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ESSAY REVIEW

Ecology and environmental impact assessment

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Summary

Environmental Impact Assessment (EIA) may provide a mechanism for implementing sustainable development and ensuring wise use of natural resources. By providing analytical procedures for studying relationships between organisms and their environment, ecological science has an obvious role in EIA, but this has been under-exploited under the existing legislation. Ecological input to environmental statements (ESs) for proposed developments has been criticized for its lack of scientific rigour and its failure to predict and evaluate ecological impacts. This article explores some barriers to the adoption of 'best practice' which derive from ambiguities in the wording of the legislation, key omissions in legislative requirements and scientific limitations. Scope for removing some of these barriers is considered. The need for a more strategic approach to ecological impact assessment, the introduction of standard protocols for survey and evaluation and of formal requirements for monitoring of ecological impacts is identified. Improved availability of data on the distributions of species and habitats is also important.

Key-words: effectiveness, legislation, monitoring, evaluation.

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Introduction

International debate on sustainable development and conservation of biodiversity has gathered speed, focusing on the need to ensure that 'the needs of the present' can be met 'without compromising the ability of future generations to meet their needs' through environmental degradation and depletion of natural resources (WCED 1987). As pressure grows to ensure that economic growth and development are compatible with conservation of world biodiversity, Environmental Impact Assessment (EIA) has been heralded as a potential mechanism for implementing principles of sustainability and 'wise use'. Principle 17 of the Rio Declaration on Environment and Development endorses the universal application of EIA 'as a national instrument' (McNeely 1994) and there is a clear role for EIA in the implementation of national sustainable development strategies (NSDSs) (Sadler 1993).

By providing analytical procedures for studying relationships between organisms and their environment, ecological science has an obvious role in EIA, but the evolution of a recognizable discipline of 'ecological impact assessment' has been slow. Because the need for ecological impact assessment arises from a political or socio-economic motivation, there has been a tendency for scientists to doubt whether it is an acceptable forum in which to 'rigorously apply the scientific method' (Beanlands & Duinker 1984). Ecological studies undertaken for EIA have been subject to considerable criticism (by other ecologists) since the United States' National Environmental Policy Act (NEPA) first created a formal requirement for environmental impact assessment of proposed development actions in 1969 (Beanlands & Duinker 1984; Spellerberg & Minshull 1992; Treweek *et al.* 1993; Thompson 1995). Many of the issues raised remain unresolved and, as a result, ecological assessments carried out under EIA and related legislation continue to be seriously flawed.

In practice, rather than developing as the mainstay of EIA, ecological impact assessment has emerged as a subdiscipline which is often under-resourced and sometimes ignored altogether. The legislation has resulted in procedural frameworks which draw on ecology too little and too late and which fail to encourage good practice. If EIA is to be developed as a tool of environmental management which can help to realise the goals of sustainability and biodiversity conservation, it is important that ecologists should have a much greater input, particularly in developing

its scientific basis. This article explores some of the possible reasons why ecology continues to be marginalized within the EIA process and why scientists continue to regard EIA as unworthy of their attention.

There appear to be persistent barriers to the adoption of 'best practice', which need to be investigated. These may be of a legislative (political), scientific or technical nature. Requirements for ecological impact assessment derive primarily from legislative demand for EIA, which is outlined in the first part of the article. Possible ambiguities in the wording of the legislation and important omissions with respect to requirements for ecological input are then explored to interpret some of the observed shortcomings in ecological input to EIA. The role of scientific limitations to the evolution of predictive power in ecological impact assessment is then considered.

REQUIREMENTS FOR ECOLOGICAL INPUT TO EIA

EIA is used to predict the environmental consequences of proposed human actions, whether these are individual projects (like the construction of a power station), groups of related projects or government policies. In most countries, EIA has been implemented through planning and other development consent procedures and its commonest application has been with respect to individual projects or single actions. However, there are many environmental effects which cannot be regulated effectively on such a restricted basis. There has been growing pressure in most countries of the world for EIA to be applied at higher tiers in the decision-making process, ensuring that the environmental implications of policies, plans, programmes and 'families' of projects are taken into account as well as those of individual projects. Otherwise there is no mechanism for assessing the overall impacts of related projects (power stations and pipelines, for example), the cumulative impacts of serial developments (a number of power stations) or the relative merits of alternative sites, methods or processes (coal-fired power stations vs. wind farms). In Europe a draft Directive on strategic environmental assessment (SEA) has been circulated for consultation, but in the meantime, EIA remains applicable only at the project level, as required under the EA Directive (85/337/EEC). In the UK, the Directive has been implemented through specific sets of Regulations covering different categories of development. The most far-reaching in application are those relating to the town and country planning system in England and Wales (SI 1988; no. 1199), but there are many others (for example the Land Drainage Improvement Works (Assessment of Environmental Effects) Regulations 1988).

In accordance with the "polluter pays" principle, the EC Directive requires proponents of certain developments to undertake assessment of the likely environmental effects of their proposals and to submit the findings to the relevant competent authority in the form of an environmental statement (ES). In common with much EIA legislation worldwide, the Directive makes some stipulations concerning the content of the ES, but does not specify the methods by which the EIA itself is to be conducted. This 'product-driven' approach to EIA has been much criticised for its failure to address obvious methodological shortcomings (Smith 1993; Ortolano & Shepherd 1995). In fact it is possible that EIA may have done little to ensure that environmentally sound decisions are actually made, as the main output of the process, the ES, is often of questionable content and quality.

While it is important that EIA methodology itself should be subject to critical appraisal in order to promote 'best practice', review of ESs remains the most straightforward way to get an overview of ecological input to EIA. There are some difficulties in conducting reviews of ESs, however, as there is no centrally coordinated, comprehensive and up-to-date collection of ESs available in the UK. Some organizations and universities (notably Oxford Brookes and Manchester Universities) which have undertaken to maintain their own collections of ESs have found them often difficult to track down and expensive to buy. In practice, ESs are summary documents which present the results of a range of EIA-related studies and it is unusual for them to include full accounts of any ecological assessments which may have been carried out. There is a great deal of anecdotal evidence to suggest that the results of ecological assessments may be misinterpreted, materially altered, over-summarized or even ignored in ESs, so reviews of their ecological content must be treated with some caution. Nevertheless, ESs are intended as stand-alone documents which provide all the information needed to evaluate the likely environmental implications of a proposal. At the very least, their content should be in compliance with the requirements of the Directive, but reviews of ESs suggest that many fail even to do this with respect to ecological considerations (Treweek *et al.* 1993; Thompson 1995; Morris 1995).

Criticism of the ecological content of ESs has been voiced so often that to reinforce it further may seem superfluous, but it is important to emphasize quite how ecologically deficient the majority of ESs are. A selection of bald statistics may help: in a review of 37 ESs for proposed new roads, the area of land to be taken was only quantified in one and none gave detailed breakdowns of the areas of wildlife habitat which would be lost (Treweek *et al.* 1993). In the same study, only 35% of ESs included results of field surveys and of these, 31% (11% of the whole sample) had been carried out at inappropriate times of the year. There were no cases where surveys had been repeated to gain any indication of temporal trends. Such shortcomings are common across the full range of development types. A summary of the most com-

Table 1. Common criticisms of the ecological content of Environmental Statements

Neglect of key issues
Failure to mention presence of designated areas and/or protected species
Failure to consider other important nature conservation resources which are not designated, or which lie outwith the actual site of a proposed development
Failure to characterize baseline conditions or identify nature conservation constraints
Failure to provide the data needed to identify or predict ecological impacts
Failure to measure explanatory variables
Failure to quantify ecological impacts or measure impact magnitude (even simple, direct impacts like habitat-loss)
Weak prediction
Over-reliance on descriptive and subjective methods
Failure to undertake field surveys
Failure to undertake appropriate surveys at appropriate times
Bias towards easily surveyed and charismatic taxonomic groups
Over-reliance on superficial 'walk-over' surveys
Inadequate replication
Failure to estimate ecological significance
Failure to describe limitations or constraints on survey methodology
Recommendations for mitigation measures which do not match impacts
Recommendations for migitation measures which are untested and unreliable
Failure to name author/consultant or to reference sources of data

mon criticisms is given in Table 1. It is important to establish where the main problems lie. The obvious first port of call is the EIA legislation itself.

INTERPRETING THE LEGISLATION

Examination of the EC Directive as implemented in the UK reveals ambiguities in meaning which may be partly responsible. The need for an ecological approach to EIA is strongly implied, but not stated explicitly, and interpretations of legislative requirements for ecological input have varied as a result. In terms of EIA practice and actual requirements for ecological input, the legislation appears almost deliberately vague.

The requirements of the Directive and the UK regulations are summarized in a *Guide to the Procedures* published by the Department of the Environment (DoE 1989). In summary, proponents are required to provide a description of the proposed development, the data necessary to identify and assess its main environmental effects, a description of the likely significant effects, a description of measures envisaged to avoid, reduce or remedy any significant adverse effects and a non-technical summary. Further information may be included to explain or amplify any of this information and some (limited) guidance is given as to what this might be. The 'Guide' also includes a checklist of 'matters to be considered for inclusion'. It is not my intention to provide a comprehensive account of the legislation, but simply to highlight some instances where ambiguities may have contributed to some observed shortcomings.

THE PROPOSED DEVELOPMENT: ITS PURPOSE AND CHARACTERISTICS

The regulations stipulate that the ES *must* contain 'a description of the development proposed, comprising information about the site and the design and size or scale'. The DoE checklist further suggests that it *may* also include 'information on the production processes and operational features of a proposal', indicating 'the types and quantities of raw materials, energy and other resources' which will be consumed and also the likely residues and emissions which will result (such as discharges to water or emissions to the air).

This information is rarely presented to decision-makers in such a way that they can identify, readily, those activities likely to generate ecological impacts. In many cases it is doubtful whether the ecologists involved in the EIA are in possession of this information either. For example, failure to quantify straightforward habitat loss is common and may result from ignorance of land-use requirements during construction, operation and decommissioning (Treweek *et al.* 1993; Thompsón 1995). There is no mandatory requirement to indicate the geographical relationship between the proposed development, its impact-generating activities and any ecological constraints, making it difficult to estimate the potential for ecological impacts to occur (particularly those beyond the boundaries of the site which will be physically occupied). In the UK it is unusual for the range of development activities to be superimposed on ecological distribution or constraint maps to identify areas at risk from specific impacts, though this is generally a staightforward and intuitive procedure and is common practice in the Netherlands. Reviews of ESs reveal that, although the majority include some sort of description of the proposed development, less than half specify the types of activity likely to generate ecological impacts, the size and location of the area likely to be affected or the timescale of the proposed development (Treweek *et al.* 1993; Thompson 1995). There is also inadequate attention given to the consideration of alternatives, whether these are sites, designs or processes.

INFORMATION ABOUT THE IMPACTED ENVIRONMENT

The need to characterize the area affected by a proposal is not specified in the EC Directive, but is strongly implied by the requirement to provide 'the data necessary to identify and assess the main effects that the development may have on the environment', which *is* specified. The provision of information describing the site and its environment is suggested in the checklist included in the official (DoE) EIA guidance, but is not an absolute requirement. The guidance also suggests that information should be included relating to all 'relevant statutory designations'.

To assess the potential ecological impacts of a proposal, it is clearly essential for all areas potentially affected to be characterized. The EIS should therefore describe not only the location and extent of the site which will be physically occupied by the proposed development, but also any other areas which might be exposed to indirect effects. Mere description of the habitats and species represented will not provide an adequate platform for definition of baseline conditions or the subsequent prediction of impacts. Information might therefore be required on the location, extent, distribution and abundance of important ecosystem components, their relationships with each other and with other biophysical components of their environment, their status (stable, increasing or declining) and the underlying factors responsible (current and historical land-uses, for example). In practice simple descriptions prevail, whether of habitats (for example, the presence of 'chalk grassland' and 'broadleaved woodland' might be noted) or land uses ('arable' or 'waste' land, for example). The majority of ESs do make reference to the presence of any designated sites and protected species, but omissions are not unusual. Furthermore, the presence of statutory designations does not appear to act as a trigger for more intensive study or field survey and there has been an over-reliance on existing information (for example, formal notification schedules for Sites of Special Scientific Interest) which may be out of date and incomplete. Perhaps more serious is the tendency to assume that the absence of a designation of any kind equates to absence of value. This tendency is (unintentionally) reinforced by the fact that the statutory consultees for nature conservation are inadequately resourced to respond to inquiries about wildlife habitats and species in the general countryside and are themselves forced to concentrate their effort on habitats or species which are formally protected.

This is an area where investment in data on the distributions of habitats and species is urgently needed, together with research on how to use it. Practitioners need sound advice on 'what they can expect to find, where and when'. They also need guidance on which ecosystem elements are most vulnerable to different impact types, their resilience, their restorability and their value as indicators or predictors of change. More practical advice is also needed on the relative efficiencies of different sampling and survey methods and the intensity and duration of survey required to gain reliable estimates of population number for different species. Research is also needed on the applicability of new techniques. Despite its obvious advantages for landscape-scale assessment and the targeting or scoping of ecological survey, remotely sensed data (aerial photography and satellite imagery) has hardly been used in EIA (Treweek & Veitch, in press). Phase I habitat survey (JNCC 1993) is generally the most that can be expected as a characterization of potentially impacted areas, but this alone will not provide the data needed to quantify potential ecological impacts.

ASSESSMENT OF EFFECTS

Under the requirements of the EC Directive, an ES *must* include the 'data necessary to identify and assess the main environmental effects of the proposal' and 'a description of the likely significant effects, direct and indirect, on the environment of the development, explained by reference to its possible effect on human beings, flora, fauna, soil, water, air, climate, the landscape, the interaction between any of the foregoing, material assets and the cultural heritage'. The DoE Guide's checklist suggests that possible 'direct, indirect, secondary, cumulative, short, medium and long-term, permanent and temporary, positive and negative effects' should be considered.

In ecological terms, this section of the Directive is very important. It is also one of the most ambiguous. It requires the provision of the necessary *data* to assess environmental effects, but goes on merely to say that these effects must be *described* (not predicted, quantified or evaluated). Review of ESs reveals a distinct lack of data and an over-reliance on descriptive prose to convey the likely effects of proposals. In ecological terms a very limited range of impact types are considered and a very small minority of these are quantified. A review of ESs for proposed road developments, for example, showed that, while 62·5% of statements referred to direct habitat loss, only 3% referred to habitat fragmentation. Ecological impacts were only quantified in 8% of statements, which gave figures for estimated land-take (Treweek *et al.* 1993). Consideration of complex effects is also very rare, the majority of ESs referring only to direct impacts on the flora and fauna and ignoring interactions with other ecosystem components. Ecological surveys undertaken for EIA tend to establish which habitats and species are represented on a development site, but not why they are there. An ES commissioned by the National Rivers Authority for the proposed Northmoor Pumping Station Pump Replacement Scheme in 1993 is a notable exception, which modelled the

proposed new water regime and predicted the likely effects of altered water tables on (*inter alia*) the species composition of mesotrophic grassland, aquatic and ditch bank flora and populations of breeding waders. In contrast, the majority of EISs fail to make ecological predictions at all, indicating the possibility that impacts 'may' occur, not estimating their probability.

MITIGATING MEASURES

The Directive states that 'where significant adverse effects are identified, a description of the measures to be taken to avoid, reduce or remedy those effects should be included'. The need for mitigation of adverse impacts (such as habitat and species loss, disturbance, pollution) is invariably acknowledged, but the measures proposed are often unrelated to specific impacts as identified in the EIA. It is also rare for ESs to give any indication of the likely success of proposed mitigation measures, to make reference to relevant practical experience or to provide even minimal prescriptions to indicate how mitigation measures should be implemented (Treweek *et al.* 1993). Again, the Directive does not require the provision of this information, but its omission has resulted in the acceptance of some very unrealistic proposals for mitigation by planning authorities. A number of EISs recommend translocation of individuals, translocation of habitat, reinstatement of lost habitat and creation of new habitat without giving any indication of how reliable these measures are likely to be in practice (Thompson 1995). This is an area where EIA might actually generate practical opportunities for research on ecological restoration techniques. Much of our knowledge about habitat creation, for example, derives from the practical experience of big companies with mitigation and/or restoration programmes.

OTHER PROBLEMS OF DEFINITION

The Directive makes frequent use of the word 'significant'. The problem of establishing what actually constitutes a significant adverse effect in ecological terms has so far proved intractable. Ecologists must develop objective methods for measuring and evaluating impacts and must clarify their interpretations of terms like 'magnitude', 'significance' and 'importance'. As a general rule, it should be possible to predict impact magnitude quite straightforwardly. There is little excuse for failure to quantify the amount of habitat likely to be lost, the numbers of individuals likely to be affected, the volume of polluted water likely to be released into a stream and so on. It is less easy to estimate the ecological significance of a measured loss of habitat, a population reduction or genetic impoverishment. It is only when we come to estimating 'importance' that it may be valid to succumb to subjectivity, however. Decision-makers may have to tackle questions like 'which is more important, an ancient woodland or a species-rich grassland?', questions which are notoriously difficult to answer objectively.

Legislative omissions

The EC's EIA Directive gives plenty of scope for an integrated, holistic and ecological approach to EIA, but has been very narrowly interpreted in practice. Although a 'purposive construction' should apply to national legislation which has been passed to comply with EU requirements, there are no clear examples where this has been enforced with respect to ecological considerations. In addition to the areas of ambiguity outlined above, the legislation neglects certain key requirements altogether. For example, it fails to make any stipulations concerning methodology, or the expertise of practitioners. In the Netherlands, the establishment of an independent review commission has gone some way towards ensuring that appropriate methods are used. In the UK, decision-making authorities cannot always be confident that the ecological information presented in an ES will be the product of good practice or that they are being told 'the whole truth'. The Government has been reluctant to legislate for independent review and concern about standards in ecological consultancy has come largely from within the ecological profession itself.

The lack of legislation for methodology and its review has been compounded by a shortage of clear, official guidance. A recent *Good Practice Guide* on the 'evaluation of environmental information for planning projects' issued by the Department of the Environment (DoE 1995) makes only sporadic references to ecology and is also guilty of perpetuating the notion that impacts like the 'loss of 4 ha of woodland' should be evaluated under a heading of 'ecology', while 'lowering of water table' should not. Unofficial guidelines for 'Baseline ecological assessment' have been issued by the Institute of Environmental Assessment (IEA 1995), but these give little guidance on how to target baseline surveys (i.e. which taxonomic groups to survey under what circumstances) or on the use of new sources of ecological data (satellite imagery, for example).

ECOLOGICAL SURVEY

The Directive does not specify the circumstances under which new surveys should be undertaken or the methods which should be used. Standards of ecological survey have suffered as a result. There are a great many instances where ecologists have been expected to undertake surveys at inappropriate times of the year, confined to inappropriate study areas and constrained by unrealistic timescales and budgets. Commercial pressures and contractual obligations have made it difficult for ecologists to lobby for improved standards. Review of ESs suggests an over-

reliance on consultation to obtain site-specific information, but also indicates frequent failure to contact statutory consultees when appropriate (Spellerberg & Minshull 1992; Thompson 1995). When field surveys are carried out, there is considerable bias in terms of the taxonomic groups surveyed. These are certainly not selected on the basis of their value as indicators of environmental quality or change. It is surprising to note the small extent to which simple indicators, for example, the list of ancient woodland species (Peterken 1974), are used to target survey work for EIA (Spellerberg & Minshull 1992). Choice of taxonomic groups for survey is far more likely to be determined on grounds of expediency, the specific skills of the surveyor or public appeal. Higher plants are surveyed much more often than animals; birds are sampled much more often than invertebrates and the microflora and fauna are almost never surveyed (Spellerberg & Minshull 1992; Treweek *et al.* 1993; Thompson 1995).

Survey techniques based on remote sensing and geographical information systems (GIS) have hardly been used, despite their obvious value in measuring and evaluating landscape-scale ecological impacts. Where EIA requires studies over large areas, data are often cheaper to acquire using remote survey techniques than using conventional field surveys. There is the additional benefit of being able to repeat surveys on subsequent occasions with minimal recorder-bias. Progress in the use of remote sensing for environmental mapping and monitoring is reviewed by Danson & Plummer (1995).

MONITORING

The lack of formal requirements for monitoring of environmental effects and project impacts is one of the main barriers to the development of a sound predictive base for ecological assessment. The need for comprehensive baseline surveys and structured monitoring programs has been repeatedly emphasized by ecologists (Eberhardt 1976; Beanlands & Duinker 1984). Because ecological assessment ends, formally, with the submission of the ES, remarkably few studies have been carried out to test the accuracy of impact predictions (Buckley 1991) or to monitor the longer-term consequences of development actions (Treweek 1995). It is therefore not surprising that predictions are so often vague and weak. Furthermore, the potential of ecological impact assessment to provide much-needed data on impact-responses has not been realised (Treweek 1995).

Post-development monitoring of project impacts is essential if ecological predictions are to be improved and it should be mandatory.

STAGE OF ECOLOGICAL INPUT TO EIA

Ecological considerations have been given low priority in project design and implementation, preferred options or designs usually being selected on engineering and economic criteria. In the UK, this can be illustrated by reference to new road development, where full ecological assessment is required and carried out only for final, preferred route options. This automatically precludes the best form of damage-mitigation, which is sensitive project design. This is a shame, as there are a number of relatively cheap and effective methods which could be used to assess the ecological impacts of different proposed route options without recourse to full, expensive field survey. Assessment of alternative sites/routes/designs is one of the main areas where techniques based on use of remotely sensed data (including aerial photography) and GIS have a potential application (Treweek & Veitch, in press), but this is likely to remain under-used unless legislation on SEA is enacted. Because ecological impacts are so often complex and cumulative, their early consideration is essential. Although it is difficult to estimate the extent to which ecological concerns have resulted in failure to gain planning consent, ecological concerns have brought many projects to public inquiry. Enlightened developers will consult with ecologists as early as possible to avoid expensive re-design and public inquiry at a later date.

Deficiencies in the scope of the Directive, together with ambiguities in its wording, may be partly responsible for some observed shortcomings in ecological input to EIA. There has been a general failure to legislate effectively for a sound ecological approach to environmental assessment and regulation. Pressure to improve the scope and quality of ecological input to EIA must therefore come from ecologists. However, deficiencies in scientific understanding may mean that some shortcomings of ecological impact assessment remain intractable. Weakness in predictive ability is the most notable barrier.

Scientific shortcomings

Management of human activity to minimize adverse environmental effects depends on information and understanding about ecosystem function which is invariably limited. Ecosystems are complex and dynamic and difficult to model, and ecology lacks some of the clear theories and laws which might be used to predict change under different scenarios. It is possible, therefore, that ecological impact assessment fails because of shortcomings in ecology as a science.

PREDICTIVE ABILITY

Because ecology is weakly predictive, so is ecological impact assessment undertaken for EIA. While the 'practical necessity for attractive, powerful, ecological theory has mushroomed', ecological science 'has languished' (Peters 1991). 'Ecology' has been criticized (*inter alia*) for its 'lack of scientific rigour, weak predictive capability, failure to harness modern tech-

nology ... lack of testable theory, low research budgets ... proliferation of uncontrolled, uncoordinated studies' ... 'and the rarity of interaction between ecologists and planners' (di Castri & Hadley 1986). Nevertheless, incomplete knowledge and understanding should not excuse the current failure to predict ecological impacts at all. 'Whether ecological problems are harder than those of other sciences or not, someone must address them' (Peters 1991). Ideally, ecological predictions for EIA should be regarded as hypotheses which can be tested using monitoring data (Buckley 1991). For this to be possible, predictions must be stated in quantitative terms and preferably presented in the form of time-series covering the projected duration of project activities and accompanied by estimates of the probability of impacts occurring (Treweek 1995). In practice, vague, verbal forecasts are much more common than quantified predictions.

LACK OF DATA

Lack of access to relevant information is partly responsible. Ecological research is relatively underfunded and there is a shortage of datasets which provide 'reasonably complete and uniform national coverage' (Pienkowski 1993). Long-term studies in particular are rarely funded. This has reinforced the tendency to take a parochial approach to ecological impact assessment and to neglect complex, higher-order, indirect, cumulative and trans-boundary impacts. National datasets on the distributions of habitats and species are essential if local impacts are to be placed in context and their real importance evaluated, and these need to be comprehensive, integrated and regularly updated. Ecologists cannot be expected to make predictions on the basis of no information. Development proponents must be encouraged to invest more in the ecological studies required to predict local impacts, but investment in national databases is also required so that these impacts can be evaluated in the wider context. These data should be accessible and available at reasonable cost. This need becomes more urgent as international agreements concerning conservation of biodiversity are implemented. We need to know the distribution and status of our biological resources, or 'natural capital' and this knowledge cannot be built up piecemeal. Nevertheless, it is important to note that the standards of ecological input to EIA are higher in some other countries (notably the Netherlands) where the availability of data is no better than in Britain.

LACK OF RESEARCH

There is an urgent need for greater investment in the research needed to improve understanding of ecological processes and responses to different types of impact. Predicting the effects of habitat loss on a species, for example, will require knowledge of the population processes determining responses to any loss or displacement of the individuals associated with that habitat. Models of the kind developed by Goss-Custard *et al.* (1995a,b) have a potential application in ecological assessment for EIA which needs to be explored, but models of this kind are rare. Studies are also needed to quantify the effects of different development or impact types on the distribution of habitats, species or individuals, their viability (short- or long-term) and their genetic diversity. Papers by Reijnen & Foppen (1994), Reijnen *et al.* (1995) and Foppen & Reijnen (1994) exploring the effects of car traffic on breeding bird populations in woodland, are good examples of the type of study required.

PROBLEMS OF MEASUREMENT AND DESIGN

Traditional approaches to quantification of impacts would, ideally, use data collected in control and impacted areas before and after an impact occurs (Green 1979). Such data would lend themselves to straightforward techniques of analysis of variance to measure impact significance. Such an approach is rarely possible in EIA, where there is usually access only to pre- and post-impact data on one impacted site (Eberhardt 1976), with no formal control. To get round this problem, use of 'control' sites as close as possible to impacted areas has been proposed, but in countries which are already greatly affected by human activity, the identification of suitable control sites can be both difficult and expensive. As a result of the difficulties inherent in treating impact assessments as controlled field experiments which measure functional attributes before and after defined impacts, statistical analyses of ecological data are rarely even attempted in the vast majority of ESs (Treweek 1995).

This, together with the fact that methods for measuring ecosystem function are much less well developed than those for measuring ecosystem structure (Cairns & Niederlehner 1993) has reinforced the tendency for ecological impact assessment to evolve as a desciptive, rather than an analytical process. Novel approaches are needed to the measurement of cause–effect relationships between ecosystem components and defined actions, not only in EIA but also in ecotoxicology. In the meantime, consistent methodology and documentation of EIAs should make it possible to build sets of case-histories so that accumulated experience can provide some sort of substitute for formal replication.

EVALUATION

There is a large range of methods for ecological and conservation evaluation, but these have been largely neglected in UK EIA (Spellerberg 1992). 'Ecological impacts' are invariably interpreted in terms of 'nature conservation value', but this is rarely quantified. No

concensus has emerged concerning the use of ecological evaluation criteria for EIA. Although there are criteria with a numerical basis which could be used (measures of diversity and rarity, for example), the use of subjective judgement is far more common. The only conservation evaluation criteria in common usage in the UK are Ratcliffe's (1977), but these were intended for use in selecting nature reserves and are not appropriate for evaluating ecological significance in the wider landscape where the implementation of principles of sustainable use is so important. It may be necessary to explore the applicability of new criteria which can be used to evaluate the effects of identified impacts on ecosystem viability. For example, there are some cases where 'resilience' has been added to Ratcliffe's list as a criterion relating to the ability of an ecosystem to return to some approximation of its pre-impacted condition. Combined terms may also be used. Species 'security', for example, combines measures of rarity and threat to specific impacts (Treweek 1995). Before it will be possible to estimate the importance of ecological effects in terms of biodiversity conservation we will need to know more about the implications of impacts like habitat fragmentation, reduced genetic diversity, chronic pollution and so on for the viability of wildlife.

Although decision-making invariably involves an element of subjective judgement, this should be delayed until all avenues of objective measurement have been explored. It is important that 'If scientific theories are to provide objective information about the external universe, subjective criteria should complement, not confound, predictive power' (Peters 1991). Ecological impact assessment should provide the scientific basis for EIA and interpret ecological information in such a way that the magnitude and/or significance of potential impacts is quantified before their importance is evaluated (whether in terms of nature conservation or other scales of value). But how can 'ecological significance' and 'nature conservation importance' be measured? This is an area where confusion is rife and it is important that ecologists should develop a clear rationale for evaluation. To give a simple illustration, the ecological significance of predicted land-take is likely to depend on the role of the lost land in providing habitat for associated species. On average, the loss of a large area of habitat supporting a wide range of species will have a greater and more significant ecological impact than the loss of a smaller area which supports only a few. It may be possible to estimate the significance of its loss in terms of effects on the breeding success of associated species and knock-on effects on their national populations. The implications of such losses for nature conservation (their nature conservation importance) on the other hand, will depend on the perceived value of the habitats and species under threat. The criteria used to estimate this value should always be clearly stated.

Most importantly, the ability to evaluate ecological impacts in terms of wildlife conservation depends on up-to-date and thorough knowledge of the current status of habitats, species and populations. In the absence of this knowledge evaluation can only be based on rules of thumb and subjective estimates.

Conclusion

Ecological effects cannot be predicted or evaluated effectively if EIA is confined to single development actions and constrained by artificial boundaries. Under the current legislation, a number of important impact-types are neglected. For example, transboundary effects, long-term or delayed impacts and the cumulative effects of associated developments are assessed very rarely. Legislation for SEA may be necessary to ensure that such impacts can be considered effectively. In the absence of such a change in the legislation, there are a number of ways in which the scope for effective ecological impact assessment might be improved. Some of these are listed below.

1. Review of ecological input by independent ecologists.
2. Formal monitoring of project impacts.
3. Official guidance or legislation for standard sampling and survey methods.
4. Minimum requirements for quantification of predicted impacts (e.g. habitat loss).
5. Injection of resources into development of local, regional and national databases.
6. Research on evaluation of ecological data and development of methods.
7. Field-testing of impact predictions.
8. Post-development monitoring.

EIA will have to be used pro-actively, rather than reactively if environmental problems are to be tackled 'at source' and it will not be possible to rely on EIA as an effective mechanism for achieving sustainable development unless its scope is widened and its scientific base strengthened. Even if it fails to fulfil its potential as a tool for proactive environmental management, however, EIA will remain important simply by giving ecologists an opportunity for formal input to planning decisions and a real influence on the use of land and other natural resources. Ecologists must endeavour to capitalize on the practical opportunities EIA can provide for applied research and must strengthen the predictive ability which is needed to make EIA credible as a scientific exercise. If ecological impact assessment is to develop, however, it is important that there should be more honesty about the limits of ecological understanding and the uncertainties associated with ecological prediction. To some extent, the existing legislation has constrained the ability of ecologists to apply their science as they might wish, but there are also internal barriers to be overcome.

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