ECOTECHNIE AND SUSTAINABLE DEVELOPMENT

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11. Perspectives in Ecology and Natural Resources Management

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11.1. Introduction

This chapter reviews the contributions made so far by Ecology to natural resources management, and the future trends that can or should, in our opinion, be expected in the coming years. Several observations must be made from the outset about the present role of Ecology as a science and the modernisation of the concept of natural resources— their social perception and the way economists generally view resources usage.

In recent texts on ecology (e.g., Ramade, 1981; Simmons, 1981), natural resources are usually discussed in a chapter dealing with man, human activity, applied ecology, etc. The definition of resources varies greatly from one author to another, and range from the broad visions of naturalists who understand resources as „natural assets”, to the restricted approaches of economists, who only regard them as being „those elements that are useful to satisfy human needs”. These distinct approaches admit widely differing inputs, and also vary in time, space and their prevailing social perceptions. Furthermore, the way in which these resources are managed can be analysed from different perspectives, stressing either the ecological, economic or social aspects.

Using a purely semantic definition, Natural could mean „produced by nature and not by humans”, and Resources could be defined as „a source used for a purpose”, or „the means available for survival”. Conjugating the two terms, Natural Resources would thus be „things produced by nature and not by humans which are relied on for something”. Conceptually, this definition is imprecise, and it has a undercurrent which in real terms can make it partially false. For example, resources considered until recently to have little or no value or usefulness such as air or landscape, which therefore were not considered to be resources as such, now have a widely accepted, albeit difficult to quantify, value.

Using an etymological approach, on the other hand, the word Resource (recurso in Spanish, ressource in French) is derived from the Latin term recurrere- resprouit or arise again (González Bernáldez, 1985). Thus, underlying this perspective is a concept of renewal, which is closer to the present trends and approaches.

The concept of natural resources is a common factor in any society, as all have had limits in terms of their use of matter and energy. However, because the identity of these limiting resources has varied according to the society and within it in time, historically there has been no widespread agreement on the identity nor even a classification of natural resources.

Looking back, there have been three basic approaches in the classification of natural resources: broad, partial and systematic. The broad classification, historically derived from inventories by naturalists, geologists, botanists, etc. for their governments on expeditions in the XVII and XIX centuries, considered resources to be all the components of nature. This list of natural resources, initially restricted to minerals, plants and animals, was enriched in the early and mid-XX century by the inclusion of elements such as water and air as pollution problems, when attempts to resolve them gave them a new economic nuance. More recently, the range of elements has been further broadened to include space, landscape, genetic resources and lately biodiversity.

Although this broad concept of resources is acceptable conceptually, in operative terms it is not. Firstly, taken to an extreme, resources could be practically all elements on Earth, making their analysis utterly impossible. Secondly, it makes no allowance for the concept of
The inclusion of new mathematical theories such as fractals (Mandelbrot, 1975), games (Maynard-Smith, 1982) and chaos (Hastings et al., 1993), along with the more commonly used ideas has permitted the development of a multitude of working models for ecological systems, adding a more predictive character to Ecology which is essential in resolving applied problems, the lack of which has been criticised by several authors (Peters, 1991)

11.3. ECOLOGICAL THEORIES APPLIED TO RESOURCES MANAGEMENT

Practically all ecological theories have, to varying degrees, had an impact on resources management, taken in its broadest sense. Some of them are listed below in decreasing order of impact.

At a population level, the most influential theories have perhaps been those related to the concept of carrying capacity and ecological niche. Analyses of population dynamics, including the theory of metapopulations, and the predator-prey and competition models, are the more applied types.

The carrying capacity of an ecosystem, although in its strictest sense often criticised for not taking into consideration the human potential to change the limits of resources usage by means of technological advance (e.g., Simon, 1981; Boresup, 1984), is one of the most important applied concepts in Ecology and in resources management (e.g., Ehrlich et al., 1977). This concept underlies both the most widely accepted classification of resources (renewable and non-renewable) and in the vast majority of theories concerning the limits to growth since the first Club of Rome report in the 1970's (Meadows et al., 1972). The updated review of these limits (Meadows et al., 1992), the World Committee on Environmental Development (WCED, 1987) and the concept of sustainable development reflect this idea to varying degrees, which is by now accepted by most authors.  

The niche theory has also been accepted to some degree in the social sciences, but has had less impact on resources management. Although this concept has been widely criticised in Ecology for its tautology, the Social sciences, especially Anthropology, have redirected it towards what is called the cultural niche in which members of a society adapt to different niches without the intervention of a genetic specialisation (see, e.g. Catton, 1987). It has had little relevance to resources management, however, as evidenced by its lack of mention in most texts on the Ecology of resources management (e.g. Simmons, 1981).

Population dynamics as well as predator-prey and competition models have made a notable contribution to the applied management of certain resources since the beginning of Ecology. Studies and measurements of biological weed and pest control, species conservation, fisheries, etc., have been based on ecological models of population dynamics and interactions, although their predictive power has often been limited by the lack of long data sets and ignorance of certain parameters that are necessary in order to apply these models.

Ecology has made many contributions at a community level. Firstly, the succession theory has been the reference point for territorial assessment. It has widespread applications in territorial planning, environmental impact studies and the selection of protected areas (Usher, 1973). Although these criteria have mostly been applied in a qualitative form due to the lack of data and problems of spatial scale, they are still valid in the establishment of a more objective approach to territorial evaluation. Furthermore, succession models have generally been applied to forest management (see e.g. Shugart, 1984).

Secondly, the study of communities has helped to identify indicators which are widely used in areas such as the typification and description of communities or the measurement and effects of air and water pollution (McKenzie et al., 1992). Researchers are now studying

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1Even the latest theories about the need for a revolution in efficiency (Wiezsäker, et al., 1995) are based on the idea of a limit to growth, although they consider that this has already been surpassed.
the means to extrapolate this indicator design process to farming systems as a measurement of intensification (OECD, 1997) and the benefits of different agri-environmental programmes (Peco et al., in press), as well as other socio-economic areas where "environmental" quality and benefits have to be estimated and monitored (Kuik & Verbruggen, 1991).

It is at the ecosystem level, however, where Ecology is perhaps making its most important contributions to resources management. Analysis of flows of matter and energy in different human societies and different ecosystems have sought a single pattern of measurement to integrate ecological and economic aspects, whether they be monetary, energy or some other. At present, there is no agreement on what this measurement should be, or whether a common measurement even exists (Diamond & Hausman, 1994). Nevertheless, the spread of environmental Economics (in the sense of Costanza, 1991) and the need for an economic evaluation of environmental assets is partially rooted in these analyses of flows of matter and energy.

11.4. PRESENT TRENDS IN ECOLOGY AND RESOURCES MANAGEMENT

Ecology and resources management coincide in a wide range of areas. An analysis of the subject matter covered by the journal Ecological Applications from its first issue until 1997, reveals that the discussion forums predominantly cover issues which try to link Ecology with Economics (Table 11.1), as well as those related to biodiversity. Other issues are of quite minor importance.

Table 11.1. Subjects discussed in Ecological Applications Forums from the first issue until 1997.

<table>
<thead>
<tr>
<th>SUBJECTS IN THE FORUMS</th>
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<tbody>
<tr>
<td>From patterns to processes: The OTTER project</td>
</tr>
<tr>
<td>Air pollution and terrestrial ecosystems</td>
</tr>
<tr>
<td>Spatial types of population models</td>
</tr>
<tr>
<td>Pollution in the Great Lakes (USA)</td>
</tr>
<tr>
<td>Integrated development and conservation</td>
</tr>
<tr>
<td>Plant diversity in managed forests</td>
</tr>
<tr>
<td>Ecological Economics</td>
</tr>
<tr>
<td>Bayesian inference</td>
</tr>
<tr>
<td>Economic growth and environmental quality</td>
</tr>
<tr>
<td>Ecological aspects in the restoration of wetlands</td>
</tr>
<tr>
<td>Detection of environmental impact</td>
</tr>
<tr>
<td>Perspectives in sustainability</td>
</tr>
<tr>
<td>Ecotones</td>
</tr>
<tr>
<td>Maintenance of biodiversity</td>
</tr>
<tr>
<td>Theory of grazing and livestock management</td>
</tr>
<tr>
<td>Weed management</td>
</tr>
<tr>
<td>Response by ecosystems to disturbances</td>
</tr>
<tr>
<td>Management of multiple usage</td>
</tr>
<tr>
<td>NAPAP and biodiversity</td>
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<tr>
<td>Conservation biology</td>
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<tr>
<td>Conservation biology</td>
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</tbody>
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This breakdown changes slightly if we analyse the subjects covered by articles not included in the forums (Table 11.2). Population studies have the highest frequency, along with the nutrient cycle, which is usually linked to the effects of pollution and disturbances. Other subjects with a somewhat lower frequency include the effects of disturbances on the composition and structure of communities and interactions amongst species. The rest of the contents have a minimal frequency.
Table 11.2. Contents of papers published in Ecological Applications from its first issue until 1997, differentiating between free subject matters (% Articles, n=256) and Forum titles (Forum, n=20).

<table>
<thead>
<tr>
<th>SUBJECT</th>
<th>% Articles</th>
<th>Forum (No.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ecosystems</td>
<td>2.3</td>
<td>1</td>
</tr>
<tr>
<td>Nutrient cycles and pollution</td>
<td>18.9</td>
<td>2</td>
</tr>
<tr>
<td>Primary and secondary production</td>
<td>3.0</td>
<td>-</td>
</tr>
<tr>
<td>Climate change</td>
<td>4.2</td>
<td>-</td>
</tr>
<tr>
<td>Landscape and fragmentation</td>
<td>3.4</td>
<td>1</td>
</tr>
<tr>
<td>Forest succession and dynamics</td>
<td>2.3</td>
<td>-</td>
</tr>
<tr>
<td>Effects of disturbances on communities</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Interactions amongst species</td>
<td>9.8</td>
<td>1</td>
</tr>
<tr>
<td>Population studies</td>
<td>19.2</td>
<td>2</td>
</tr>
<tr>
<td>Genetic studies</td>
<td>1.9</td>
<td>-</td>
</tr>
<tr>
<td>Biodiversity</td>
<td>3.8</td>
<td>3</td>
</tr>
<tr>
<td>Economics</td>
<td>1.5</td>
<td>5</td>
</tr>
<tr>
<td>Protected areas</td>
<td>0.7</td>
<td>-</td>
</tr>
<tr>
<td>Restoration</td>
<td>1.9</td>
<td>1</td>
</tr>
<tr>
<td>Indicators</td>
<td>2.3</td>
<td>-</td>
</tr>
<tr>
<td>Environmental impact</td>
<td>2.3</td>
<td>1</td>
</tr>
<tr>
<td>Introduction of species</td>
<td>1.9</td>
<td>-</td>
</tr>
<tr>
<td>Ecotones</td>
<td>1.1</td>
<td>1</td>
</tr>
<tr>
<td>Others</td>
<td>9.1</td>
<td>2</td>
</tr>
</tbody>
</table>

The differences between the forums contents and the articles can be linked to the priority research areas for the 1990's suggested by Lubchenco et al. (1991) (Sustainable Biosphere Initiative or SBI). These authors identified three broad areas: global change, biological diversity and sustainable ecological systems, which are covered most frequently in the forums but not in the articles, where subjects dealing with the Ecology-Economics interface are practically untouched. Most ecologists therefore still appear to be carrying out relatively classical research and do not seem to have accepted the lines proposed by the SBI as widely as might be expected. This may be due to either the difficulty of tackling new subject areas or simply to personal preferences.

There is, however, a series of sub-disciplines and subjects related to natural resources which seems to be entering an important stage of development. These areas are the following:

11.4.1. Cycles of matter and energy, and trophic networks

One of the fields that has advanced most in recent times is the understanding of global processes, linked to the greenhouse effect and the destruction of the ozone layer. This step forward is not limited to modelling the effect of CO2 emissions and other gases responsible for atmospheric warming, but also covers our understanding of the processes that regulate these flows of matter and energy. The large amounts of money spent on these studies has greatly heightened awareness of these processes, although there are still several unclarified matters. The most important advance in these studies, however, is perhaps conceptual: a "Planetary Ecology" has been established in which the processes, most of which were formerly studied at a local, sectorial level in reductionist terms, have been broadened and analysed in a more holistic perspective. Furthermore, the rising trend in the number of analysed aspects of these processes, all aimed at improving the standard of predictions, has enabled different processes to be interrelated and researched at different spatial scales (e.g., the effects at the biosphere level or regional predictions). Similar directions are being taken in other sciences (e.g., Economics) and may well provide regularities and common points that improve understanding of Ecology at this scale.

Pollution is a different study area in the cycles of matter. Traditionally, pollution analysis has focused on three time phases: emission, immission and effects. There is
obviously a point of union between them which are modelled in a relatively simple way in the form of emissions-immissions and immissions-effects. These models have usually been empirical and to a much lesser extent theoretical.

This approach now appears to be changing. On the one hand, pollution analyses are included in the overall cycles of ecosystem matter, which leads to the consideration of the cycles of other elements, given that there are synergies and non-linear behaviour which complicate the matter considerably. On the other hand, although precedents already exist, pollution has been included in the overall concept of disturbance, broadening its theoretical framework by considering that it is a co-substantial process to the working and structure of natural and human-managed ecosystems. All of this has helped to set pollution in a more general framework, linking it to a smaller spatial scale in terms of disturbances and a broader scale in terms of global Ecology. The results of this new approach are still unconsolidated, but they can be expected to be relevant to the studies of the cycles of matter and energy in ecosystems subjected to disturbances.

Finally, the study of trophic networks, which in recent years has undergone a great upsurge, has facilitated the establishment of a series of useful indices for estimating the complexity of ecosystems and their relationship to other structural parameters that are difficult to measure (e.g., resilience, stability). Although there is little detailed research into the trophic networks of different ecosystems, the analysis and search for common patterns in parameters such as connectivity will provide basic tools for resources management in the future.

11.4.2. Interaction between Ecology and Economics

In the same way that Ecology can be interpreted as „the Economics of nature”, following Heckel's (1834-1919) definition, Economics, as stressed by Costanza (1996), can be taken to be „the Ecology of humanity”, with special emphasis placed on the way we manage our business. The common ground of the two disciplines is the analysis of complex systems, in which uncertainty plays an essential role. It is true that Economics and Ecology have been separated conceptually until very recently. This has been due firstly to their differing origins and secondly, to the fragmentation and specialisation of the sciences at the end of the XIX and early XX centuries. resources usage has, however, caused a gradual convergence, and attempts have been made in Economics to include natural values that are unmeasurable in monetary terms, while Ecology has included the human element in its concepts (Costanza, 1991, 1996).

The development and application of sustainable development and the search for eco-environmental indicators are fields with a high level of interaction and confluence between Ecology and Economics in terms of resources. The concept of sustainable development was implicit in the theories of T.R. Malthus and J.S. Mill at the start of this century, the former stressing demographic aspects and the latter, the need to protect nature from uncontrolled growth if the assets were to be maintained and their benefits were not to be diminished (Georgescu-Roegen, 1978, Kula, 1994; Goodland, 1995). However, it was not until the oil crisis and the work by Meadows et al. (1972) that economists began to become aware of the limits to growth, although the idea is still not accepted by many of them (see Fritsch et al., 1994). Thus, the „Global Report 2000” (Barney, 1980), the Bruntland report (WCED, 1987) and the Rio Earth Summit have been useful in disseminating this line of argument and the need for this type of development.

The theory of sustainable development has advanced considerably in recent time, but must still proceed on a broader and deeper front, and above all become more applied. Several authors still make the distinction between sustainable social, economic and environmental development6. Although this approach might be practical in analytical terms,

A good example of this is Goodland's (1995) proposed objectives for sustained social, economic and environmental development.
conceptually it signifies a degree of stagnation. Furthermore, sustainable development is affected by problems of scale in terms of time (dependency on time limits and contemporary economic situations) and space (regional, national etc.). This has prevented all but a very few genuinely „sustainable” programmes and activities from being actually put into practice. In addition, the application of sustainable development must feed the environmental dimension into econometric indices, and seek measures that are common to the economy as well. Only by this means can government plans be expected to genuinely embrace this concept. In synthesis, sustainable development still requires theoretical and practical refinement. Its application must not be reduced to well-intended platitudes enunciated by the most highly developed nations. The design of more complex models and their integration with real Economics are therefore the most urgent needs if the theory sustainable development is to move forward.

Linked to but also superimposed on the above is the design of environmental indicators that can be merged with conventional economic balances. Although environmental Economics has developed a solid range of economic techniques, environmental indicators have only been proposed as measurements of environmental „health” and included in classical and neo-classical economic indicators since the start of the 1990’s. Different formulae have been proposed to change the GDP (e.g. Daly & Coob, 1989) and a set of indicators of sustainable development have been advanced on the basis of the pressure-state-response system (OECD, 1993; Hammond et al., 1995), within a dynamic context defined by cause-effect relationships. Nevertheless, there are serious limitations to the current understanding and applicability of these indicators, especially when dealing with large or small-scale economic systems (at a national level, see Hamblin, 1991; McRae et al., 1995; at a local level, see Peco et al., in press).

11.4.3. Conservation Biology

According to Murphy (1990), conservation biology can be regarded as „the application of classical scientific methodology to the conservation of biological diversity”. In this sense, Conservation Biology, which has largely grown out of Ecology, overlaps with natural resources in the preservation and maintenance of biodiversity (see Meffe & Carroll, 1994; Primack, 1995).

There are three aspects which probably require the greatest degree of conceptual and applied development in this field: the analysis of population viability (including space), the study of the processes which generate biodiversity, and the design and management of protected natural areas.

In relation to the first aspect, in recent years endless models have been developed to analyse the viability of species, not only considering genetic aspects but also their population dynamics (see Schafer, 1981). These models have the great disadvantage of almost totally ignoring the spatial aspects (e.g., the effect of each environment on quality and the different rates of colonisation/extinction), and their results are thus merely orientative. These shortfalls are, however, starting to be overcome. The application of the concept of metapopulations has been a significant step forward (see Murphy et al., 1990) and, while not applicable in all cases (see a discussion of this aspect in Hanski & Gilpin, 1991), as an approach it seems more valid than previous models. Secondly, the dissemination and user-friendliness of Geographic Information Systems (GIS) is undoubtedly aiding the modelling of spatial aspects of population dynamics, and now models of this type are starting to appear (e.g., Pulliam et al. 1992).

The need to study the processes that generate biodiversity at different spatial scales is one of the aspects stressed by Schluter & Ricklefs (1993) as an important field of research in the coming years. Despite a solid range of theories about the processes that generate and limit biological diversity (e.g., Huston, 1979, see review in Tilman & Pacala, 1993), the latter authors accept that „the balance of the processes that determine local diversity have not been identified for the majority of the ecosystems”. Furthermore, in recent years there has
been a tendency to replace the concept of „conservation of emblematic species” with „biodiversity”; a philosophy which is now accepted by most institutions and governments, at least in theory. It is therefore essential to understand the processes that generate and limit diversity, while in applied terms there is a fundamental need for a conceptual tool or model that can be used in different geographic environments and time scales.

The third aspect worthy of attention by ecologists is the design and management of protected natural areas. The classical controversy, derived from the island theory, surrounding the size and distribution of protected areas (Soulé & Simberloff, 1986) has been extended to consider aspects such as the effects of fragmentation and the importance of corridors. However, the results obtained to date lend themselves more to debate than to the establishment of a general theory. Thus, as with the case of population dynamics, the application of theoretical models that include space and the need for empirical results are crucial to the design and management of protected areas.

Conservation biology may well need new paradigms, not only considering well-conserved ecosystems as assets that provide services such as the maintenance of biodiversity, improvement of health standards, etc. as suggested by Boersma (1997), but also focusing on the integration of conservation biology into the new approaches to economic analysis and development that are now being proposed.

11.4.4. Ecosystem recovery

Ecosystem restoration is one of the management areas most closely watched by ecologists. Although this discipline used to focus on the application and development of techniques (see Bradshaw & Chadwick, 1980), many authors consider that restoration is a litmus test for Ecology in the sense that these techniques are „experimental tests” used to check different hypotheses about the composition, structure and performance of the ecosystems (see Jordan III et al., 1987). This feeling, common to the majority of disciplines that deal with applied subjects or in an interface with other sciences, should not be taken as an axiom.

First of all, ecosystem recovery is limited by the varying objectives it pursues (aesthetics, recovery of certain species, landscape integration, etc.). The restoration of the „original ecosystem” or the creation of a new one with pre-determined characteristics is rarely proposed, and in fact it is extremely difficult to ascertain whether this can be achieved, given the usual lack of complete data sets describing the previous situation. Moreover, this vision is based on the idea that ecosystems are stable, which is not always accepted.

Secondly, we find the problem of the spatial scale. The majority of restoration work is done on a very small scale, and thus the results may not necessarily be extrapolated to ecological theories. They may therefore be influenced by the scale factor (e.g., the importance of scale in the colonisation and succession of biocenosis; Levin, 1992). Finally, the majority of recovery work is aimed at recreating relatively simple ecosystems, which are therefore different from complex systems in terms of the importance of each factor involved and the processes inherent to them.

Despite these limitations, ecosystem recovery is without a doubt a promising and fascinating field for experimentation, although more emphasis should be placed on complex restoration work in which there are clear predictive hypotheses, instead of „aesthetic” landscape recovery which is often sterile.

11.4.5. Hierarchical analysis of ecosystems and landscapes

While in the late 1960's and early 1970's we saw the emergence of hierarchical landscape analyses, which focused on territorial planning (Christian & Stewart, 1968),

1Agricultural and forestry practices are also sometimes large-scale "experiments" which have generated a large volume of influential information and interpretations for ecology.
awareness of their potential did not spread until the publication of the influential work by Allen & Starr (1982).

Forman & Godron (1986) established the term „Landscape Ecology“. As a sub-discipline, it has developed significantly in recent decades through attempts to formalise the structure and properties of landscape by means of indexes (see e.g. Wiens, 1989), and also through the discovery of fractal patterns and common structures amongst spatial scales and landscapes (e.g. Naveh & Lieberman, 1993; Forman, 1995).

Landscape Ecology has great potential, both theoretical and practical. Firstly, remote sensing via satellite has spread considerably due to the reduction of processing costs, the increase in the number of images available at different scales and band widths, and their connection to GIS. This has given rise to a finer-grained analysis and has facilitated the hierarchical comparison of different spatial scales. Secondly, considerable effort has been expended on modelling and relating the influence of physical and historical factors on different processes and variables (e.g., erosion, biodiversity) and, while the models are sometimes limited in terms of scale, they have provided Landscape Ecology with greater predictive power (see Goodchild et al., 1993). Finally, hierarchical analyses which are structured according to physical variables and organisational levels may, in areas where there is a considerable accumulation of information, be the basis for a more functional analysis of the territory, and hence closely linked to management.

Space has always been regarded as a natural resource although, due to its transversal nature with respect to others, its due importance might not have been fully appreciated. Territorial planning, intimately linked to space, has lost some of its protagonism as a mechanism for its management, and methodologically has advanced little in recent years. It has tended to be replaced by environmental impact assessments as a planning mechanism without considering that both approaches are complementary and necessary (Clark & Herington, 1988). The greatest challenge facing Landscape Ecology may well be to advance in this direction, integrating different spatial scales and linking them to resources management.

11.4.6. Invasion by species

Although the introduction and dispersal of species is one of the classic subjects of Ecology, the globalisation of human activity is facilitating a large-scale experiment in which to test the hypothesis and our ability to make predictions (Groves & Di Castri, 1991). In general terms, the hypotheses dealing with the need for disturbances for an invasion process to occur (Fox & Fox, 1986) and the negative relationship between ongoing and historical disturbances on the one hand, and rates of invasion on the other (Di Castri, 1990), permit a general explanation of the factors which determine an invasion. At a more specific level, however, we are less able to make predictions. Even in the study of crop invasion by weeds, where this aspect has been widely researched, the analyses are more descriptive than analytical, and they lack even reasonably robust predictive models (Bruce & Howard, 1990; Cousens & Mortimer, 1995).

Invasion and control of species is therefore a considerable and growing problem at present. It has important implications for resources management and conservation, and applied ecology can play a key role in its solution. Doubts such as whether the initial population size affects colonisation rates, or what effects the invading species might have on the original communities, etc. (Guillerm, 1991) still remain unanswered satisfactorily in a way that can be extrapolated from previously researched situations.

In addition to attempts to model the processes and consequences of such invasions more rigorously, the scientific trends in this field can be expected to move in two directions: inductive analysis based on a larger number of data sets and situations which will have to be collated, and the development of spatial models, which in recent years have become prominent in sectorial publications (see articles in the last two years in the journals Weed Science and Weed Research). Such models will not only involve the variables and factors
normally related to the population dynamics of species, but also other non-linear factors (e.g., catastrophe types) which may be decisive in the invasion processes.

11.5. CONCLUSIONS

The environmental debate has undergone profound changes in recent years. Widespread acknowledgement of the global scope of environmental problems has been the catalyst for an „environmental awareness” which is beginning to impregnate the analysis of relationships between our species and our natural surroundings in a more or less decided manner.

The notion of sustainable development has also emerged as a key element in the effort to alleviate the world’s ecological problems. To date, it has proven to be extremely useful as a stimulus for dialogue across a wide range of disciplines (from Ecology to the Social sciences), and antagonistic social and political groups. At this point, the debate is clearly facilitating the conceptualisation of relations between societies and the environment from perspectives that cut through varied disciplinary bodies in the natural and social sciences.

Sociology is beginning to rise above its perspectives which ignored the material and physical properties of society, and treated it as a mere system of communication. It is beginning to explore the ways that societies have hitherto regulated their exchange with the natural environment (Fischer-Kowalski & Haberl, 1997). In Economics, there are also increasingly notable attempts to overcome the neo-classical paradigms which only consider the monetarist facet of reality, anchored as they are in the consideration of a system of stocks and cash flow. There are obvious difficulties in formalising the elements that comprise the „nature market”, but this is not hindering the use of the systemic concept of natural resources in a dynamic, formal framework which, in addition to the flows of energy, matter and information, also contemplates their sources, their sinks and the interaction between each element (Costanza, 1996).

What role can Ecology play in this debate? To answer the question, we must acknowledge the fundamental misunderstandings that have traditionally characterised the discussion. Different groups of actors begin from utterly different perceptions of environmental problems, anchored in the „unifying concepts” of each scientific tradition. We believe that, while these differences should be acknowledged and the basic legitimacy of the different paradigms accepted, it is necessary to overcome the danger of relegating Ecology to a role as a mere field of concepts and debate within the development of simple tools for monetarisation. In historical terms, human societies have produced environmental problems for themselves from their very commencement. They have tried to overcome them through the regulation of population growth and spatial distribution, and by means of the introduction of new means of production. Each state in this evolution corresponds to specific regimes of exchange between societies and their natural environment, and thus a precise understanding of the structural and functional dimensions in the different ecological scenarios is bound to contribute essential information to the definition of sustainable development as the new and urgently necessary paradigm needed by contemporary societies to tackle the unavoidable inflection and uncertainty of the future.
11.6. REFERENCES


