Scientific Uncertainty, Ecologically Sustainable Development and the Precautionary Principle

*Alan Stewart**

Market economics expects certainty in environmental controls, but science accepts natural uncertainty. Probability theory was developed to gauge uncertainty. The proliferation of academic disciplines and the growth of the conservation movement led to new demands on this methodology. Terms such as 'ecology', 'sustainability', 'development' and 'biodiversity' came into common use, without due attention to their scientific application. The legal concept of certainty has little to do with probability or the accuracy of environmental predictions. It involves the interpretation of words describing environmental controls. Preoccupation with legal certainty can result in misconceived policies for management of natural resources. The policy of ecologically sustainable development naïvely assumes ecological certainty. The precautionary principle originated in West Germany as the *Vorsogeprinzip* — a precept for foresight in environmental policy. In Australia, the precautionary principle has been defined in tangled syntax, with certainty coupled to double negative logic. This obscures the common sense of the precept. However, a distinct shift in the burden of proof is intimated. With scientific uncertainty, the environment should receive the benefit of doubt.

> If a man will begin with certainties, he shall end in doubts; but if he will be content to begin with doubts, he shall end in certainties.
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> — Francis Bacon, *Advancement of Learning*, 1605[1]

Introduction

At the dawn of the twenty-first century, market economists still believe in a mechanistic Newtonian world.[2] They expect certainty in environmental controls affecting economic development. Yet contemporary scientists accept natural uncertainty, a notion derived from probability theory and quantum physics.[3] This conflict of paradigms has had serious consequences. Australian

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1 F Bacon (1605), *Advancement of Learning*, cited in *Dictionary of Quotations*, (1953), Oxford University Press.

2 B Toohey (1994) *Tumbling Dice*, Heinemann, p 6.

3 See J Gribbin (1991) *In Search of Schrodinger's Cat*, Black Swan.

statutes and policies relying on 'scientific certainty' are fundamentally misconceived.

Scientists consider that the prediction of effects in nature can never be exact, that some degree of error is inevitable in the continuing search for truth. Karl Popper, doyen of the philosophers of science, distinguished truth from certainty:

> There are uncertain truths — even true statements that we take to be false — but there are no uncertain certainties. Since we can never know anything for sure, it is simply not worth searching for certainty; but it is well worth searching for truth; and we do this chiefly by searching for mistakes, so that we can correct them.[4]

Probability Theory

Science deals with uncertainty by calculating various levels of probability. Practical applications of probability theory originated in games of chance — which required decision-making under conditions of uncertainty.[5] The Swiss mathematician Jacques Bernouilli (1654–1705) studied probability in relation to betting odds. By the time of the French Revolution, Pierre Simon Marquis de Laplace could write of the growing recognition of probability theory:

> It is remarkable that this science, which originated in the consideration of games of chance, should have become the most important object of human knowledge.[6]

A little more than a century later, probability theory provided universal tools for the physical and social sciences. The influential work of Sir Ronald Fisher at Cambridge University, first published in the 1930s, garnered a range of statistical techniques.[7] Hypothesis testing was promoted as the standard form of scientific inquiry. Numerical tests were devised to estimate standard errors, confidence limits and correlations. Games theory was applied to predictive modelling in economics and ecology.[8] Experimental designs and sampling techniques were developed for estimating the probability of various causal relationships.

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4 K Popper (1992) *In Search of a Better World: Lectures and Essays from Thirty Years*, Routledge, p 4.

5 A Birnbaum (1969) 'Concepts of Statistical Evidence', in Morgenbesser, Suppes, and White (eds), *Philosophy, Science, and Method*, St Martin's Press, p 132.

6 Cited in P Mason (1986) *Half Your Luck! Or Discovering Probability*, Penguin, p 83.

7 For example, RA Fisher (1930) 'Inverse Probability' 26 *Proceedings of the Cambridge Philosophical Society* 528.

8 J von Neuman and O Morgenstern (1953) *Theory of Games and Economic Behaviour*, Princeton University Press; J Maynard Smith (1982) *Evolution and the Theory of Games*, Cambridge University Press.

The study of agricultural crops seemed particularly amenable to formal experimental designs. Glasshouse pot trials were often transferred to the field in the compliant environment of an 'experiment' farm. Test plots could be laid out on cultivated land in a randomised pattern, allowing separation of variables and replication of treatments. Such investigations might include the effects of rainfall, temperature and fertiliser on the production of selected species. With monoculture of domesticated plants and intensive cultivation of land, spatial and temporal parameters were relatively easy to control. Artificial selection of plant varieties had left little genetic diversity and reduced the influence of individual differences. Randomised blocks coped with fluctuations in soil type and fertility.[9] Similar research dealt with selectively bred domestic animals, confined to yards or small paddocks where conditions could easily be manipulated. This experimental methodology entailed reductionism, simplifying conditions by testing isolated variables and then extrapolating to the 'real' world.

Other scientists remained committed to classification, dividing the world's natural resources into smaller and smaller categories. This empirical task aimed at revealing the grand mechanism of evolution by identifying its myriad parts and adding to the list of species.

Environmental Classification

Much of the definitive field work and classification of the Australian environment was undertaken during the nineteenth century.[10] Explorers such as Sturt, Mitchell, Leichhardt, Stuart and Giles traversed the landscape and reported strange animals and plants in diverse habitats. Many species were meticulously described by naturalists such as Gould and von Meuller. Most Australian scientists followed a theory of evolution by natural selection formulated in Victorian England. Peter Bowler, an English historian writing in 1992, described the implications of this theory for human progress:

> It could now be argued that, throughout the history of the earth, Nature had rewarded those who were able and energetic, and punished those who could not keep up with the race towards higher things. Human progress through the conquest of the environment was merely a continuation of the evolutionary process that had encouraged the traditional virtues of industry and enterprise throughout the ascent towards humankind.[11]

By the twentieth century, science had moved indoors to the laboratory bench, where the focus was on physics, chemistry and medicine. Australian industries still carried out some applied research, and this had been reinforced by the creation of the CSIR (later CSIRO) in 1926 by the Commonwealth

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9 N Bailey (1959) *Statistical Methods in Biology*, English Universities Press, p 108.

10 See A Moyal (1993) *A Bright and Savage Land*, Penguin.

11 P Bowler (1992) *The Environmental Sciences*, Fontana.

government. This statutory authority was charged with conducting research for the 'benefit of Australia's primary and secondary industries'.[12] Coincidentally, much of this research gathered basic information on geology, botany and zoology.

New Disciplines

Australian universities rapidly expanded during the 1960s and 1970s, entailing the recruitment of large numbers of staff and the creation of many new disciplines. Traditional schools of law, economics, engineering and medicine now had to share campuses with more esoteric disciplines — such as sociology, palaeontology, climatology and ecology. Students were encouraged by the prospect of new jobs in the public service and universities, where they hoped to establish careers and satisfy a desire to protect the environment.

Some established scientists were critical of the direction being taken by the environmental debate. Harry Frith, Chief of the Division of Wildlife Research in the CSIRO, complained in 1979 about the misuse of terminology:

> In some ways it was unfortunate that before public interest had focused on the real problems and had been translated into enough money on the ground to ensure an effective wildlife-conservation program, the interest expanded and swung towards one species, Man. The wildlife-conservation movement disappeared before the appeal of terms like 'The Ecology' and 'The Environment'. These, in turn, came to be almost synonymous with industrial pollution in a tiny part of the continent. Reducing the petrol fumes and smoke in the dark canyons of the cities and recycling beer cans became more popular, and apparently more urgent, than the conservation of our dwindling wildlife resources.[13]

The role of the CSIRO had gradually expanded to include work on conservation, urban planning and other environmental fields not related to specific industries. Theoretical research proceeded alongside applied research. Scientists claimed a part in serving the community as a whole, by putting ecological and environmental theories into practice.

Complex Systems

In the 1970s, a reaction against reductionism, the simplification of experimental design, became apparent. The study of complex biological and physical systems demanded a more eclectic approach. Agricultural scientists began to use ecological methods, measuring interactions between species, for assessing the human impact on natural resources. Zoologists discovered ethology, the study of the behaviour of animals in relation to their normal environments.

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12 A McKay (1976) *Surprise and Enterprise: Fifty Years of Science for Australia*, CSIRO, p 4.

13 HJ Frith (1979) *Wildlife Conservation*, Angus & Robertson, Preface.

Ecology and ethology had practical applications in pest control, which required an understanding of how populations interacted. The theory of population dynamics benefited from applied research on prickly pears, locusts and rabbits.[14] Writing in 1981, Jones and Kitching explained:

> Pest species — just because they are pest species — tend to receive much more attention from biologists than species of no economic significance. A complete list of pests would include the subjects of almost all the detailed long-term ecological studies of undomesticated organisms that have been carried out in Australia — or indeed, anywhere else ... Because they often have access to better and more reliable financial support than studies on species of no economic importance, good ecological studies of pests have often been more long-term and exhaustive. In addition, perhaps because their work is usually expected to result in prescriptions for practical action, applied ecologists have tended to produce work which is more field-orientated, and, in many cases, more experimental and quantitative, than has been the usual elsewhere in ecology.[15]

Attempts at extermination gleaned useful information for conservation. Wildlife damage to crops, pastures or domestic stock had been the *raison d'etre* of the CSIRO Division of Wildlife Research. With the rise of the conservation movement, the pest status of native species became controversial.[16] Scientists from the Division were given the task of assessing the place of the species in its community and the resources it required for survival. They needed to work on interactions with other animals and plants in the subject environment. Conservation strategies required prediction of the impact of human activities on sensitive habitats. Basic research on flora and fauna increased, and the methodology originally developed for pest control found a wider application. This presaged a trend towards a more holistic view of nature. It raised fundamental questions about evolution and the environment, and the utility of scientific methodology.[17]

Classical statistical methods, calculating probabilities by treating only a few variables at a time, were found unsuitable for many environmental investigations.[18] Ecological studies seemed not amenable to rigorous experimental design.[19] Laboratory experiments proved difficult to relate to many field conditions. Natural variability complicated manipulation and

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14 M Fox and D Adamson (1979) 'The Ecology of invasions', in H Recher, D Lunney and I Dunn, *A Natural Legacy: Ecology in Australia*, Pergamon, p 135.

15 R Kitching, and R Jones (1981) *The Ecology of Pests*, CSIRO, p 1.

16 CSIRO (1969) 'Australian Wildlife', *Rural Research* 66, June, pp 2–5.

17 C Birch and P Ehrlich (1967) 'Evolutionary History and Population Biology', 214 *Nature* 349.

18 See W Williams (ed) (1976) *Pattern Analysis in Agricultural Science*, Elsevier.

19 H Recher (1992) 'Ecology on Trial', in D Lunney (ed), *Zoology in Court*, Royal Zoological Society of New South Wales, p 27.

replication.[20] Such research required simultaneous examination of interactions between a host of variables.

Ecologists began to employ information theory, which could provide mathematical functions for prediction with an appropriate range of variables.[21] During the 1960s, a computing method known as multivariate analysis was used to create information models of plant and animal communities.[22]

Increasing access to powerful computers had stimulated the wider use of multivariate methods in many branches of science, and even economics.[23] These used new objective units — bytes of information.

Unstable Ecosystems

Early theories of ecosystem dynamics relied on a general tendency towards stability — with slight perturbations or movements around a normal equilibrium condition. This honoured an ancient belief in the 'balance of nature'.[24] However, reviewing model ecosystems in 1971, Robert May warned:

> in general mathematical models of multi-species communities, complexity tends to beget instability rather than stability. This straightforward mathematical fact contradicts the intuitive verbal arguments often invoked, to the effect that the greater the number of links and alternative pathways in the web, the greater the chance of absorbing environmental shocks, thus damping down incipient oscillations.[25]

May showed that unstable, non-linear mathematical models were appropriate even for simple systems. By 1986 he had concluded:

> The simplest mathematical models describing the dynamics of natural populations of plants and animals are nonlinear. These models can

20 C Walters and C Holling (1990) 'Large-scale Management Experiments and Learning by Doing' 71 *Ecology* 2060; C Peterson (1993) 'Improvement of Environmental Impact Analysis by Application of Principles Derived from Manipulative Ecology' 18 *AJE* 21.

21 R Margalef (1958) 'Information Theory in Ecology', 3 *Gen Syst*, 36; E Pielou (1966) 'The Measurement of Diversity in Different Types of Biological Collections', 13 *J. Theoret Biol* 131, M Dale (1971) 'Validity and Utility of Information Theory in Ecological Research' 6 *Proc ESA* 7.

22 W Williams, J Lambert and G Lance (1966) 'Multivariate Methods in Plant Ecology: V-similarity Analysis and Information Analysis 54 *J. Ecol* 427.

23 Gauch, H. (1982) *Multivariate Analysis in Community Ecology*, CUP, Cambridge, 236.

24 This belief had been challenged by Wallace and Darwin. The theory of evolution emphasised the *instability* of nature: C Birch and J Cobb (1981) *The Liberation of Life*, CUP, p 41.

25 R May (1971) 'Stability in model ecosystems', in H Nix (ed), 'Quantifying Ecology', 6 *Proceedings of the Ecological Society of Australia* 46.

> exhibit an astonishing array of dynamical behaviour, ranging from stable points to period-doubling bifurcations that produce a cascade of stable cycles, to apparently random fluctuations; that is, simple deterministic systems can produce chaotic dynamics.[26]

Observations in natural situations supported the notion of instability. Studying whole-lake systems, Carpenter found that large perturbations over periods of many years did not show a tendency towards equilibrium.[27] He cautioned, however, that the feasibility of large-scale experiments was threatened by costs and the scarcity of equivalent ecosystems. Undetected natural perturbations could be confused with impacts from human intervention. Prediction of impacts depended on measuring and comparing erratic curves, with start and end points poorly defined.

According to environmental legislation, a discrete environmental impact assessment (EIA) for a proposed development must be concerned with detecting particular causal relationships, related to planning and economic imperatives.[28] Unlike basic research, the procedure moved from the general towards the particular: to assess the impact of a certain disturbance on a certain site, in the light of experience and accepted theory.

Many EIA sampling procedures lacked opportunities for the replication dictated by traditional statistical design. The administrative process, defined by statute, supported decision-making in a one-off, positive or negative mode. A project was either approved or rejected. EIA under such circumstances might seem conclusive, but it remained inherently uncertain.

Sampling Through Time

To overcome spatial limitations, Green proposed a design with 'pseudoreplication'.[29] This was to be known as a before-after-control-impact (BACI) design — taking samples before and after the subject activity, at both control and impact sites. Detection of an effect could be accomplished by measuring the difference between simultaneous samples from the two sites.[30] A series of paired-system experiments, repeated over time in many locations, might provide more information than a single replicated experiment at one site. Few statistical techniques were available, however, to test extensive

26 R May (1986) 'When Two and Two Do Not Make Four: Nonlinear Phenomena in Ecology' B228 *Proceedings of the Royal Society of London,* p 241.

27 S Carpenter (1989) 'Replication and Treatment Strength in Whole-lake Experiments' 70 *Ecology* 453.

28 A Brown (1990) 'Environmental Impact Assessment in a Development Context' 10 *EIA Review* 135.

29 R Green (1979) *Sampling Design and Statistical Methods for Environmental Biologists,* Wiley, p 161.

30 A Stewart-Oaten, W Murdoch and K Parker (1986) 'Environmental Impact Assessment: 'Pseudoreplication' in Time?' 67 *Ecology* 929.

experiments of this type.[31] In any case, the information obtained might not be relevant to the immediate issues.

BACI sampling was criticised by Antony Underwood, who advocated asymmetrical designs, including several control locations:

> When abundances of populations in different locations show temporal interaction, the asymmetrical designs allow tests for impact that are not possible in BACI designs.[32]

As an example of poor design, Underwood cited the benthic monitoring of the Third Runway project in Botany Bay in Sydney. He identified three fundamental deficiencies:[33]

1 lack of external control locations;

2 inappropriate timing of the sampling; and

3 failure to consider the power of the statistical analysis.[34]

Valid control sampling required complete isolation from the subject disturbance. In this case, the disturbance was dredging near the construction site. As the whole body of water in Botany Bay could have been affected, the control sampling should have been carried out in several similar bays. Without room for such external control sampling, the spatial scale of the design was flawed. Populations of benthic fauna were known to fluctuate at various frequencies, but the temporal scale of sampling had not been adjusted to avoid confusion of dredging effects with effects due to natural fluctuations. Differences between disturbed and control locations were unlikely to be detected if the analysis of the sampling had a low statistical power. This power had not been estimated in the Third Runway study.

Legal Certainty

The legal concept of certainty had little to do with the accuracy of environmental predictions. Instead it dealt with the meaning of words

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31 C Osenberg, R Schmitt, S Holbrook, K Abu-Saba and R Flegal (1994) 'Detection of Environmental Impacts: Natural Variability, Effect Size, and Power Analysis' 4 *Ecological Applications* 16.

32 A Underwood (1994) 'On Beyond BACI: Sampling Designs that Might Reliably Detect Environmental Disturbance' 4 *Ecological Applications* 3.

33 A Underwood (1993) 'How Not to Design an Environmental Monitoring Program: A Case Study from the FAC (up in Botany Bay)' 6 *Australian Biologist* 194.

34 In statistics, the power of a test is defined as 'the probability of rejecting the null hypothesis' (J Pollard (1979) *Handbook of Numerical and Statistical Techniques*, CUP, p 134). A low-powered test can suffer from Type I or Type II errors — a relationship is accepted when one does not exist (false positive), or a relationship is rejected when one does exist (false negative).

describing environmental controls.[35] Lawyers argued about the *interpretative* and the *invalidity* approaches to deciding whether an order (or condition) was valid if uncertain.[36]

Government preoccupation with legal certainty has generated flawed strategies. These reflect ignorance of scientific uncertainty in natural resource exploitation.[37] Political and social imperatives may receive a degree of support in the community, but at the risk of imprudent exploitation. Optimum levels of management might only be achieved by trial and error and some adverse impacts detected only when they became severe. Subtle environmental effects take decades to become obvious. By this time, remedial action could be too late.[38]

Biodiversity and Economics

The National Strategy for the Conservation of Biological Diversity addressed the value of Australia's natural resources:

> The conservation of biological diversity provides significant cultural, economic, educational, environmental, scientific and social benefits for all Australians.[39]

The continent is enriched by its unique life forms. Both the intrinsic and instrumental values of these resources have to be taken into account in decision-making.[40] However, many critical interactions involving biodiversity and conservation are poorly understood.[41] Research is needed on relationships between carrying capacity, genetic variability, redundancy and resilience.[42]

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35 For example, J Watts (1995) 'Reconciling Environmental Protection with the Need for Certainty: Significance Thresholds for CEQA' 22 *Ecology Law Quarterly*, 213; S Molesworth (1996) 'The Integration of Environmental Imperatives into Decision-making' 5 *Significant Environmental Speeches* 33.

36 A Harman (1995) 'Pollution Abatement Notices: The Requirement for Certainty' 12 *EPLJ* 147.

37 D Mercer (1991) *A Question of Balance: Natural Resources Conflict Issues in Australia,* Federation Press, p 43; D Ludwig, R Hilborn and C Walters (1993) 'Uncertainty, Resource Exploitation, and Conservation: Lessons from History', 3 *Ecological Applications* 547.

38 S Boyden, S Dovers and M Shirlow (1990) *Our Biosphere Under Threat: Ecological Realities and Australia's Opportunities*, OUP, p 268.

39 Australian Government (1996) *National Strategy for the Conservation of Australia's Biological Diversity*, DEST, p 5.

40 A Stewart (1998) 'Natural Values and the Economic Rationale', in D Lunney and T Dawson (eds), *Ethics, Money and Politics: Modern Dilemmas for Zoology*, Royal Zoological Society of NSW, p 39.

41 See I Spellerberg and J Sawyer (1996) 'Standards for Biodiversity: A Proposal Based on Biodiversity Standards for Forest Plantations' 5 *Biodiversity and Conservation* 447.

42 M Holdgate (1996) 'The Ecological Significance of Biological Diversity' 25 *Ambio*, 409.

This work takes time and money. Nonetheless the instrumental value, or usefulness, of biodiversity is already driving research on many fronts. Andrew Beattie describes the practical applications in disparate fields:

> Overall, an unexpected variety of organisms have provided resources for an unexpected variety of organisations. In this context, the beneficiaries of biodiversity — including molecular biologists, biotechnologists, chemists, and pharmacologists together with the medical and engineering professions — may wish to play a more central role in biodiversity conservation. It would be very much in their own interests.[43]

Different Perceptions

Political decision-makers try to reconcile competing demands for resources. When balancing the opposing interests of exploitation and conservation, account has to be taken of stakeholders with differing perceptions of time and space.

In estimating the fate of bioresources, ecologists look at evolutionary changes.[44] MacArthur and Wilson described area and distance effects that limited biodiversity.[45] This encouraged the calculation of species/area curves in many types of habitat.[46] Reports of imminent extinctions and loss of biodiversity generated urgent demands for conservation.[47] Consequently, there was a call for an operational definition of biodiversity and for suitable indicators.[48]

This science was far from exact — even the fundamental task of estimating the number of species present remained problematic.[49] Dispersal and migration complicated assessment and management of populations.[50] Faith and Walker, from the Division of Wildlife and Ecology of CSIRO, suggested a system of multi-criteria analysis for the selection of protected areas, based on the use of environmental diversity (ED) as a surrogate for

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43 A Beattie (1996) 'Putting Biodiversity to Work'27 *Search*, 111.

44 C Folke, C Holling and C Perrings (1996) 'Biological Diversity, Ecosystems and the Human Scale'6 *Ecological Applications* 1018.

45 See E Wilson (1993) *The Diversity of Life*, Penguin.

46 M Begon, J Harper and C Townsend (1990) *Ecology: Individuals, Populations and Communities*, Blackwell.

47 D Hutton and L Connors (1999) *A History of the Australian Conservation Movement*, CUP, p 251.

48 R Noss (1990) 'Indicators for Monitoring Biodiversity: A Hierarchial Approach' (1990) 4 *Conservation Biology* 355; R Lande (1996) 'Statistics and Partitioning of Species Diversity, and Similarity Among Multiple Communities' 76 *Oikos* 5.

49 R May (1989) 'How Many Species?', in L Friday and R Laskey (eds), *The Fragile Environment*, CUP.

50 Fairweather, P (1991) 'Implications of "Supply-side" Ecology for Environmental Assessment and Management' 6 *Trends in Ecology and Evolution* 3.

biodiversity. They believed that the former was an acceptable estimate that 'avoided unwarranted assumptions about the relationship of species to environment'.[51] The ED model allowed a form of risk assessment, taking into account uncertainty of information about species richness and the costs of land-use alternatives.

Cultural Appropriation

The architects of *ecologically sustainable development* (ESD) committed a form of cultural appropriation — the taking of intellectual property from a culture that is not one's own.[52] This appropriation did not respect the bounds of science. It naïvely assumed ecological certainty, that the assessment of the impact of present development on future ecosystems could be definitive. The adoption of a definitive ESD policy by the Hawke government was not a commitment to ecological methodology. It was a response to the perceived desire of the electorate for some kind of scientific solution. Targeting the green vote, Prime Minister Hawke expediently borrowed the terminology in his own political interests:

> Ecologically sustainable development means using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained and the total quality of life, now and in the future, can be increased.[53]

Sustainability became a popular cause in the early 1970s through a convergence of political, economic and environmental events. Intricate political events in the Middle East had caused an 'oil crisis', threatening the economies of the Western world. The agricultural 'green revolution' in Southeast Asia appeared to be faltering. Conservation movements proclaimed an urgent need to husband the limited resources of the planet. Attention focused on the dependence on fossil fuel of the developed nations and the rapid population growth of undeveloped nations. Energy flows and cycles in the biosphere were seen to be relevant to food production and industrial development. The Club of Rome, a private 'think tank' formed in 1968, commissioned a predictive model of the Earth's resources. A best-selling book, *The Limits to Growth*, published the conclusions from this model:

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51 D Faith and P Walker (1996) 'Integrating Conservation and Development: Effective Trade-offs Between Biodiversity and Cost in the Selection of Protected Areas' 5 *Biodiversity and Conservation* 431.

52 See B Ziff and P Rao (1996) *Borrowed Power: Essays on Cultural Appropriation* Rutgers University Press. The anonymous architects of ESD probably worked in the Prime Minister's Office.

53 Australian Government (1990) *Ecologically Sustainable Development: A Commonwealth Discussion Paper,* AGPS. 'Ecological' was added in the Australian derivation of 'sustainable development'. This was attributed to Prime Minister Hawke: D McEachern (1990) 'Environmental Policy in Australia 1981–91: A Form of Corporatism?' 52 *Australian Journal of Public Administration* 175.

> 1. If the present growth trends in world population, industrialization, pollution, food production, and resource depletion continue unchanged, the limits to growth on this planet will be reached sometime in the next one hundred years. The most probable result will be a rather sudden and uncontrolled decline in both population and industrial capacity.
>
> 2. It is possible to alter these growth trends and to establish a condition of ecological and economic stability that is *sustainable* far into the future ... [my emphasis].[54]

Charles Birch, a scientific member of the Club of Rome, saw a relationship with ecology and economics:

> Whereas traditional economics seems to have set itself on a collision course with ecological realities, the economics of the sustainable society is essentially an ecological concept.[55]

Birch went on to describe sustainability in terms of natural ecosystems:

> The sustainable society is analogous to sustainable ecosystems such as rain forests and coral reefs. Here we have a great diversity of plants and animals which, instead of exhausting the resources of the environment, sustain them.[56]

In contrast, the Stockholm Declaration of 1972 opted for the term 'sustainable development'.[57] The use of 'development' in place of 'society' implied an active policy of intervention in natural ecosystems. This was aimed to, 'meet the needs of the present without compromising the ability of future [human] generations to meet their own needs'. The problem remained one of striking a balance — apportioning resources between the present and the future. Such a balance would require comparison of needs over time, and some understanding of the capacity and resilience of pertinent ecosystems. Key questions remained unanswered. How many generations were to be considered? Could need be distinguished from greed? Should sustainable development be equated with economic growth? What was the probability of the ecosystems surviving?

Adequate explanations require a mixture of idealism and pragmatism, with contributions from a range of the humanities and sciences. Still, an overriding anthropocentric philosophy persists. According to the Brundtland Report:

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54 DH Meadows, DL Meadows, J Randers and W Brehrens (1972) *The Limits to Growth*, Pan, p 23.

55 C Birch (1993) *Confronting the Future*, Penguin, p 36.

56 ibid., p 37.

57 United Nations (1972) *Declaration on the Human Environment.*

> The satisfaction of human needs and aspirations is the major objective of development. The essential needs of vast numbers of people in developing countries — for food, clothing, shelter, jobs — are not being met, and beyond their basic needs, these people have legitimate aspirations for an improved quality of life. A world in which poverty and inequity are endemic will always be prone to ecological and other crises.[58]

Despite their general approval of ESD, conservationists remain wary of development.[59] A spokesperson for the Australian Conservation Foundation warned:

> Policies and decisions should err on the side of caution, placing the burden of proof on technological and industrial developments to demonstrate that they are ecologically sustainable.[60]

At an institutional level, EIA now has to take into account *inter-generational equity.* Government agencies have made little progress in defining this objective, even less in describing the means of achieving it. The CSIRO blandly suggested three conditions for sustainable development:[61]

1 maintaining the value of renewable natural resources;

2 maintaining the capacity of the environment to assimilate waste;

3 conserving the diversity of native species and ecosystems.

There could be little argument about the virtue of these 'motherhood' conditions. But the basic policy differences between conservationists and developers remain. Business interests emphasise the development part of the policy.[62] Conservationists stress the ecological.[63] Neither side uses terminology in a form that is useful for reaching a consensus. Despite numerous working parties and seminars, the meaning of ecologically sustainable development remains unclear years after it became government policy. Writing in the *Sydney Morning Herald,* Anne Susskind described the difficulty:

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58 World Commission on Environment and Development (1987) *Our Common Future*, OUP, p 8.

59 See S Beder (1993) The *Nature of Sustainable Development*, Scribe.

60 B Hare (1991) 'Ecologically Sustainable Development', *Habitat*, April, p 10.

61 M Young, K Cocks and S Humphries (1990) *Australia's Environment and Its Natural Resources: An Outlook,* CSIRO, p 4.

62 For example, K Setches (1990) 'Sustainable Development Does Not Mean No Development' 62 *Canberra Bulletin of Public Administration* 23.

63 Hutton and Connors (1999).

> For the past five years, the concept [ESD] has dominated the environmental debate. But its meaning is elusive; and there are people who are questioning whether it is a useful construct in the first place.
>
> It's the catch-cry of governments and industry and the hope held out by some of the more mainstream environmentalists ... [64]

The Australian Conservation Foundation participated in the ESD working groups set up by the Hawke government, and became disillusioned with delays in implementation.[65] Ben Boer, an academic lawyer, was also pessimistic about the outcome:

> In theory, it is an attractive concept. In practice it would take a long time. The ESD working parties produced some really excellent ideas, but there's little hope of implementation. It's so difficult to have environment and development sectors agree on basics.[66]

Ron Brunton, from the Institute of Public Administration, found an unjust bias against developers:

> Sound principles can become open-ended and selectively applied weapons of righteousness against development projects which greens dislike for aesthetic, ideological or opportunistic reasons, with the supporters of these projects invariably cast as morally tainted.[67]

Politicians on the Right favour a pro-development interpretation of ESD. Robert Webster, National Party Minister for Planning in New South Wales, declared:

> A democratic capitalist system running a strong economy provides, I believe, the best means of producing sound development with rigorous environmental safeguards ... To be pro-development no longer means to be anti-environment. That division is in fact the very fallacy at the root of our paralysis.[68]

Development has different meanings for different people. To a market economist, it might involve an increase in gross national product (GNP), an increase in goods and services or an increase in the built environment — all quantitative rather than qualitative changes. To a farmer, development of land

64 A Susskind (1992) 'Environment, Economy Accord Founders', *Sydney Morning Herald*, 29 October, p 15.

65 ibid.

66 Cited in ibid.

67 R Brunton (1994) 'The Precautionary Principle: The Greatest Risk of All', *IPA Environmental Backgrounder* 20, p 2.

68 Cited in Susskind (1992).

often means 'permanent improvements', such as clearing and fencing, which are designed to increase the quantity of produce won from the soil. To an architect-planner, development could mean replacing low warehouses with office towers, or covering 'green fields' with rows of new houses. In biology, development is a part of evolution: striving to maintain homeostasis in a changing environment, adapting form and function to circumstances. Ontogeny is the development of an individual throughout its lifetime, while phylogeny involves development at the group or species level.

Successive generations of daisies change the colour of their petals in adaption to changes in ambient temperature.[69] A city moves outwards and upwards, in response to the needs and desires of its people.[70] Both are developing, and both are interacting with their environment. The common process is an input of energy or information — and a corresponding decrease in entropy or disorder. Neither type of development could be considered in isolation. They constitute parts of the evolving biosphere, limited by the laws of nature in the struggle for existence.[71]

According to the *Macquarie Dictionary*, to develop is to, 'bring out the capabilities or possibilities'.[72] Lyuba Zarsky, writing in the *Canberra Bulletin of Public Administration,* suggests that development might mean simply 'desirable change'.[73]

The Precautionary Principle

EIA, as a predictive process, should follow the age-old maxim that prevention is better than cure.[74] This maxim was institutionalised by West Germany in the early 1970s as the *Vorsorgeprinzip* (literally: worrying before)[75] or *precautionary principle*, a precept for foresight in environmental policy.[76] It required a commonsense approach. Udo Simonis saw it as progress from a strategy of *react-and-cure* to one of *anticipate-and-prevent.*[77]

Germany had been suffering from the effects of widespread industrial pollution in the air and water. With the *Vorsorgeprinzip,* high priority was

69 J Lovelock (1988) *The Ages of Gaia*, OUP.

70 R Fowke and D Prasad (1996) 'Sustainable Development, Cities and Local Government: Dilemmas and Definitions' 33 *Australian Planner* 2, p 61.

71 See D Brookes and E Wiley (1986) *Evolution as Entropy: Towards a Unified Theory of Evolution*, University of Chicago Press.

72 *Macquarie Dictionary* (1985) Macquarie Library, p 495.

73 L Zarsky (1990) 'Our Common Future: The Brundtland Report Revisited'62 *Canberra Bulletin of Public Administration* 128.

74 J Glasson (1994) 'EIA — only the tip of the iceberg?', *Town &Country Planning*, February, p 42.

75 From the combination of *vor* (before) and *Sorge* (worry): *Collins German Dictionary*, London, 1980, pp 610, 730.

76 U Simonis (1991) *Environmental Policy in the Federal Republic of Germany: Curative and Precautionary Approaches,* WZB.

77 ibid., p 2.

given to prevention of toxic emissions, conservation of resources and proactive planning. Such foresight demanded a broader scope than the previous policy of retrospective controls. It encountered resistance from entrenched political and administrative decision-makers, who had been accustomed to looking backwards, at the mistakes of the past. They were concerned with *effects* rather than *causes*. The methodology of cleaning up after pollution events was much more focused than that required to predict the flow of energy and matter through an ecosystem. A disaster prevented might not be evident. In the complex web of life, nostrums for a sick few could seem less costly than prophylactics for the healthy multitude. The individual held responsible for a particular impact did not expect to pay for prevention of similar events in the future. So, soon after the introduction of the *Vorsorgeprinzip,* its scope became limited by a criterion of *wirtschaftliche Vertretbarkeit* or 'economic feasibility'.[78] Nevertheless, in the German context, the emphasis on anticipation led to stricter emission standards and a shift away from narrow cost-benefit analysis towards wider social and ecological assessments.[79]

At an international level, conventions designed to combat marine pollution articulated precautionary measures. The Declaration on the North Sea, issued at a meeting of ministers in London in 1987, was explicit:

> in order to protect the North Sea from possibly damaging effects of the most dangerous substances, a precautionary approach is necessary which may require action to control inputs of such substances even before a causal link has been established.[80]

By the early 1990s, the precautionary principle had been advocated at a range of international conferences.[81] In particular, it was included in the Rio Declaration,[82] which was signed by many nations including Australia. This employed a negative form and made an oblique reference to science:

> the precautionary principle ensures that a substance or activity posing a threat to the environment is prevented from adversely affecting the environment, even if there is no conclusive scientific proof linking that particular substance or activity to environmental damage.[83]

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78 ibid., p 15.

79 A Weale (1992) *The New Politics of Pollution*, Manchester University Press, p 79.

80 International Conference on the Protection of the North Sea, *Ministerial Declaration*, London, November 1987.

81 Z Lipman (1992) 'Institutional Reform: The New South Wales Environment Protection Authority' 9 *EPLJ* 445.

82 *Declaration on Environment and Development* (1992) Rio de Janeiro, Article 15.

83 J Cameron and J Abouchar (1991) 'The Precautionary Principle' *XIV Boston College International and Comparative Law Review* 2.

Vague and misconceived terminology suggested myopia instead of foresight. Without a specified test, or mathematical axiom, 'conclusive scientific proof' is not possible. Scientific proof is very rare in the natural world. In these circumstances, to say that it was not required was disingenuous and misleading. The name of science had been invoked and compromised in a spurious cause. No logical conclusion could flow on to decision-making. A commonsense approach should have been followed if real progress in environmental protection was intended. But such progress is not always politically expedient.

Some people retained a modicum of common sense. Responding to the Rio Declaration, the German Council of Environmental Advisers restated a simple definition of *Vorsorgeprinzip*:

> According to this precept, natural resources may not be used to the limits of their capacity for intake and regeneration.[84]

In Australia, the precautionary principle was defined by the authors of the Intergovernment Agreement on the Environment (IGAE). Their tangled syntax further obscured the meaning of the precept, with certainty coupled to double-negative logic:

> Where there are threats of serious or irreversible environmental damage, *lack* of full scientific certainty should *not* be used as a reason for postponing measures to prevent environmental degradation ... [85] [my emphasis]

The parliamentary draftsperson may have been unfamiliar with hypothesis testing and perhaps confused probability with certainty. Rejecting a null hypothesis on the basis of statistical analysis is hardly the same as identifying a lack of full certainty, without any measurement. The former could be achieved with objective testing, while the latter remained beyond scientific methodology. Nevertheless, the 'guiding' clauses of the IGAE possessed a redeeming quality:

> In the application of the precautionary principle, public and private decisions should be guided by:
>
> (i) careful evaluation to avoid, wherever practicable, *serious* or *irreversible* damage to the environment; and
>
> (ii) an assessment of the *risk-weighted consequences* of various options.[86] [my emphasis]

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84 Der Rat von Sachverstandigen fur Umweltfragen (1994) cited (1995) in 25 *Environmental Policy and Law* 90.

85 *National Environment Protection Council Act* 1994 (NSW), Schedule 3.5.1.

86 ibid.

The threshold of 'serious' damage was obscure. It might be decided on moral or perceptual grounds.[87] Catastrophic 'irreversible damage', such as extinction of a species, is obviously to be avoided. Mistakes of this kind cannot be corrected. Therefore, they demand a small margin of error in prediction — a very low probability of their occurrence. The extent of irreversibility, however, is not always easy to distinguish. As well as services which could not be replaced, economists consider those that can only be restored with great cost or long delay.[88] In natural systems, complex interactions might make assessment and restoration difficult. Many environmental issues raise questions about causal relationships that have not been answered by science.[89]

Risk Analysis

With respect to the 'risk-weighted consequences' mentioned in the IGAE, Edward Christie predicted:

> environmental risk analysis will have an increasing role, in the future, because it combines the probability of occurrence of an event with its ecological consequences, based on scientific reasoning and theory.[90]

Scientific reasoning relies on quantifying the probability of sets of events in nature with objective calculation. But the assessment of ecological consequences is compounded by subjective estimation of economic, political and social variables. Lele and Norgaard argue for a pluralistic approach in environmental science:

> The discourse on environmental science has highlighted the interconnectedness of environmental processes, the consequent inappropriateness of single-user models and the need to confront the variety of values and effects involved in environmental policy making.[91]

Carpenter defines risk as, 'an expression of chance, combining both frequency and severity of damage from hazards.'[92] Risk analysis could act in two stages: an objective calculation of the probability of the subject set of

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87 S Dovers and J Handmer (1995) 'Ignorance, the Precautionary Principle, and Sustainability, 24 *Ambio* 92.

88 ibid.

89 D Bodansky (1991) 'Scientific Uncertainty and the Precautionary Principle' 33 *Environment* 4.

90 E Christie (1993) 'Ecologically Sustainable Development and Environmental Dispute Resolution' *ADRJ* 257.

91 S Lele and R Norgaard (1996) 'Sustainability and the Scientists' Burden' 10 *Conservation Biology* 354.

92 R Carpenter (1995) 'Risk Assessment', in F Vanclay and D Bronstein (eds), *Environmental and Social Impact Assessment*, John Wiley.

events; and a subjective estimate of the consequences.[93] The former involves scientific reasoning and quantitative measurement, while the latter requires value judgment, qualitative assessment and weighting.

A scientist's primary role is to identify the subject events, measure their frequency and magnitude, calculate their probabilities and predict their occurrence. But the nature of uncertainty has a complicated structure. Wynne proposes a 'taxonomy of uncertainty':[94]

- ◊ *Risk* applies where a system's behaviour is known and the probability of outcomes could be calculated.
- ◊ *Uncertainty* pertains to a system when the main parameters are known but not the probabilities.
- ◊ *Ignorance* is not knowing what is not know.
- ◊ *Indeterminacy* is where no parameters or probabilities could ever be discerned.

Risk requires analysis of previous outcomes to allow prediction of their future incidence. *Uncertainty* deals with potential events within finite limits, perhaps defined by a 'worse case scenario'.

Empirical Knowledge and Proof

In 1974, Peter Medawar outlined a hierarchy of sciences — physics, chemistry, biology, ecology — in ascending order of empirical content, with knowledge entirely derived from experience.[95] He believed that ecology had potential to find the highest level of empirical knowledge, but as a relatively new discipline it had much left to attain in research and development. It had already established links with philosophy and ethics and was regarded as particularly important in environmental decision-making.[96]

If the precautionary principle involves foresight, then it should rely on predictions based on hindsight. Ecology, with its potential for empirical

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93 K Shrader-Frechette (1985) *Risk Analysis and Scientific Method: Methodological and Ethical Problems with Evaluating Societal Hazards*, D. Reidel.

94 B Wynne (1991) 'Uncertainty and Environmental Learning: Reconceiving Science and Policy in the Preventive Paradigm' 2 *Global Environmental Change* 111.

95 P Medawar (1974) 'A Geometric Model of Reduction and Emergence', in F Ayala and T Dobzhansky (eds), *Studies in the Philosophy of Biology: Reduction and Related Problems,* Macmillan, p 57.

96 P Fairweather (1993) 'Links Between Ecology and Ecophilosophy, Ethics and the Requirements of Environmental Management' 18 *AJE* 3. See also K Mainzer (1994) *Thinking in Complexity: the Complex Dynamics of Matter, Mind and Mankind*, Springer-Verlag.

knowledge, can have the clearest hindsight. But much is yet to be seen. So far, there are many urgent questions but few conclusive answers.

Because of its relevance to popular causes, environmental science is prone to misinterpretation and manipulation by pressure groups, ranging from conservationists to exploitive industries. Stakeholders seek scientific proof of some environmental benefit or harm, safety or danger. But science, by its very nature, may not give absolute proof.[97] Much of the environmental debate inevitably hinges on attitudes formed out of either ignorance or indeterminacy. Scientists try to explain what *is known*, what *is not known*, and also what *cannot be known*. They perceive a world where proof is hard to find.

Conclusion

The language employed by decision-makers reflects a desire to emulate scientific methodology, often without an understanding of the theoretical and practical limits involved. Jargon gives policy a semblance of credibility. So the Australian translators of the precautionary principle incorporated 'scientific certainty', a *non sequitur*. This term could not be correctly ascribed to science. The etymology was legalistic and the intention populist. An implied recourse to scientific procedure might reassure the public. It did nothing to assist the pursuit of truth or the protection of the environment.

Some lawyers recognised the dilemma posed by such an abstruse version of the precautionary principle. Bodansky concluded: 'It is too vague to serve as a regulatory standard because it does not specify how much caution should be taken.'[98] He argued that, in circumstances of scientific uncertainty, a value judgment must favour the environment:

> This 'risk-averse principle' becomes particularly important if scientific knowledge is too limited to quantify uncertainty and thus cannot establish a probability distribution of possible outcomes. Since costs and benefits cannot be quantified and compared in such a situation, a value choice must be made about where to place the risk of error. The precautionary principle says that any error in risk calculation should be to the advantage of the environment and that definite economic costs must, therefore, be incurred to avert uncertain environmental harms.[99]

In legal parlance, a distinct 'shift in the burden of proof' is intimated.[100] The precautionary principle can reverse the onus by requiring the proponent to discharge the burden. Without scientific certainty, the environment should receive the benefit of doubt.

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97 B Wynne and S Mayer (1993) 'How Science Fails the Environment' 138 *New Scientist* (1876), 5 June, p 32; A Milne (1993) 'The Perils of Green Pessimism' (1993) 138 *New Scientist* (1877), 12 June, p 34.

98 Bodansky (1991).

99 ibid.

100 W Gullett (1997) 'Environmental Protection and the "Precautionary Principle": A Response to Scientific Uncertainty in Environmental Management' 12 *EPLJ* 52.

Environmental disasters may be avoided with a genuine commitment to foresight. Decision-makers must now heed the maxim of 'look before you leap'.

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