultures, when crops failed, turned to hunting and gathering using uncultivated areas, so that their population density proved to be a function of the pre-agricultural carrying capacity of the land. The necessity for the reservoirs of fall-back foods was not understood by western exploiters, who saw them as representing under-utilised resources. With the loss of biodiversity these reservoirs are no longer available. Solbrig sees further loss of biodiversity as detrimental to all human kind, and to prevent this calls for help to third world countries from the better endowed to help resolve their numerous problems. This is based on the premise that population growth will stabilise only when conditions are improved.

Biodiversity itself is the outcome of natural selection acting on the genetics of populations, helping establish new genetic material that is advantageous for the organism in its particular environment, helping eradicate disadvantageous variants. In addition to this process, a proportion of biodiversity derives from the incorporation of random changes into the gene pool of populations. Gian Franco De Stefano points out that the same processes were responsible for *Homo sapiens* today, and for all the biological diversity that mankind manifests. Human variation is seen as the direct outcome of the effects of the diversity of the biotic and non-biotic environment in which he lives. However in modern man the genetic variability that exists is maintained in part by non-adaptive factors, and Dr. De Stefano illustrates these from his genetic surveys in northwest Ecuador. In the two populations he studies, the gene pool of the Blacks is characterised by elevated frequencies of alleles thought to protect against malaria, presumably derived from the genetic constitutions of their ancestors in Africa where selection for protection against malaria must have been strong. The gene pool of the Indians shows no such concentration of these alleles. This difference in gene frequency between the two populations is maintained not by any demonstrable selection but clearly by the mating patterns of the two communities.

In the final paper D.F. Roberts explores the importance of biodiversity to man at the cultural and health levels, and at the same time demonstrates the complexity of the interactions. Of the three different aspects of the relationship between biodiversity and health, the first example examines in more detail a process introduced by Dr. Garruto, the territorial expansion of an insect species. The example relates to the tsetse fly in Uganda. The health relevance is that the species is a potential vector for trypanosomiasis. The example shows how numerous were the factors, some totally unexpected, responsible for the spread. The second example enquires into a process that was not touched on in the discussions but also occurs in other migrant savanna peoples, the direct contribution of biodiversity to their nutritional status. The third example recounts one of the few attempts at assessing the effect of change of biodiversity on health, by comparison of child health in communities in Yucatan, Mexico.

In the general discussion there were several princpal themes, each of which emerged on several occasions in different presentations.

1. The historical time depth of the human impact

Numerous other illustrations that man's effects on biodiversity were not recent were quoted to supplement those given by Stahl and Forstenpointner. There was a great increase in grass pollen in the Lake Victoria Basin and northern Zambia about 2000B.C. and a widely distributed charcoal horizon in the Kalahari sands of about 1000B.C. suggesting regular burning of the bush as part of the technology of the then hunter-gatherers. On the other hand some regions show virtually no changes in plant communities of savanna woodlands over long periods e.g. 22000 years in northern Zambia, but it seems that the savanna and forest conditions over much of Africa today derive largely from the spread of shifting cultivation with the enhanced power that the relatively recent iron technology brought. The virtual absence of primal forest in northeast America and the extent of cut-over, are much more recent historical examples of man's long continuing exploitation of the forest.

There was some concern that too much may be read into the results of archaeological studies. How can anthropogenic change be distinguished from that due to other natural processes? Is accurate identification of the number and abundance of different species present possible by palynology or any other kinds of indicator? If a species disappears from a site, does it necessarily mean that it has become extinct in that locality? From its nature the material is limited in amount, so that a sampling error would attach to apparent change in frequency of species. Indeed concern was expressed whether it was really possible to obtain an accurate impression of past biodiversity, how far research could be pushed back into the past. It was felt that it may not be realistic to attempt quantitative assessment at the species level but it is possible at the level of the genus.

The amount of work on this historical aspect of changes in biodiversity is limited, and more sites in a variety of ecosystems should be investigated, using as many different methods as possible. This was particularly relevant as regards interpretation, for example the anthropogenic attribution of the black earth of the Amazon. This was for a long time a puzzle to Brazilian pedologists and soil morphologists. It is so extensive that it first led soil morphologists to believe that it was a natural soil formation. However the more recent technologies available, chemical analyses with neutron activation, phosphorus residue analyses and others, appear to identify an anthropogenic origin, compatible with the evidence of human presence (the distribution of cultural material such as ceramics, food remains), but its extent still remains a problem.

As to the contribution that archaeology can make, this depended on the objective of the study of biodiversity itself. The study of biodiversity should not be restricted to the descriptive level, but should aim at the understanding of function, the identification of change, and tracing the causes of change, and in that sense the objectives are similar to those of modern archaeology. So that even though the quantitative description of number of individuals of a species at a given site may not be accurate, from the overall synthesis of a number of sites in a region a real contribution may be expected.

2. The evaluation of traditional ecotechnologies

The scientific assessment of the effect of traditional methods on maintenance of the ecosystems is one of the more exciting recent developments. Dr. Monasterio expanded her formal presentation by describing some recent experimental work on the high altitude (over 3000 meters) field regeneration. There are several distinct processes. First there comes regeneration of the vegetation cover; this is relatively rapid for she found that in 15 years more than 80% of the natural vegetation had become reestablished. The second process, the reestablishment of the fertility of the soil, takes longer, and again the various components differ in the period required; the amount of mineral nitrogen may be adequate, but the more important microbial nitrogen takes longer to restore. Thirdly there is the regeneration of the whole biotic complex. The theme of assessment of traditional practices was also illustrated by Dr. Little with reference to savanna pastoral peoples.

Such appraisal deserves much more attention with reference to other practices, other peoples, other habitats. One example of its practical utility is from the aborigines of the savanna of northern Australia who practise a traditional burning regime. When in June and July the tall grasses have fallen and there is dew and cool weather to help extinguish the fires, the aborigines systematically light and control fires in such a way that only the grass litter is burnt and most trees are not damaged. These fires are used as part of hunting drives, stimulate the growth of fresh new grass, and help keep down the numbers of snakes and mosquitos. This traditional fire management policy results in the maintenance of important plant associations such as the jungle thickets. It is indeed thought that the pyrophytic response of many Australian tree species may partly be an adaptation to an aboriginal fire regime over some 40,000 years of occupation of the continent, and this suggestion is supported by the fact that similar species in New Zealand are very sensitive to fire. In the middle of the 1960s the Australian government imposed an authoritarian policy of fire prevention. The unfortunate result was that by about 1974 there was a sporadic eruption of gigantic wild fires feeding on several years' accumulation of dead grasses, and these caused scorching of trees up to heights of about 20 meters (cf. 1 meter of the aboriginal practice) and killed many mature woodlands of cypress pine which the policy was intended to protect. The result was a detailed assessment of the whole fire policy of the northern forestry service, which concluded that the aboriginal type of fire management programme was in the long run the best policy for these tropical savannas (Haynes, 1978).

3. The biodiversity-generating practices of human communities

These were referred to in the majority of the papers. They are sometimes intentional, as with the present day laboratory generation of enhanced genetic variation or the historic domestication processes referred to by Dr. Forstenpointner. Others were brought out in the discussion. For example the spread of the multifarious varieties of sweet potato in New Guinea is largely due to the practice by individuals, whenever travelling away from home, of taking cuttings from plants in the localities through which they passed and subsequently establishing them in their home areas - a practice which is common to gardeners the world over perhaps. But often such practices are unintentional, as was well illustrated in Dr. Garruto's discussion of the capacity for variation at a different biotic level, the viral, and the ways in which the human factor has contributed to the dissemination of viral variation through the practices of migration, travel, and most recently the effects of crowding. The enhancement of biodiversity through the host/parasite relationship is an escalating process - as a new variety of virus appears, mans' immune system also evolves a response in parallel, this reduces the efficiency of the new viral strain, a new strain evolves. Similarly widespread unintentional effects have resulted from the modern use of pesticides. For example spraying in west Africa by DDT to control the mosquito hosts of the malaria parasites led to the emergence of DDT resistant strains of mosquito, i.e. the enhancement of biodiversity with the emergence of new strains of drug-resistant organisms.

4. Biotic reservoirs

Several of the presentations showed the importance of these in different ways. From Dr. Monasterio's discussion of regeneration, and Dr. Stall's demonstration of vegetational recolonisation in the eastern Mediterranean, it is clear that there must have existed reservoirs from which the new growth spread. Their cultural, political, economic, nutritional and ecological relevance was demonstrated in Ankole by Dr. Roberts, and Dr. Little pointed out a parallel to the non-use of the wildniss areas which occurred amongst the Turkana on a temporary basis. As the livestock population increases so the resultant overgrazing depletes the vegetation, this leads to livestock loss which may be disastrous in drought years, and it takes time for the vegetation to recover. But this has important social repercussions, for the livestock depletion leads to tribal raiding. This means that there are some areas into which a tribe will not move with its cattle for fear of being raided by its neighbours, and neither will the neighbouring tribe occupy it for the same reason. In these areas the grasses are thus not grazed for a period and they become areas of quite lush vegetation with tall grass savanna and a large variety of other vegetation that no one will exploit. There is thus a cyclical pattern of plant richness in these areas as a result of a combination of climatic and social factors.

5. Population size

Otto Solbrig's formal introduction of human population size as a critical factor affecting diversity opened up an extensive discussion, for the importance of human population size and density is implicit in every paper. For example in the context of Dr. Monasterio's demonstration of the time required for ecosystem regeneration, there are several essential factors. 1) The retention of a source from which a species can recolonise can only occur if the human population size does not require complete removal of the reservoir areas. 2) There will be ample time for reestablishment if the population is small enough so as to require only a proportion of the total area to be utilised for cultivation at sufficiently long intervals. If the population grows above that point, then there will be insufficient time for regeneration.

Concern was expressed that despite the length of time in which the deleterious effects of increasing population size have been known there has been so little change in fertility habits. Indeed the scientific arguments appear to have been submerged by political, economic, religious and a whole host of other arguments. Moreover the fertility transition forecast by demographers is not emerging, and in a number of countries economic wellbeing has not brought about the expected reduction in fertility. On the other hand, as a result of the efforts at propagation of fertility control by various voluntary bodies such as the International Planned Parenthood Federation, and some far-sighted government actions, there has been some slight drop in fertility in some previously highly prolific populations. In many countries people generally are much more aware of ecological considerations and of the importance of quality rather than quantity of children. At the administrative level the increased government interest is an encouraging sign, and the Rio de Janeiro conference particularly so. Perhaps the situation is not quite as negative as it might have been, though it is still very far from optimistic. One alternative to attempting to control population numbers would be to modify cultural nutritional patterns so that instead of using extensive areas for the production of carcass meat, more land use-efficient food stuffs should be encouraged; there is a sign that economic forces may already be bringing this about in the west.

6. Monoculture

The problems created by the introduction of monoculture are far reaching not only as they affect biodiversity but also as they affect health and social wellbeing as exemplified in the final presentation. Their social and economic implications have been amply discussed elsewhere, but less attention has been given to their biotic and health implications. Other examples were adduced in the discussion, for example that from the scrtao of north east Brazil which concerned the encouragement of sisal (Gross, 1971). The peasants in Vila Nova were encouraged by high prices to replace their subsistence crops with sisal, with the expectation of economic riches to come. Unfortunately by the time the crop was ready for harvest 4 years later, the bottom had dropped out of the market and the villagers were left with very little to show for their efforts other than their plots choked with unusable sisal, were no longer self sufficient and had to become labourers on the few large estates to earn money. Traditionally people produce and consume their own crops, and so, with the transition to commercial monoculture and the change in use of their land from food production, there may be a decrease in the variability of the nutrients concerned and an increase in malnutrition. A nutritional survey in Vila Nova showed a quantitative deficit of calorie intake in the labourers' families, undernutrition and stunted children's growth. The longterm disadvantages attaching to commercially introduced crops and methods has been repeatedly shown.

To this theme the discussion of traditional technologies is also relevant. In the region of the raised fields discussed by Dr. Monasterio, the Canadian development authority planted an extensive area of oil seed rape. Then came El Nino, the disturbance of the air pressure systems that brings change of temperature and drought to different localities; its arrival caused the loss of the whole crop, and indeed the only areas with vegetation were the raised fields surrounded by their irrigation ditches.

7. Intraspecific diversity

The final main common theme to the discussion, put into perspective by the contributions on natural selection, viral disease, population numbers, and health respectively by Drs. De Stefano, Garruto, Solbrig and Roberts, was the extent to which intraspecific diversity should be a component of the biodiversity programme. In justification for greater attention to biological variation in man, a great deal is known about this at all levels, from the morphological and functional to the genetic and molecular. This may be helpful to understanding intraspecific biodiversity in a broader setting, for such a wealth of information is not available for any nonhuman species. The omission of the human factor from the biodiversity equation is unfortunate, for man is indeed part of the biosphere, and it would be advantageous to the programme as a whole to have this human information available.

Conclusion

Concluding, Dr. Little noted that one of the objectives of the conference was to draw attention to the types of biodiversity, and the factors influencing it, that are not dealt with in the more traditional ecological approaches. He saw two principal goals:

> 1) To identify areas of research in which the approaches of the ecologist and the human scientist are complementary, and in which the latter can provide insights into phenomena which the ecologist may not have.

2) To identify those studies which are uniquely human, and which can contribute to a greater understanding of the processes of biodiversification and the maintenance of the resulting diversity.

He felt that the conference has achieved this objective and that it would be of direct relevance to the biodiversity programme, for it had given a glimpse of what human studies could offer. To be of greatest value to the future programme it is essential to consider human biodiversity in all its complexity. But to include it, it must be defined so as to be manageable for the purposes required by the programme and these must evolve from those working in the programme.

In the meanwhile a number of more limited topics can be set out. These are recommended for consideration by the steering committee for inclusion in the current biodiversity activities. They are based on the common themes that emerged from the day's presentations.

1. The antiquity of the human impact; exploration of the prehistoric record at selected sites where current biodiversity investigations are in progress, in order to give them a time perspective.

2. Scientific assessment of traditional ecotechnologies, to establish quantitatively their advantages and disadvantages, how they have helped maintain or have contributed to the existing biodiversity.

3. Documentation of the effects on human health of loss of biodiversity.

4. Human biodiversity generation; documentation of the effects of creation of new habitats by human activities (e.g. of urban areas and their colonisation by wild life), of the effect on biodiversity of feralisation of domestic animals and imported exotic species, and of new strains that are arising as a result of public health measures and genetic engineering.

In addition to these interim recommendations, there are two specific suggestions. It may be useful to produce a small handbook on biodiversity in the past, which would be a guide to methods to be utilised in exploring the antiquity of the human impact on biodiversity. Such a book would be practicable, useful, and would not take too long to produce since much of the material is already available in specialist journals. Secondly, to give perspective, a small volume on the contributions of human populations to biodiversity would be useful.

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