1. Introduction

So far as the laws of mathematics refer to reality, they are not certain. And so far as they are certain, they do not refer to reality.

Albert Einstein

1.1 The Research Problem and Research Objectives

In a world where Ecologically Sustainable Development (ESD) is increasingly important, many scholars and world leaders in environmental management have asserted that an integrated approach to dealing with complex environmental problems is crucial if sustainability is to be achieved. This is generally taken to mean that economic, social and ecological goals need to be integrated within policies and management objectives, and that there must be purposeful and effective discourse among system stakeholders. This view is also to be found among environmental managers in Australia, the country where the majority of the applied work reported in this thesis has been undertaken.

The issue of integration has been addressed at length within the relevant literatures over the last ten years or so. The international literature on ESD has explicitly addressed the need for integration, while international treaties and strategic programs that embody integrating principles have been implemented through the United Nations. Ecological economics, a field of study that has developed during the last 15 years, has produced a literature in which the need to integrate across these key areas has also been addressed as a fundamental part of the transdiscipline. There are also many advocates of integration in the context of the management of land and water resources. Extensive literatures can be identified that make the need for integration explicit; integrated resource management (IRM), integrated environmental management (IEM) and integrated catchment management (ICM) are examples of these.

The active involvement of system stakeholders in the planning and decision making processes is a theme that can be found within the international literature on ESD, and it is also strongly advocated within IRM, IEM and ICM literatures.

Ecological economics has as yet contributed very little to the understanding of the role of public participation in environmental management (Gill 1997). However, in other ways, ecological economics provides an ideal framework from which to address problems of sustainable development. This is mainly due to the fact that it has developed as a specialised

research agenda focused on general issues of sustainability. Practitioners assert the need to adopt a broad approach in which economic issues are analysed within the system constraints of ecological limits. Among some ecological economists, there is also a recognition of the need for other perspectives (sociological, ethical and political) to be included within the decision making framework (Faber *et al.* 1996, Luks 1998). Ecological economics has been described as a transdisciplinary approach to environmental problems, that is, it seeks to transcend conventional disciplinary boundaries and thus produce policies and strategies that are more holistic.

The research problem is essentially that whereas integration and a transdisciplinary approach are thought to be applicable to complex environmental problems, there is no general consensus on how to put these into practice. This issue can be split into two distinct, but closely related, research problems.

1.1.1 Research Problem 1 – A failure to integrate effectively

Despite the efforts of theorists and practitioners from the ecological economics and IRM/ICM/IEM fields, there is still no general agreement about how to achieve effective integration across the social, ecological and economic aspects of environmental management problems. The practical implication of this is that environmental policy makers and resource and environmental managers generally have no clearly articulated suite of methods to employ in order to achieve, or assess, holistic and effective integration. In the absence of such methods, it can be inferred that the rhetoric about integration often fails to be put into practice.

1.1.2 Research Problem 2 – Lack of an identifiable transdisciplinary framework

Whereas a transdisciplinary ecological economics framework may be able to facilitate a more holistic and integrated approach to environmental problems, it is first necessary to identify the essence of such a transdisciplinary framework and how to implement it. If this could be done, it may well provide a solid foundation for the development of methodologies to underpin systematically effective and repeatable integrative approaches to environmental management.

Some commentators within the ecological economics field maintain, at least implicitly, that the methodological foundations of the transdiscipline are best serviced through the application of existing methodologies from within its disciplinary constituency (as seems to be suggested by Costanza 1998). This implies an undescribed process for bridging the methodological

conventions of those ordinarily separated disciplinary fields. Unfortunately, little guidance has been forthcoming from within the ecological economics community as to how effective transdisciplinary discussion and learning, let alone integration, across methodologically unaligned approaches should proceed. As long as the theories pertaining to specific disciplines are less than completely understood by colleagues operating in other fields, an effective barrier to transdisciplinary cooperation is always likely to prevail. In order to harness the potential of transdisciplinarity, there would appear to be a major need to develop a meta-methodology with the aim of at least facilitating effective across-disciplinary discourse and learning. If this meta-methodology is aimed only at the facilitation of effective communication as the foundation for cooperation, it would still constitute a major contribution to the field. Such a methodology would need to be both academically acceptable and practical in application.

Based on the research problems identified above, this research has two related objectives:

1.1.3 Research Objective 1 (addressing Research Problem 2 as the basis for dealing with Research Problem 1)

To refine and develop a transdisciplinary meta-methodology, which can be readily applied to complex environmental problems. This methodology will be applied in the field of integrated resource management to demonstrate its relevance and effectiveness as an approach to dealing with complex environment problems. Within this context, the proposed methodology should have the potential to result in the effective integration of the economic, ecological and social dimensions to achieve outcomes consistent with those broadly defined sustainability objectives that are at the core of the integrated resource management as well as the ecological economics agendas.

1.1.4 Research Objective 2

From the specific focus applying to Objective 1, an attempt will be made to develop a set of common principles and methodological recommendations that can be generalised to support ecological economics work relating to areas other than IRM. This is consistent with the findings of the 1995 workshop entitled "R&D Priorities for Ecological Economics", where the development of "... the process of transdisciplinary cooperation" and "Extending the transdisciplinary research agenda" (Land and Water Resources Research and Development Corporation 1996, p.4) were identified as essential components of the ongoing development of ecological economics.

1.2 Chapter Overview

In the rest of this chapter a more thorough preview of the study is presented. In the next section, a discussion of the general background of the research is provided, while a justification for the research is given in Section 1.4. The proposed transdisciplinary framework and methodology are outlined in Section 1.5, where an approach synthesised from a number of disciplinary traditions is outlined. Some comment on the Australian context for the research is provided in the following section, while the outline of the thesis proper is given in Section 1.7 along with a justification for the particular structure chosen. A discussion of the delimitations of scope and key assumptions can be found in Section 1.8, and the chapter concludes with some summarising comments.

1.3 General Background to the Research

1.3.1 Sustainable Development

The ecological well-being of the world is an issue that has received much attention in recent years. In particular, it is the environmental impacts of human activity that cause the most concern – acid rain, greenhouse-effect changes, deforestation, poor air quality in cities, biodiversity reductions, hormone-mimicking chemicals, soil degradation and eutrophication of waterways are well known examples. The social and political reactions to these problems are many and various – ranging from apathy to the formation of green political parties in Europe and Australia, through to confrontational action by environmental activist groups such as Greenpeace.

Fundamental to the environmental debate is the conflict between economic development and environmental protection. On the one hand, economic development is necessary to produce greater quantities of consumption and investment goods to satisfy the ever increasing demands of a rising world population and rising community expectations about standards of living. On the other hand, economic activity has inevitable environmental effects with regard to the sustainability of production systems to satisfy that demand through time. The degree of actual and potential environmental impact varies depending on the type and location of economic activity, with some activities being relatively benign while others have severe environmental consequences. Society may well demand goods and services at ever increasing levels, but at the same time it must face the consequences of economic activity that have negative environmental impacts. Failure to do so will inevitably lead to a situation where poor

environmental quality substantially detracts from the standard of living. Indeed, this has already happened in many countries.

As the need to accommodate the competing demands of economic development and environmental protection becomes more urgent, many environmental policy makers have adopted the notion of ESD in their policy statements. ESD is a concept that was articulated as an outcome of the Brundtland Commission which produced the publication *Our Common Future* (World Commission on Environment and Development 1987). Since this work was published, a great increase in world attention to environmental matters has been noted (Troyer 1990).

Following the publication of *Our Common Future*, most literature dealing with the meaning of ESD refers to the definition provided within that report:

> Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts - (1) the concept of 'needs', in particular the essential needs of the world's poor, to which overriding priority should be given; and (2) the idea of limitations imposed by the state of technology and social organisation on the environment's ability to meet present and future needs.
>
> (World Commission on Environment and Development 1987, p.87).

From the overall WCED report, Troyer (1990, p.*x*) paraphrases the quest for sustainable development as "... we cannot find the resources we need to sustain and repair our environment without development – but we can live only with development which can be continued – 'sustained' – without environmental damage".

There is a plenitude of literature that addresses the issue of sustainability, and a more thorough review of that literature as relevant to this research will be pursued in Chapter Two. For the present it is sufficient to note that since the late 1980s sustainability has been very much on the international agenda.

1.3.2 Ecological Economics

Closely tied to the growth of sustainability as a topic for discussion and study, has been the nascent field of ecological economics. Although Martinez-Alier (1987) has suggested that ecological economics had its beginnings with W.S. Jevons' 1865 work *The Coal Question*, the rise of contemporary ecological economics can be dated from the late 1980s, when concerned scholars set out to address problems of sustainability that were not being adequately addressed

by existing approaches (Costanza and Daly 1987). In the introduction to the book *Ecological Economics: The Science and Management of Sustainability*, Costanza (1991, p.3) describes ecological economics as a "... new *transdisciplinary* field of study that addresses the relationships between ecosystems and economic systems in the broadest sense" (italics in original). He goes on to note that these relationships "... are central to many of humanity's current problems and to building a sustainable future but are not well covered by any existing scientific discipline." He sees ecological economics as being involved in the important endeavour of achieving sustainability, and as addressing "... the critical problems of managing our use of the planet". (Costanza *et al.* 1991, p.3). Elsewhere, it has been suggested that it should "... take a broad view encapsulating economic, social, ethical, institutional, biological and physical elements" (van den Bergh 1996, pp.35-36). It has also been observed that it will serve to bring economics much closer to ecology by treating "... technology and consumption preferences as endogenous to the economic growth process ..." (Perrings *et al.* 1995, p. 35).

Ecological economics can be characterised as a field of study that has been developed expressly to address issues of sustainability. In fact, the International Society for Ecological Economics (ISEE) includes in its mission statement the assertion that "Ecological Economics goes beyond conventional conceptions of scientific disciplines and attempts to integrate and synthesize many different disciplinary perspectives in order to achieve an ecologically and economically sustainable world (ISEE 1998a)". In the foreword to a book about practical applications of ecological economics, under the heading "About ISEE", Costanza *et al.* (1996) describe the field as follow:

> Ecological economics is the name that has been given to the effort to transcend traditional disciplinary boundaries in order to address the interrelationships between ecological and economic systems in a broad and comprehensive way. Ecological economics takes a holistic worldview with human beings representing one component (albeit a very important one) in the overall system.
>
> (Costanza *et al.* (eds) 1996, foreword page)

As a field that incorporates the principles of integration and transdisciplinary practice, ecological economics concerns itself much more with the study of whole systems than is the case for the essentially reductionist fields of economics, ecology and many other disciplines. As Costanza *et al.* (1991, p.3) point out, "(i)ts domain is the entire web of interactions between economic and ecological sectors". This strongly suggests that ecological economics is predicated on an holistic view of problem solving, in contrast to the partial and reductionist methodological stance of the sciences in general. Indeed, the authors make this explicit where

they note "Ecological economics takes a more holistic view..." (Costanza *et al.* 1991, p.3). Gill (1997) also makes this holistic character explicit in his article in which he explores the transdisciplinary nature of ecological economics.

Whether or not the pursuit of ecological economics has achieved the transdisciplinary holism implied in the above, is an issue that has received little attention in the literature. Gill (1997, p.6) argues that "... the general tendency of the ecological economics community is to spend little time with its core and underlying philosophy of transdisciplinarianism". Moreover, he asserts that little effort is "... devoted to coming to grips with what the word *transdisciplinary* really means and implies. In a paper presented to a gathering of ecological economists, Wolfenden (1997b) observed that there is little evidence of true transdisciplinary work in the ecological economics literature. Meppem and Gill (1998) link a learning approach to sustainability with the transdisciplinary framework of ecological economics. Other than these articles, there appears to be little dialogue in the ecological economics literature that explicitly deals with transdisciplinary methodology, neither how to do it nor whether it is happening. A review of present transdisciplinary practice will be provided in Section 2.2.2.

1.3.3 Integrated Resource Management

While the sustainability debate has been engaged and ecological economics has been growing, an applied field of study that involves many themes that are common to these has continued to develop - the field of integrated resource management (IRM). Following is a description of how IRM fits with both ESD and ecological economics.

In suggesting IRM as "One way to implement ESD", Hooper (1996, p.3) describes it as treating "... a catchment (the watershed, or runoff area of a portion of the land surface) or a bioregion (an area of similar ecosystems...) as an integrated ecological system, in which natural resources are managed in a wholistic way" (bracketed text in original). Also known in different contexts as integrated catchment management (ICM), integrated environmental management (IEM), and sometimes just referred to as integrated land and water management[1],

---

[1] These various labels all refer to an approach to the management of natural systems that is consistent with Hooper's description of IRM above. Variations occur mainly in terms of geographical differences. For example, ICM refers to a particular and identifiable geographical unit, i.e. a river or stream catchment, while IRM and IEM could refer to a catchment, or to some other area such as a bioregion. Whereas this thesis focuses upon ICM in that the case studies are catchment based, the general principles involved can also be applied to an

IRM can be observed to focus on issues very similar to the generic sustainability questions, and to embrace an integrated and cross-disciplinary ethos similar to the transdisciplinary approach of ecological economics.

Following is an example of the similarities between IRM and ecological economics. Under the rubric "Natural Resources Management Strategy", the Murray-Darling Basin Ministerial Council has implemented an integrated catchment management approach with the following features. The goal of the strategy is to "... promote and coordinate effective planning and management for equitable, efficient and sustainable use of the land, water and other environmental resources of the Murray-Darling Basin" (Murray-Darling Basin Ministerial Council 1990, p.8). The strategy includes the principles of "...sustainability, ...equity and justice, ...(and) economic efficiency", and is "...consistent with the objectives of the National Conservation Strategy of Australia, (namely): to maintain essential ecological processes and life-support systems; to preserve genetic diversity; to ensure the sustainable use of species and ecosystems; (and) to maintain and enhance environmental quality" (pp. 8-9). When compared with the ecological economics focus on "...environmental integrity..., equity ..., and (economic) efficiency..." (Young 1997, p.4), the similarity can be noted.

Another perspective on the way that IRM (or the related ICM) has similarities with ecological economics can be found in Mitchell and Hollick (1993). In this article, the authors reported on a review of ICM that they had carried out during 1991 (reported as Mitchell 1991 and Hollick and Mitchell 1991). A number of recommendations were made in this report, and these included the suggestion that ICM should be based on the following building blocks:

1. A systems approach, in which attention is directed toward both natural and human systems, their component parts, and the interrelationships among those parts.

2. An integrated approach ... in which attention is directed to key issues and variables identified through consultation with stakeholders and to the linkages among the key issues and variables ...

3. A stakeholder approach, in which it is recognized that citizens and nongovernment groups should be able to participate in decisions about what ought to be, what can be, and what will be for an area.

---

integrated approach to general land and water resources management. Thus, for the present purposes, ICM, IRM, IEM and generic approaches to integration are effectively interchangeable. Within the thesis, the terms will largely be used interchangeably, and for the sake of convenience, the general term IRM will be adopted.

4. A partnership approach, in which it is recognized that state agencies, local governments, and non-government organizations and individuals each have a role...

5. A balanced approach, in which attention is directed to weighing concern about enhancing economic development, protecting the integrity of natural systems, and satisfying social norms and values. In this manner, the integrated approach becomes (an) implementation of the ideas of the Brundtland Report on sustainable development at the local scale.

(Mitchell and Hollick 1993, p.740).

1.3.4 Stakeholder Participation and Learning

The recommendations of Mitchell and Hollick provide an extra dimension to the discussion - that of stakeholder participation. The involvement of stakeholders in the decision making process is not new in IRM praxis, a fact that will be explored in the next chapter. However, it does not seem to be consistently addressed in the ecological economics literature. A few authors in this literature have recently referred to research in which they have used stakeholder involvement as part of the overall decision making process. Gill (1997, p.8) provides a conceptual basis for its use when he argues that "... the most effective way to develop a sound understanding of complex ecological economic issues is through a facilitated cooperative stakeholder learning process". Cameron (1997) reports on research in which stakeholders are involved in developing understanding of the use of contingent valuation methods, and thus implies the use of stakeholder involvement as an appropriate practice. Meppem and Gill (1998, p.121) argue that the "... sustainable development agenda should be more geared towards learning processes..." and that "(l)earning is enhanced through a participatory framework inclusive of stakeholder interests". Wolfenden (1997b) reports the development of a particular participative approach and its use as a tool of ecological economics, and expands on that approach in this thesis.

The use of participative processes and an explicit recognition of the need for a learning approach are themes that are apparent in the above. It will be argued that each of these should be necessary parts of an approach that can effectively integrate across the social, economic and ecological dimensions.

The extension of the ecological economics framework to include a more explicit use of participatory learning processes as an appropriate tool for dealing with questions of sustainability will be addressed in this thesis. This idea will be explored and demonstrated in

detail, with the ESD debate, ecological economics and the praxis of IRM together providing the context of the study. The concept of participative learning is one that has been addressed, *inter alia*, in the learning organisation literature which has developed during the last 10 years (e.g. Senge 1990, Sterman 1994 and Parker and Stacey 1995). This literature provides a comprehensive theoretical and practical basis for the implementation of a learning culture within individual organisations. This knowledge base will be accessed to provide the foundations of a learning approach for use in the stakeholder-driven participative framework that is to be articulated in this thesis.

1.4 Justification for the research

Environmental problems are an increasingly important part of the natural world, and of human interaction with it; so important, in fact, that they led the United Nations General Assembly to convene the World Commission on Environment and Development (WCED) in 1983. The WCED had on its agenda, *inter alia*, "... to help define shared perceptions of long-term environmental issues and the appropriate efforts needed to deal successfully with enhancing the environment ..." (WCED 1990, p.xiii). Within this context, the WCED report identified the need for an holistic approach. In the report, the comment that "... (environmental) problems need a more holistic approach" (WCED 1990, p.355) was noted, along with the observation that:

> The ability to choose policy paths that are sustainable requires that the ecological dimensions of policy be considered at the same time as the economic, trade, energy, agricultural, industrial, and other dimensions - on the same agendas and in the same national and international institutions. This is the chief institutional challenge of the 1990's.
>
> (WCED 1990, p.357).

Following the WCED, the United Nations Conference on Environment and Development (UNCED) was convened in Rio de Janeiro in June 1992. Popularly called the "Rio Earth Summit", this conference produced a number of documents including, among others, Agenda 21. This is a broad ranging document that includes discussion of many environmental problems and suggested responses. One of the responses is the program "Integrating environment and development at the policy, planning and management levels". The overall objective of this program "...is to improve or restructure the decision-making process so that consideration of socio-economic and environmental issues is fully integrated and a broader range of public participation assured." (UNCED 1992, Annex II, paragraph 8.3). In order to

achieve this, it is suggested that "...integrated approaches to sustainable development at the regional level, including transboundary areas..." be adopted (UNCED 1992, Annex II, paragraph 8.5).

The need for an integrated or holistic approach to environmental problems is thus firmly placed on the international agenda. Furthermore, ecological economics, the field of study that is arguably most closely aligned with the international sustainability debate, and is predicated upon holistic and transdisciplinary foundations, would seem to be an appropriate vehicle through which to pursue such an approach.

However, as noted previously, the ecological economics literature contains a paucity of conceptual or practical information about holism and transdisciplinarity. Moreover, much of the work reported in the literature appears to be based upon methodologies that could be construed as neither holistic nor transdisciplinary. If ecological economics is lacking in these areas, then one can speculate that the more traditional disciplinary approaches must be even more severely curtailed.

The preceding comments suggest the need for the development of methodologies that explicitly and systematically support an holistic approach to environmental problems. Moreover, if an holistic approach is of critical importance to success in environmental management, then a lack of suitable methodologies that support such an approach may be severely hindering responses to these complex problems. This suggests the possibility that if the holistic paradigm of environmental management could be fuelled by the development of suitable methodologies and tools, then the potential for improved environmental performance may be enormous. The present research is intended to contribute towards such a methodological advance, and as such its potential impact is likely to be large in respect of environmental, social and economic outcomes.

1.5 Methodological Framework

The research will be carried out within the general field of ecological economics, which has, as a principal focus, the interaction of economic and ecological sustainability. The argument that will be developed in this study concerns the complex nature of the problems encountered in the context of ESD, and the necessity to take an holistic or systems approach to dealing with these problems. Whereas ecological economics has been founded on the principle of holism, it seems that it contains no immediately apparent tools to implement such an holistic approach. It

is the purpose of the present research to identify tools that could be used to support an holistic approach, particularly in relation to IRM. The need for a systems approach that explicitly embeds learning will be argued from a philosophical perspective drawing on work in systems theory, complexity theory and the small literature on transdisciplinarity. Building on this epistemological foundation, specific methods and tools will be identified from within the disciplines of management theory (specifically the learning organisation work of Senge (1990) and others), and systems theory (specifically the field of system dynamics). These methods and tools will be the basis for the articulation of an integrated decision making process that can be applied to the resolution of environmental problems.

In order to test the efficacy of this decision making process, its application will be assessed through the mechanism of case study illustrations. The field of IRM has been chosen for the case studies because its objectives are consistent with both ESD and ecological economics, and there are many instances of its application from which to choose.

Since the nature of this process is that its application is context dependent, it is not possible to test its superiority to any other approach in a scientifically rigorous way. However, from a case study perspective, it is possible to reflect on its apparent efficacy as a decision support tool and as a mechanism through which to implement the combined objectives of holistic sustainability, and to be able to point to ways in which the process could be improved in future applications. The legitimacy of this type of research is recognised by the current president of ISEE, Richard Norgaard who, when describing the pluralism of ecological economics, noted that some ecological economists "... argue that universal answers do not 'exist', but only arise when those with academic knowledge and those with experiential knowledge set out to resolve a particular problem in its local cultural and ecological context" (Norgaard 1996, p.4).

By way of demonstration of the integrated decision making process to be described in this thesis, two major case studies will be examined. One of these involves work with the Throsby Creek Catchment Management Committee, which is responsible for an urbanised and channelised creek within the urban area of the city of Newcastle in New South Wales, Australia. The other involves an application of the process as part of the strategic management of the water quality in an urban water supply system. In addition to the two main case studies, a further application of the integrated decision making process in the context of a strategic scoping study carried out in conjunction with the Environment Agency of England and Wales is reported.

1.6 The Australian context

Although the research problems and objectives are transnational in scope, there is nevertheless, a great deal of emphasis placed upon the Australian context in this thesis. There are a number of reasons for this, none of which should be taken to imply that the issues addressed are peculiar to Australia, or that the findings of the research might not be applicable outside of Australia. The reasons for an Australian emphasis are:

- The research was jointly funded by the Australia Research Council and the New South Wales Environment Protection Authority; the former requiring an Australian focus, while the latter only has a mandate within New South Wales, and thus only funds work directly relevant to that State;

- There are many examples of IRM available for study. Indeed, in New South Wales, IRM has been implemented as Total Catchment Management by way of an Act of Parliament. There is thus ample opportunity for selection of case studies to demonstrate the methodology; and

- Accessibility. The researcher is based in New South Wales, and it has proven cost- and time-effective to carry out the majority of the field research in that State.

1.7 Outline of the thesis

This introductory chapter has provided an overview of the thesis, outlining the scope of coverage, and the main themes that are to be developed. In the next chapter, a survey of the theoretical literature is undertaken within the fields of sustainability, ecological economics, transdisciplinarity, chaos and complexity, and systems thinking.

Chapter Three provides a survey of the literature pertaining to the practice of a systems approach. Drawing from the literatures of system dynamics and learning organisation theory, a number of methods and tools are discussed. Taken together, Chapters Two and Three provide the foundation for the methodology to be explicated later in the thesis. Chapter Four includes a description of integrated resource management in terms of the general principles, the institutional framework in Australia, and perspectives from some specific examples within Australia.

Following the articulation of the methodology in Chapter Five, a number of research case studies are described in Chapter Six. These serve to illustrate the applied dimensions of the

methodology. There are two main case studies described in the thesis as follow. The Throsby Creek urban catchment planning case study was the primary empirical work of the thesis and thus receives a more detailed treatment than the other two. A second application of the methodology highlighting the importance of good stakeholder identification will also be reported. The work for this case study was carried out as a consultancy in conjunction with the management committee of the Malpas Dam catchment. This catchment provides the major water supply for the city of Armidale, and there are a number problems relating to poor water quality. A less comprehensive case study is the third one reported, and involved work with the Environment Agency of England and Wales. In this particular example, an exploration of the use of a focused subset of the methodology is presented. Following the description of the case studies, is a chapter that provides an analysis of the outcomes of the case studies, particularly how these have helped to clarify, and indeed refine, the methodology. The eighth and final chapter contains a discussion of the conclusions and implications of the study.

1.8 Delimitations of scope and key assumptions

The thesis will be presented as a focused attempt to develop a methodology to support holistic approaches to environmental management. Moreover, the need for a transdisciplinary approach will be argued, and the illustration of such an approach will be the purpose of the case studies. An implication of the above is that the research style adopted will be one that is suited to such an approach. Therefore, the reader should expect to find only cursory reference to methods that are best suited to more conventional reductionist research. Examples of such methods would include statistical analysis of data to determine whether a null hypothesis is accepted or rejected, and the development of a deterministic predictive model with which to determine the probabilistic outcomes of various options. Rather, in an effort to reflect the different paradigm implicit in holistic scholarship, this thesis will take a synthesising approach to the development of new knowledge. That is, by drawing from a number of areas of learning, the author will attempt to create a specific methodological synthesis relevant to the research objectives previously articulated. The work thus needs to be judged in this context, with an assessment of its worth being based on its success in clearly articulating and demonstrating such a methodology.

A further constraint will apply to the case studies. They are intended to be an illustration of the methodology, not an implementation of the methodology in which actual solutions and strategies are implemented. Therefore, the models and other conceptual tools that will be

applied within the case studies will generally only incidentally reflect manipulation of real data. Moreover, since the case studies are intended to be a demonstration only, no attempt will be made to calibrate or validate the models.

1.9 Conclusion

This introductory chapter has provided an outline of what it is hoped will prove to be a substantial piece of research and scholarship. In it, the scene is set for an exploration of a wide range of literature, and for the development and demonstration of a methodology that explicitly addresses the need to be more holistic when dealing with questions of sustainability.

2. The Theoretical Foundations

This thesis is being constructed as an eclectic work that advocates an holistic approach to environmental problems, and in the process a concurrent attempt is made to embody a pragmatic holistic perspective for the internal organisation of the thesis itself. Whereas it is plainly not feasible for this work to be holistic in the strict sense (i.e. where anything that is possibly related in any way is dealt with), the author has nevertheless adopted a style that is broadranging in scope and which attempts to synthesise from across as broad a range of literature as is practical. This approach to the thesis points to a literature review that is extensive and, where appropriate, intensive; extensive in scope of coverage, and intensive in the depth of exploration of particular literatures.

The purpose of this chapter is to explore the literatures that are relevant to the task at hand – namely the specification of a transdisciplinary methodology for ecological economics such that complex environmental problems can better be managed in an integrated fashion. This immediately suggests the literatures on ecologically sustainable development (ESD) and ecological economics as obvious contenders for review. Also implicit in the above is the need to explore the literature which addresses questions of transdisciplinary methodology. Thus, the first two sections of this chapter address sustainability issues (Section 2.1), and ecological economics and transdisciplinarity (Section 2.2). This latter emerges as a key aspect of ecological economics in the first part of Section 2.2, and is addressed in detail in subsequent parts of that section.

A theme that recurs throughout Sections 2.1 and 2.2 and which will also be identified in Chapter Four on IRM, is that when dealing with complex environmental problems it is crucial to adopt a systems approach. An articulation of the philosophy of the systems approach is provided in Section 2.3. Systems theoretic approaches are not particularly new, with much of the contemporary literature cited dating back to the 1970s. In more recent times, systems theorists have tended to concentrate on the relatively new sciences of chaos and complexity. A brief review of these contemporary literatures is included as Section 2.3.1.

This chapter is intended to serve two functions. One of these, a review of the relevant literatures, is outlined above. A related function is to articulate some epistemological underpinnings for the methodology to be described in Chapter Five. In particular, the

philosophy of transdisciplinary research is explored in some depth, a task that has demanded the study of some French transdisciplinary philosophers, most of whom have published in their own language. A final observation is that the exploration of transdisciplinarity that is described in this chapter appears to be unique in the ecological economics literature in particular, and the sustainability literature in general. As such, the methodology that is to be described in Chapter Five is based upon conceptual foundations that have not previously been explicitly addressed within these contexts.

This chapter and the next cover a range of topics which at first reading may appear disjointed. Sustainability, ecological economics, transdisciplinarity, complex systems, chaos, system dynamics and learning organisations are indeed a set of topics with perhaps only minimal commonality. However, in order to provide the required underpinning of the broad perspective needed for the proposed integrative approach, it is necessary first to explore these various fields. A synthesis of the ideas identified in the two chapters will be provided later in the thesis as the proposed integrative approach is developed.

2.1 Sustainability Issues

2.1.1 Sustainability and Governance

It might perhaps seem inappropriate and/or irrelevant to start a discussion on sustainability with issues of governance. However, if one takes the view that environmental problems are in fact a result of human activity and its interaction with the environment, then it is reasonable to argue that questions of governance are vital to an understanding of how to deal with environmental problems. Indeed, a number of authors *do* take the position that environmental problems are human caused. For example, Norgaard (1994, p.15) writes:

> Environmental problems are problems of social organization. This fact is frequently portrayed as a problem of our inability to devise social systems which can foresee and control the problems of new technologies.

In a similar vein, Ludwig *et al.* (1993, p36) state that "Resource problems are not really environmental problems: they are human problems that we have created at many times and in many places, under a variety of political, social, and economic systems." Following from this perspective, the way that the international community is organising itself and making decisions about the management of environmental problems is an important aspect of sustainability.

As noted in Chapter One, the main case study work for this research has been carried out in Australia. In order to describe the context of this, it is therefore appropriate to take account not only of the international scene, but also of the way in which sustainability issues have been dealt with in Australia. The remainder of this section contains a review of these issues, starting at the international level, and encompassing the National, State and Local government level in Australia.

There are a number of pointers to the fact that Ecologically Sustainable Development (ESD) is of major importance in the world political arena, and perhaps the most obvious has been the attention paid to ESD by the United Nations (UN). The World Commission on Environment and Development was convened by the General Assembly of the UN in 1983 and produced the Brundtland Report (WCED 1987). Subsequently, the United Nations Conference on Environment and Development (UNCED) was held in Rio de Janeiro in 1992. Also known as the Rio Earth Summit, this conference produced a number of documents including Agenda 21 (UNCED 1992b). More recently, the issue of global warming was addressed at the 1997 Summit on Climate Change held in Kyoto. The Kyoto meeting resulted in an international agreement on actions to be taken to reduce global warming. Each of these UN-hosted meetings involved the participation of governments from around the world, and addressed various aspects of ESD.

The UN commitment to ESD goes further than hosting international meetings. It has an ongoing program called the United Nations Environment Program (UNEP), the mandate of which "...is to provide leadership and encourage partnership in caring for the environment by inspiring, informing and enabling nations and peoples to improve their quality of life without compromising that of future generations" (UNEP 1998). This mandate is effectively a generalised version of many definitions of sustainability, some of which will be explored in subsequent sections.

Another ongoing initiative of the UN concerning ESD is the Commission on Sustainable Development (UNCSD). Formed in 1993, the role of the Commission is to follow up on the agreements reached at the UNCED in Rio. In its Terms of Reference (UNCSD 1998), this role is articulated as:

- to review progress at the international, regional and national levels in the implementation of recommendations and commitments contained in the final documents of the United Nations Conference on Environment and Development (UNCED), namely: Agenda 21; the Rio Declaration on Environment and Development; and the Non-legally Binding Authoritative Statement of Principles

for a Global Consensus on the Management, Conservation and Sustainable Development of All Types of Forests (also known as the Forest Principles)

- to elaborate policy guidance and options for future activities to follow up UNCED and achieve sustainable development
- to promote dialogue and build partnerships for sustainable development with governments, the international community and the major groups identified in Agenda 21 as key actors outside the central government who have a major role to play in the transition towards sustainable development ...

Whereas the UNEP and the UNCSD are examples of ongoing commitment to ESD at the highest levels of world government, many national governments have shown individual commitment as well. In Australia, the Commonwealth government has also demonstrated significant commitment. In response to the 1987 Brundtland report, the Australian Government has developed the National Strategy for Ecologically Sustainable Development. This strategy was developed over a two year period beginning in 1990, and was adopted by the heads of Australia's three tiers of government (federal, state and local) in 1992. Although developed before the Rio Earth Summit, the view in Australia is that the national strategy is in alignment with the outcomes of that meeting. The official word on this is that:

> The links between Australia's National Strategy for ESD and Agenda 21 are clear. Each seeks to provide a framework for the development of environmentally sound and ecologically sustainable decision-making at all levels. While Agenda 21 takes a global perspective, it is also very much focused on the actions that individual governments need to take in order to ensure that development is sustainable. The two plans are seen as entirely compatible and complementary, and Australia's commitment to, and implementation of, its own National Strategy fulfils the obligation it entered into in Rio De Janeiro to implement Agenda 21.
>
> (Environment Australia 1998b)

The Australian states have adopted the principles of ESD within their legislative frameworks to varying degrees. Following is a review of some key legislation in New South Wales, Victoria and Queensland.

In the State of New South Wales, the *Protection of the Environment Administration Act 1996* both authorises the creation of the Environment Protection Authority and sets out its objectives as:

- to protect, restore and enhance the quality of the environment in New South Wales, having regard to the need to maintain ecologically sustainable development, and
- to reduce the risks to human health and prevent the degradation of the environment

(New South Wales Parliament 1991, Section 6)

Another New South Wales Act that explicitly addresses sustainable management of the environment is the *Catchment Management Act 1989.* This Act is the basis for the implementation of Total Catchment Management (TCM) in New South Wales. One of the objects of this Act is "...to promote the sustainable use of natural resources" (New South Wales Parliament 1989, Section 5).

In the State of Victoria, there is a broad range of legislation that supports that State's implementation of the principles of ESD. The way that the legislation combines to provide this support is summarised by the Victorian Department of Natural Resources and Environment as follows:

> The Catchment and Land Protection Act 1994 establishes a framework for the integrated management and protection of catchments that encourages community participation in the management of land and water resources. ... The Catchment and Land Protection Act operates in conjunction with a range of other legislation that also affect the management and conservation of Victoria's natural resources (eg Environment Protection Act; Water Act; Flora and Fauna Guarantee Act; Planning and Environment Act; National Parks Act; Forests Act; Land Act; and the Conservation, Forests and Lands Act). Together, these form a strong legislative base for ensuring ecologically sustainable development which protects environmental values while supporting a productive and developing primary industry sector.
>
> (Victorian Department of Natural Resources and Environment 1998)

Clearly, both New South Wales and Victoria have a strong legislative basis for pursuing ESD within the states. Each has a number of state departments and/or agencies which, under the above legislation, carry out various aspects of managing the environment within the framework of ESD. Australia has a three-tier government structure, with federal, state and local government each having different responsibilities in the public management of the nation. It is at the local level that the decisions about many of the day-to-day development issues are taken.

From the beginning of 1998, local government in New South Wales has operated under an Act of Parliament that requires them to include ESD explicitly in their decision making. The New South Wales Department of Local Government has observed that this Act requires councils to "... adopt a strategic 'whole of council' approach toward the recognition of ecologically sustainable development and to respond positively to environmental problems in their areas" (NSW Department of Local Government 1998, p.3). Called the *Local Government Amendment (Ecologically Sustainable Development) Act 1997*, it alters the charter under which councils operate so that it clearly includes reference to ESD. The relevant part of this new charter reads "...to properly manage [sic], develop, protect, restore, enhance and conserve the environment

of the area for which it is responsible, in a manner that is consistent with and promotes the principles of ecologically sustainable development" (New South Wales Parliament 1997, Schedule 1). The Act also imposes comprehensive State of the Environment (SoE) reporting requirement on councils. In their annual reports, they are now required to include

> ... a report as to the state of the environment in the area, and in particular in relation to the following environmental sectors: (i) land, (ii) air, (iii) water, (iv) biodiversity, (v) waste, (vi) noise, (vii) Aboriginal heritage, (viii) non-Aboriginal heritage, with particular reference, with regard to each such environmental sector, to: (ix) management plans relating to the environment, (x) special council projects relating to the environment, (xi) the environmental impact of council activities.
>
> (New South Wales Parliament 1997, Schedule 1).

Local government in the State of Queensland is also now required to make explicit allowance for ESD within its activities. The *Integrated Planning Act 1997* provides the legislative framework for this, and is designed explicitly so that ecological sustainability will be addressed in all planning and development in the State. Section 1.2.1 states that the purpose of the Act is to

- ... seek to achieve ecological sustainability by –
- coordinating and integrating planning at the local, regional and state level; and
- managing the process by which development occurs; and
- managing the effects of development on the environment.

(Queensland Government 1997)

The above survey is intended to give the reader a sense of the degree to which sustainability issues have become entrenched in the international scene. Through the coordinating actions of the UN, governments around the world have joined the international community to express their commitment to dealing with environmental problems and for development to be as sustainable as possible. Australia is one nation that has made significant political and legislative advances towards ESD, with its National Strategy for Ecologically Sustainable Development an example of this. At the state level, there is legislation that supports the principles of ESD, while local government in New South Wales and Queensland is directly confronted with ESD through the *Local Government Amendment (Ecologically Sustainable Development) Act 1997* and the *Integrated Planning Act 1997* respectively.

Other legislation that refers to sustainability is the New South Wales *Catchment Management Act 1989*. Although actual mention of ESD is absent from this Act, the sustainable use of natural resources use is articulated as the key focus. Section 4 of the Act reads "total

catchment management is the co-ordinated and sustainable use and management of land, water, vegetation and other natural resources on a water catchment basis so as to balance resource utilisation and conservation" (New South Wales Parliament 1989, Sect. 4). The objectives of the act are stated as:

> (a) to co-ordinate policies, programs and activities as they relate to total catchment management; and
>
> (b) to achieve active community participation in natural resource management; and
>
> (c) to identify and rectify natural resource degradation; and
>
> (d) to promote the sustainable use of natural resources; and
>
> (e) to provide stable and productive soil, high quality water and protective and productive vegetation cover within each of the State's water catchments.
>
> (New South Wales Parliament 1989, Sect. 5).

The review points to the fact that ESD is an important international issue that is becoming increasingly entrenched within legislation in Australia. With that now established, it is perhaps appropriate to explore what is meant when people talk and write about ESD and/or sustainability. The next section provides a survey of the various ways that ESD has been defined. A particular focus of the section will be to explore sustainability from the perspective of decision making and choice.

2.1.2 What is Sustainability?

There have been numerous attempts at articulating just what is meant by sustainability and/or sustainable development. The concept of ESD was brought to world prominence following the WCED and the report *Our Common Future* (WCED 1987). The definition of sustainable development which was provided in that report has subsequently been referred to by just about every serious work on sustainability. Indeed, that definition was quoted in the introductory chapter of this work, but it has been so significant in the literature that it bears repeating here.

> Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts - (1) the concept of 'needs', in particular the essential needs of the world's poor, to which overriding priority should be given; and (2) the idea of limitations imposed by the state of technology and social organisation on the environment's ability to meet present and future needs.
>
> (WCED 1987, p.87).

Following the WCED report, numerous attempts have been made to define clearly what ESD is, how it can be measured, and how it can be achieved. For example, Pezzey (1992) lists 51 different definitions of sustainability, and notes that even that apparently comprehensive listing is not exhaustive.

Munasinghe and Shearer (1995) reported on the World Bank's 1992 "International Conference on the Definition and Measurement of Sustainability: The Biogeophysical Foundations". They noted that in seeking a workable definition of sustainability, the participants decided that the following were important aspects of a definition:

- the number of variables it contains;
- ease in measuring these variables;
- its capacity for generalization;
- its applicability to different situations; and
- the flexibility it allows.

As an outcome of the conference the following definition was developed (Munasinghe and Shearer 1995, p.5):

> Biogeophysical sustainability is the maintenance and/or improvement of the integrity of the life-support system on Earth. Sustaining the biosphere with adequate provisions for maximizing future options includes providing for human economic and social improvement for current and future human generations within a framework of cultural diversity while: (a) making adequate provisions for the maintenance of biological diversity and (b) maintaining the biogeochemical integrity of the geosphere by conservation and proper use of its air, water and land resources. Achieving these goals requires planning and action at local, regional and global scales and specifying short- and long-term objectives that allow for the transition to sustainability.

Interestingly, the Rio Earth Summit did not produce yet another attempt at defining sustainability or ESD. Rather, a series of general principles was agreed in relation to environment and development. In all, 27 principles were included in the *Rio Declaration on Environment and Development* (UNCED 1992a). A few of these principles point the way toward the working definition of sustainability that seems to underlie the entire UNCED report:

- Principle 1 - Human beings are at the centre of concerns for sustainable development. They are entitled to a healthy and productive life in harmony with nature;
- Principle 2 - The right to development must be fulfilled so as to equitably meet developmental and environmental needs of present and future generations;

- Principle 15 - In order to protect the environment, the precautionary principle approach shall be widely applied by States according to their capabilities ...

Taken together, these suggest the following definition: *Current economic activity must be undertaken in such a way so as to minimise risks to the environment, and to provide fairly for the material, environmental and other needs of people today and in the future.* This definition is little different from that developed by the WCED and reported above, except perhaps that this one makes no explicit mention of the world's poor, although they are implicitly included in the words "provide fairly".

A further two principles from the Rio Summit are particularly relevant to the present research. These are:

- Principle 10 - Environmental issues are best handled with the participation of all concerned citizens, at the relevant level. At the national level, each individual shall have appropriate access to information concerning the environment, ... and the opportunity to participate in decision-making processes. States shall facilitate and encourage public awareness and participation by making information widely available. ... ; and
- Principle 25 - Peace, development and environmental protection are interdependent and indivisible.

As outlined in Chapter One, public participation in decision making is seen as an important part of dealing appropriately with complex environmental problems, and this issue is clearly articulated in Principle 10. Also, the need for an holistic systems approach was discussed, and this is consistent with the principle that "peace, development and environmental protection are interdependent and indivisible" (i.e. they form a system).

The Federal Government in Australia has suggested the following working definition of ESD: "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" (Environment Australia 1998a, p.1). This definition is included in the Australian National Strategy for Ecologically Sustainable Development (NSESD), wherein the following articulation of the ideas is also provided:

> Put more simply, ESD is development which aims to meet the needs of Australians today, while conserving our ecosystems for the benefit of future generations. To do this, we need to develop ways of using those environmental resources which form the basis of our economy in a way which maintains and, where possible, improves their range, variety and quality. At the same time we need to utilise those resources to develop industry and generate employment.
>
> (Environment Australia 1998a, p.1)

The NSESD also includes five key principles:

- integrating economic and environmental goals in policies and activities;
- ensuring that environmental assets are properly valued;
- providing for equity within and between generations;
- dealing cautiously with risk and irreversibility; and
- recognising the global dimension.

(Environment Australia 1998b)

These are included here because they serve to give a more complete picture of how ESD is envisaged for Australia at the federal level.

In the New South Wales *Protection of the Environment Administration Act 1996*, ESD is not defined as such. Rather, its scope is described by the actions, principles and programs that need to be undertaken. The Act states that ESD "... requires the effective integration of economic and environmental considerations in decision-making processes" and that ESD can be achieved through the implementation of the following:

(a) The precautionary principle namely, that if 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.

(b) Inter-generational equity namely, that the present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations.

(c) Conservation of biological diversity and ecological integrity.

(d) Improved valuation and pricing of environmental resources.

(New South Wales Parliament 1991, Section 6.)

There are obvious similarities between this and the principles of the NSESD. Indeed, the precautionary principle, intergenerational equity and improved valuation of environmental resources are themes that can be found throughout the various definitions of ESD. Item (c) in the above list reflects the biogeophysical perspective outlined by Munasinghe and Shearer (1995).

The IRM literature (and ICM, IEM, TCM literatures) also contribute to a general understanding of what is meant by ESD. Whereas no definitions of ESD as such are apparent in that literature, the praxis of IRM is arguably about ESD in action. As such, the bounds of what ESD is and what it is not, can to some extent be inferred from the scope of IRM. A comment will be made on this following the review of that literature in Chapter Four.

The above discussion gives something of the sense of the nature of ESD. Intergenerational equity, the precautionary principle, the protection of biodiversity and ecological integrity, better valuation of natural resources and the integration of economic and environmental issues in decision making are common themes. Moreover, although only a few definitions are explored above, these themes are also common in many other writings. A review of Pezzey's (1992) listing of 51 definitions taken from the literature reveals the same recurring themes.

2.1.3 ESD and the Systems Approach

Notwithstanding the above generalisations, there is a further aspect of sustainability that usually does not find its way into definitions, but is either implied therein or addressed in a different manner. This is the fact that questions of sustainable development involve the management of complex systems in which the economy and the environment interact inexorably through complex linkages and feedback mechanisms. Agenda 21 alludes to this by suggesting that the "... integration of environment and development concerns and greater attention to them will lead to the fulfilment of basic needs, improved living standards for all, better protected and managed ecosystems and a safer, more prosperous future" (UNCED 1992, Para. 1.1). What is implied here is that because of the interacting nature of environment and development (i.e. that they form a system), an integrated approach is required.

This complex system aspect of sustainability is addressed explicitly by a number of authors. Borrowing from Pezzey (1992), the following comments can be found elsewhere in the literature.

> ... development ... depends upon conservation, and that conservation depends equally upon development (Allen 1980, p.9).
>
> conservation of the biosphere is a prerequisite for human survival and well-being; ... interdependence is an inescapable part of life (Allen 1980, p.16).
>
> Throughout most of history, the interactions between human development and the environment have been relatively simple and local affairs. But the complexity and scale of these interactions are increasing ... What were once straightforward questions of ecological preservation versus economic growth now reflect complex linkages - witness the feedbacks among energy and crop production, deforestation and climatic change that are evident in studies of the atmospheric 'greenhouse' effect (Clark and Munn 1986, p.5,).
>
> ... economic development and environmental quality are interdependent and, in the long term, mutually reinforcing (Tolba 1987, p.150).

It is the fact of this interdependence between the environment and economic activity that strongly suggests the use of a systems approach in dealing with environmental problems. This is a theme that many ecological economists pursue. Common (1995, p.10), in his paper "What is Ecological Economics?", captures the essence of this where he writes:

> Sustainability might be regarded as *the* problem in ecological economics. The problem has its origins in the interdependency of economic and ecological systems [emphasis added].

This review of ESD suggests the content for the rest of this chapter and Chapters Three and Four. Following Common, ecological economics is centrally placed as a research agenda that focuses on sustainability. This field will be reviewed in the next section, including an in-depth review of transdisciplinarity as a concept. The systemic nature of environmental problems has also been identified in the above, and some theoretical aspects of systems study will be presented in Section 2.3 on Complex Systems and the Systems Approach. Chapter Three address systems praxis – the applied side of systems theoretic approaches. Within this general topic, the methods and tools of system dynamics will be presented, and these provide the basis of the methodology to be developed in Chapter Five. Other examples of applied systems work to be explored in Chapter Three include cognitive mapping techniques and principles of learning organisations. Each of these will be drawn upon in the articulation of the methodology presented in Chapter Five. The need for an integrated approach is also identified in the ESD literature, and this will be addressed in Chapter Four which deals with Integrated Resource Management. In respect of integrating across social, economic and ecological aspects of environmental management problems, stakeholder participation will also be explored in that chapter as a key principle underlying effective integration.

2.2 Ecological Economics and Transdisciplinarity

The first research objective for this thesis is to explore the philosophical foundations of transdisciplinary research, and from these to develop a methodology that may be pragmatically applied specifically in the IRM area. Based on this objective, and since ecological economics has been inextricably linked with transdisciplinarity (Costanza 1991), it is appropriate to address both ecological economics and transdisciplinarity within the one section.

Ecological economics is a relatively new field of academic and policy endeavour which, as observed in the first chapter, has mainly developed over the last 15 years. In recognition of its relative youth as an area of scientific investigation and the fact that many people may thus not

be familiar with it, it is perhaps appropriate to describe the field as it is practised. A simple description could be that "Ecological Economics is a new field formed at the intersection of two older ones" (i.e. ecology and economics), an observation made by Costanza (1989, p.5) in his introductory article to the then newly published journal *Ecological Economics*. However, this description is unsatisfactory in that it does not give any insights into the nature of this new epistemological space. The review presented in this section is intended to provide a detailed exploration of various aspects of ecological economics. Normative aspects will be identified from authors who have addressed various parts of the question 'What is ecological economics?'. Once these 'ought to be' issues have been described, the nature of transdisciplinarity and how it might be identified, applied and critically reviewed is discussed.

2.2.1 Ecological Economics - a Normative Focus

Perhaps the earliest tangible and publicly accessible evidence of the beginnings of the new field of ecological economics is to be found in a special issue of the journal *Ecological Modelling* (1987, Vol. 38, Part 1). The collection of papers presented in that issue was seen as "... a hopeful first step toward a true synthesis of ecology and economics that could lead to better management of renewable and non-renewable natural resources and a sustainable future" (Costanza and Daly 1987, p.1). The need for pursuing such a synthesis was that "... current economic paradigms have some serious shortcomings when it comes to dealing with natural resources...(and that) ecological paradigms tend to ignore human cultural behavior as an object of direct study" (Costanza and Daly 1987, p.1). As a way of emphasising the importance they attached to this synthesis of economics and ecology, they noted that for the present generation, this issue is second in importance only to avoiding nuclear war.

Elsewhere, Costanza and others have identified this synthesis of economics and ecology as a "... new *transdisciplinary* field of study that addresses the relationships between ecosystems and economic systems in the broadest sense" (Costanza *et al.* 1991, p.3, emphasis in original). They explain why they call ecological economics transdisciplinary in that it

> ... goes beyond our normal conceptions of scientific disciplines and tries to integrate and synthesize many different disciplinary perspectives. One way it does this is by focusing more directly on the problems, rather than the particular intellectual tools and models used to solve them, and by ignoring arbitrary intellectual turf boundaries.
>
> (Costanza *et al.* 1991, p.3)

This transdisciplinary problem-focused approach, suggests a field of study that is eclectic in its methodologies, broad in it epistemological foundations and diverse in its practitioners. Common (1995) argues that whereas such methodological pluralism might be messy, it should nevertheless be willingly accepted by ecological economists. Norgaard (1996, p.4) identifies a "pluralistic vision" for ecological economics, which means that practitioners must be "... open to working in a multitude of contradictory ways".

Subsequent to the special issue of *Ecological Modelling*, the International Society for Ecological Economics (ISEE) was formed in 1988. According to its internet home page, "ISEE is a nonprofit organization that encourages the integration of economics and ecology into a transdiscipline aimed at developing a sustainable world" (ISEE 1998b). The journal *Ecological Economics* was also first published at that time, and includes in its aims and scope the statement that "The journal is transdisciplinary in spirit and methodologically open" (inside front cover of each issue of the journal). Taken together, these beginnings of ecological economics emphasise the importance and centrality of a transdisciplinary meta-methodology.

However, although transdisciplinarity has been inextricably linked with ecological economics, researchers have given little attention to how it might be achieved in practice. Indeed, one only needs to scan the contents tables of *Ecological Economics* over recent years to observe the paucity of articles that deal explicitly with transdisciplinarity - either as a concept or as a methodology. Since ecological economics is supposedly a "transdisciplinary field of study" (Costanza *et al.* 1991, p.3), and since this particular research is explicitly about the articulation of a methodology that is transdisciplinary, it is appropriate to address the concept of transdisciplinarity in some detail. A discussion of this will be presented at the conclusion of the present section.

The ecological economics world view incorporates a strong systems perspective. That is, it is an approach that "... addresses the relationships between ecosystems and economic systems in the broadest sense" (Costanza *et al.* 1991, p.3). This is in contrast to the distinct and largely disjointed fields of economics and ecology, which do not usually deal with the relationships between ecosystems and economic systems, and address fundamentally different issues (Common and Perrings 1992). Indeed, it has been written that ecological economics *begins* from a systems view of environmental problems: "Ecological economics starts from an appreciation of the interdependence of economic and natural system(s) ... and much of its core literature is an exploration of the implications of that interdependence" (Common 1995, p.2).

The systems view that underpins ecological economics leads to some important methodological observations. Common (1995, p.11) identifies risk as important: "Coming at things from the systems interdependence perspective, ecological economics recognises uncertainty as a fundamental feature of economic activity, as economics does not". Perrings *et al.* (1995) note that the existence of a jointly evolving ecological economic system means that:

> ... environmental 'risks' associated with economic activity have become endogenous (the 'risks' are affected by that activity), and correlative (they are not statistically independent). Given that they are also potentially catastrophic, it is not surprising that the menu of policy choices should focus on measures that preserve options whilst encouraging learning ...
>
> (Perrings *et al.* 1995, p.22. Brackets in original)

On the existence of strong links between the economy and the environment, Perrings *et al.* (1995, p.18) have written: "The adoption of a systems perspective serves to re-emphasise the point that economic systems are underpinned by ecological systems, and that there is a dynamic interdependency between the two". Interrelated economic and ecological systems are not amenable to conventional economic analysis because "... the ecological-economic system is neither observable (through the set of prices) nor controllable (through any set of incentives based on those prices)" (Perrings *et al.* 1995, p.23, brackets in original). Furthermore, since a system includes relationships between system components (a characteristic of systems that will be addressed in Section 2.3), it is important to understand these relationships and to recognise that some problems may exist as a function of these relationships. Proops (1989, p.71) has observed that it is particularly the relationships "between humankind and nature" that generate environmental management problems.

As discussed above, there are a number of characteristics of this field of study called ecological economics, and these have implications for the way analysis is undertaken and decisions are made. Following is an articulation of some of the implications of these distinguishing characteristics.

Ecological economics is transdisciplinary and thus cuts across traditional disciplinary boundaries. However, with university departments and government agencies usually organised along disciplinary lines, it is not easy to identify where an ecological economics project should fit, nor which disciplinary tradition should take the lead in initiating and managing the project. Such organisational problems are not trivial, involving issues such as budgets, individual reward structures and the relative status of the various disciplines, and have the potential to

divert significant resources away from productive use and into defensive strategies which reduce the prospective benefits from effective transdisciplinary cooperation.

There is an intentional problem focus. With environmental problems being complex in terms of system relationships and system dynamics, it is important that selected methodologies are able to handle such complexity. However, disciplinary approaches, even if robust within their disciplinary domain, are soon found inadequate when applied to problems where system interrelationships are significant. This is because they are not designed to deal with the problem space between disciplines, but only the problem space within disciplines. A problem focus thus requires the development of methodologies that explicitly take account of the system complexities.

Closely related to the previous point is that ecological economics adopts a systems stance to environmental problems. Among other things, the systems perspective emphasises the understanding of relationships among system components. A more detailed review of the systems theoretic approach will be presented in Section 2.3.

Risk and uncertainty are seen as key elements of environmental problems, and are addressed explicitly within the ecological economics framework. Perrings *et al.* (1995, p.22) comment that "... policy choices should focus on measures that preserve options..." is another way of saying that policy should be consistent with the precautionary principle. Moreover, in the context of managing under uncertainty and risk, Perrings *et al.* (1995, p.22) point to the need for "learning" as part of the process. Although they do not explain what they envisage by this, it does not seem unreasonable to suggest that "learning" could include actions like; receiving feedback from mistakes and successes, adapting to changes, keeping options open, and modifying policies and management practices as new information is received.

With ecological economics recognising the interrelatedness of ecological and economic systems, it is not appropriate for practitioners to use analytical techniques that ignore such relationships and focus on just one aspect of the system. The methods that have been most commonly used in environmental policy assessment are derived from the market model of traditional neoclassical economics. However, since these approaches depend on market prices (either actual or imputed), they are not satisfactory for application to a complex system which "...is neither observable (through the set of prices) nor controllable (through any set of incentives based on those prices)" (Perrings *et al.* 1995, p.23. Brackets in original). Ecological economics must therefore develop new analytical techniques that explicitly account for system

relationships. Moreover, the political framework within which environmental policy is formulated will need to be substantially influenced by such techniques, so that resultant policies are more integrated and reflective of the complexities of the real systems.

The above discussion has served to outline a normative foundation of ecological economics, and to suggest how this should influence environmental management professionals in the way they deal with environmental problems. The purpose of this review is to provide a springboard for the development of the methodology that is described in this thesis. As such, the review is not exhaustive of the entire field of ecological economics, but is rather an attempt to highlight those major foundations that are relevant to the present work.

There are some aspects of ecological economics that have not been explicitly addressed in this review. For example, Costanza *et al.* (1991) have identified the following as fundamental to ecological economics:

1. the basic world view is dynamic, systems, evolutionary;
2. the time frame is multi-scale, from days to eons;
3. the space frame includes a hierarchy of scales from local to global;
4. the species frame is whole ecosystems including humans;
5. the primary macro goal is ecological economic system sustainability;
6. the primary micro goal must be consistent with the overall system goals;
7. there is a prudent scepticism about technical progress; and
8. the academic stance is transdisciplinary, pluralistic and problem focussed.

Whereas the present work is generally in accord with all these points, it is points 1, 4, 5, 6, and 8 that form the explicit foundation of the new methodology developed in this thesis. The remaining points are not overlooked entirely, as the methodology itself is able to account for them as part of its application.

The next main task in this thesis is to explore the practice of ecological economics, and to assess to what extent it is consistent with its normative foundations. However, since one of the key characteristics of ecological economics is transdisciplinarity, it is important first to discuss the nature of transdisciplinarity in more detail.

2.2.2 Perspectives on Transdisciplinarity

Ecological economics has been characterised as a "... transdisciplinary field of study that addresses the relationships between ecosystems and economic systems in the broadest sense" (Costanza et al. 1991, p.3). The authors explain why they call ecological economics transdisciplinary in that it:

> ... goes beyond our normal conceptions of scientific disciplines and tries to integrate and synthesize many different disciplinary perspectives. One way it does this is by focusing more directly on the problems, rather than the particular intellectual tools and models used to solve them, and by ignoring arbitrary intellectual turf boundaries.

(Costanza et al. 1991, p.3)

The notion of transdisciplinarity has been institutionalised by the International Society for Ecological Economics via their journal *Ecological Economics*, which includes among its aims and scope the statement that "The journal is transdisciplinary in spirit and methodologically open".

Whereas transdisciplinarity is foundational to ecological economics, the epistemological basis of this concept has been all but ignored in the mainstream literature. The meaning of *transdisciplinary* is generally not explicitly defined, but tends to be implied either by common usage or by its etymological roots (i.e. *trans* meaning across or beyond, and *disciplinary* taking its usual academic meaning). Many people seem to imply that *transdisciplinary* is roughly synonymous with *multidisciplinary* or *interdisciplinary* and use the words interchangeably. An example of this is Faber *et al.* (1996), who while arguing for an ecological economics that is clearly transdisciplinary, choose to identify *interdisciplinary* research as the means of achieving this. Moreover, they appear to avoid all use of the word *transdisciplinary* – even the index of their book omits reference to it.

Perhaps this is all just a matter of semantics. Possibly, though there do appear to be some factors which distinguish between *multidisciplinary*, *interdisciplinary* and *transdisciplinary*.

Following is a review of some work on the nature of transdisciplinarity. A theme that recurs throughout the review is that transdisciplinarity *is* different to the others, and at a fundamental level. Among other things, transdisciplinarity involves a blurring of disciplinary boundaries and a genuine integration among the disciplines such that synergistic outcomes are achieved.

One author who has tackled this issue is Gill (1997). He criticises the ecological economics community for failing to come to grips with its "... core and underlying philosophy of

transdisciplinarianism" (Gill 1997, p.6). His view is that "... the ecological economics transdisciplinary focus implies a synergistic[2] alliance between and across conventional disciplinary boundaries" (Gill 1997, p.6). However, if the synergies of such an alliance are to be captured, there needs to be a change in the way cross-disciplinary communication is carried out.

> No less than a new language of universal transparency is required. There can be no recourse to disciplinary jargon if cross-disciplinary cooperation is to proceed.

(Gill 1997, p.6)

A diagramatic representation of the concept of transdisciplinarity is presented in Figure 2.1, a diagram adapted from Gill (1997, p.7). In the diagram, transdisciplinarity is depicted as being part of the vortex of activity generated by the synergistic combination of the individual intellectual traditions of economics, other social sciences and ecology. Note that the identity of each of these traditions is lost within the vortex, with a new identity, ecological economics, emergent from this blurring of disciplinary boundaries. Moreover, the vortex gets wider as the degree of transdisciplinarity increases, and this represents the capture of synergies that are hypothesised to be available through effective transdisciplinary cooperation. Just as for transdisciplinary work, inter- and multi- disciplinary work involves crossing of the boundaries of the individual disciplines. However, following the diagram, in contrast to the integration that occurs under transdisciplinarity, with inter- and multi- disciplinary work the identity of the individual disciplines remains distinct.

---

[2] The concept of synergy is referred to throughout this thesis. Synergy, resulting from cooperative action, is understood to embed the notion that a whole is greater than just a simple sum of its parts. This will be discussed in detail in Section 2.4.

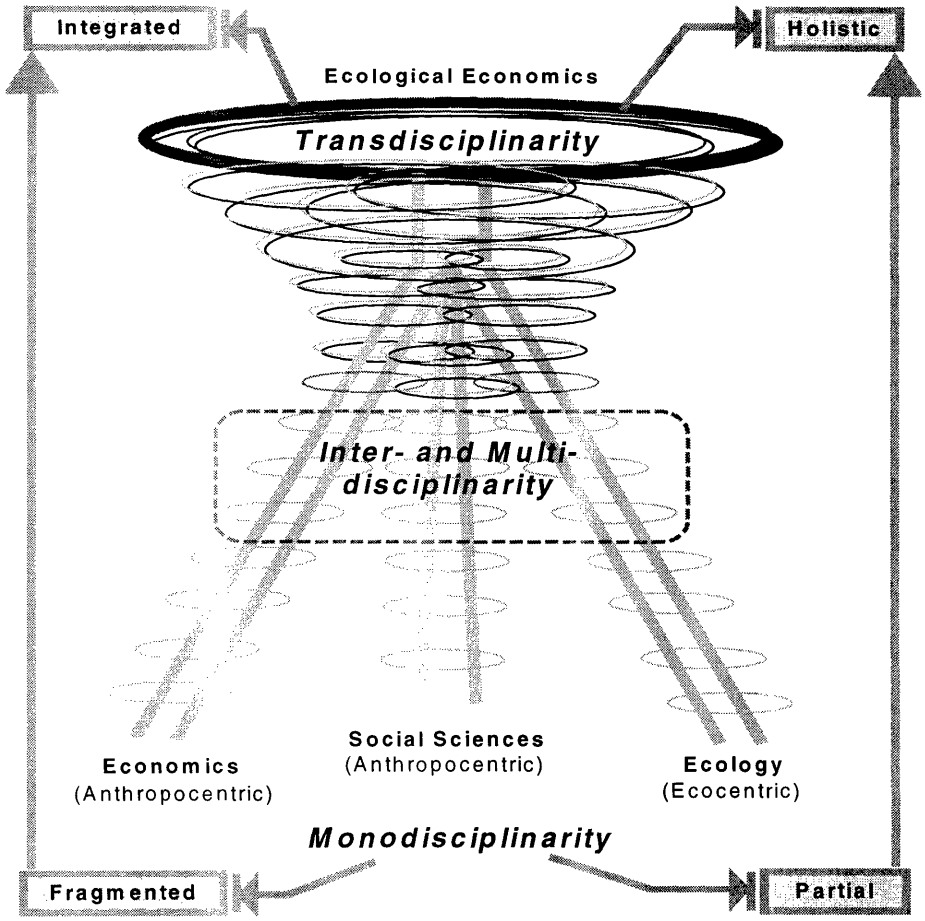

Figure 2.1 **A representation of the disciplinary to transdisciplinary transition, including the explicit linking of the concepts "integrated" and "holistic" with transdisciplinary ecological economics.**

(adapted from Gill 1997, p.7)

As well as the blurring of boundaries between the disciplines, the move in the diagram from monodisciplinarity through to transdisciplinarity involves a move from fragmented partial study, to integrated holistic study. The need for integrated and holistic work has been identified in the preceding discussion on sustainability, and will also be shown to be important in a subsequent discussion of integrated catchment management, the general field of endeavour within which the case study work for this research was conducted.

A further insight embedded in the diagram that needs to be explored is the notion that economics and the social sciences are 'anthropocentric', and ecology is 'ecocentric'. This typology follows Eckersley (1992) in which she explores the various philosophical positions that underpin different views about environmental problems. Commenting on the then current state of green politics, she observes that:

> ... the most fundamental division from an ecophilosophical point of view is between those who adopt an anthropocentric ecological perspective and those who adopt a nonanthropocentric ecological (or ecocentric) perspective. The first approach is characterized by its concern to articulate an ecopolitical theory that offers new opportunities for *human* emancipation and fulfilment in an ecologically sustainable society. The second approach pursues these same goals in the context of a broader notion of emancipation that also recognizes the moral standing of the nonhuman world and seeks to ensure that it, too, may unfold in its many diverse ways.
>
> (Eckersley 1992, p.26)

Gill has by implication extended this general argument to categorise disciplinary environmental enquiry as having either a fundamentally human focus (economics, social sciences) or a fundamentally ecological focus (ecology). The integration that transdisciplinarity provides must thus be able to cope with such philosophical diversity. The need for integration across methodologically diverse frontiers is also asserted by Luks (1998).

In the quote above from Costanza *et al.* (1991), the view that ecological economics is problem-focused was expressed. Looking outside the ecological economics literature, a typology that uses classes of problems to differentiate between monodisciplinary, interdisciplinary and transdisciplinary work is to be found in Kesik (1996). A slightly modified summary of Kesik's work appears below as Table 2.1. In this typology, transdisciplinarity is seen as that approach that is indicated for "wicked problems", where there is no problem formulation methodology available, no explicit basis for termination of problem solving activity and plausible alternative solutions can always be provided. Solution strategies are by trial and error, and dialogue about the problems will be complex, chaotic and require a learning stance. Examples of such problems are social policy, urban design, and environmental problems.

Table 2.1 Classification of problems

	Classes of Problems		
	Well Defined	**Ill Defined**	**Wicked**
Characteristics	Ends or goals are prescribed or apparent	Both the ends and the means of solution are unknown at the outset, to a lesser or greater degree	No problem formulation methodology available. No explicit basis for termination of problem solving activity. Plausible alternative solutions can always be provided.
Solution Strategies	Analytical or algorithmic	Iterative and evolutionary	Trial and error - no formal strategies.
Examples	- alphabetical sorting - analytical geometry	- architectural design - management systems	- urban design - social policy - environmental problems
Disciplinary Involvement	**Monodisciplinary**	**Multidisciplinary**	**Transdisciplinary**
Dialogue Characteristics	- procedural - linear - self-referential	- explorative - non-linear	- complex - chaotic - learning

Source: Adapted from Kesik (1996)

However useful the above descriptions of transdisciplinarity might or might not be, they do not really deal with the epistemological basis of transdisciplinarity. For this, one must look to philosophers of knowledge who have dealt explicitly with transdisciplinarity as a valid approach to understanding and coping with complex problems. The remainder of this section will provide a discussion of a literature that has developed exclusively around the concept of transdisciplinarity. Prior to this thesis, there appear to be no authors who have made the explicit link between the transdisciplinarity literature and ecological economics. Moreover, there is a general dearth of scholarship in the area, and this has meant that transdisciplinarity has been poorly addressed. Commenting on "transdisciplinary ambiguity", Judge (1994a, p.1) writes:

> Whereas many are familiar with efforts at interdisciplinarity over the past decades, transdisciplinarity is as yet poorly defined – if it does not lie beyond what is commonly accepted. Clearly it is in some way associated with whatever can be understood to be "beyond" interdisciplinarity and a discipline-bound perspective.

Here Judge is making a clear distinction between interdisciplinarity and transdisciplinarity. Clearly, for him at least, the issue is greater than one of mere semantics.

Bourguignon (1997), attributes the source of the concept of transdisciplinarity to Niels Bohr (1955). Although the word itself does not appear in Bohr's work, Bourguignon identifies the concept where Bohr writes "the problem of the unity of knowledge is closely related to our search for a universal understanding, intended to uplift human culture" (cited by Bourguignon 1997 as Bohr 1991, p.272), and notes that these thoughts of Bohr's were provoked by the quantum revolution in physics.

Bourguignon (1997) attributes the first use of the word "transdisciplinary" to Piaget (1970), who expressed his hope that the interdisciplinary method would proceed to the higher stage of transdisciplinary research. While the former is characterised by interactions and reciprocities between the disciplines, the latter would be developed with a system perspective in which the disciplinary boundaries and the links between them would be properly spanned.

Following his review of the history of transdisciplinarity, Bourguignon (1997) identifies Nicolescu (1985 and 1993) as the author who has developed the most elaborate and original contributions to the epistemology. He observes that for Nicolescu, transdisciplinarity is inextricably linked with the revolution in quantum physics, which has led Nicolescu to develop ideas from quantum physics about *the logic of the included third* and *levels of reality*, and to apply these to his understanding of transdisciplinarity.

Nicolescu distinguishes transdisciplinarity from multidisciplinarity (or pluridisciplinarity as he sometimes calls it) and interdisciplinarity. He asserts that multidisciplinarity concerns the study of a topic from within a particular disciplinary perspective, but with the addition of insights from other disciplines. He points to an enrichment of the topic by "... blending the perspectives of several disciplines" (Nicolescu 1997, p.1). Whereas multidisciplinary research obviously includes insights from many disciplines, its goal nevertheless "... remains limited to the framework of disciplinary research" (Nicolescu 1997, p.1).

Interdisciplinarity is similar to this, but it has a different goal, namely "the transfer of methods from one discipline to another" (Nicolescu 1997, p.1). It can involve the application of

methods from one discipline within the realms of another (e.g. the application of methods of nuclear physics within medicine has led to new cancer treatments), or the creation of new disciplines (e.g. the discipline of econometrics is the result of the combination of applied economic theory and statistical analysis). Interdisciplinarity is also similar to multidisciplinarity in that its goal "... still remains within the framework of disciplinary research" (Nicolescu 1997, p.1).

So, according to Nicolescu, whereas inter- and multi- disciplinary work involve the crossing of disciplinary boundaries, the work nevertheless *remains within the framework of disciplinary research.* In contrast:

> ... transdisciplinarity concerns that which is at once between the disciplines, across the different disciplines, and beyond all disciplines. Its goal is the understanding of the present world, of which one of the imperatives is the unity of knowledge.
>
> (Nicolescu 1997, p.2)

Nicolescu is arguing that there is similarity among the three multiple disciplinary approaches, but difference in terms of their purpose and method. However, it seems that it is often the case that the distinction between the three is blurred, and the important differences ignored. Nicolescu (1997, p.2) comments:

> If transdisciplinarity is often confused with interdisciplinarity and multidisciplinarity (and by the same token, we note that interdisciplinarity is often confused with multidisciplinarity) this is explained in large part by the fact that all three overflow disciplinary boundaries. This confusion is very harmful to the extent that it functions to hide the different goals of these three new approaches.

According to Nicolescu, the three approaches have distinct goals and characteristics, and these can be summarised as in

Table 2.2

Table 2.2 Goals and characteristics of inter-, multi- and transdisciplinary research (following Nicolescu 1997)

Disciplinary Mode	Goal/Characteristics
Multidisciplinary	The study of a research topic in several disciplines at the same time. The aim is to enrich the perspective of the 'home discipline' by bringing insights from others disciplines. There are distinct disciplinary boundaries, and the overall research thrust is locatable within a particular discipline.
Interdisciplinary	The transfer of methods and/or concepts from one discipline to another. Still primarily constrained within a home discipline, or creating of a new discipline.
Transdisciplinary	Between, among and across the disciplines (not constrained by disciplinary borders). It seeks unity of knowledge and understanding of the present world.

So, for Nicolescu too, the issue transcends semantics. He sees distinctive differences among the three approaches and observes that the confusion which people experience about the meanings can be "harmful".

The preceding discussion has served to highlight that there are real differences between transdisciplinarity on the one hand, and interdisciplinarity and multidisciplinarity on the other. The particular outlines of the natures of the latter two modes of investigation are presented to provide a contrast with transdisciplinarity. It should be noted, however, that this is not the only way that interdisciplinarity and multidisciplinarity have been described. Authors such as Jantsch (1972) and Klein (1990) reflect a different view of interdisciplinarity and multidisciplinarity, although, like the authors surveyed above, they both recognise these as being distinct from transdisciplinarity.

Klein (1990), in reviewing, and to a large extent echoing, Jantsch (1972), describes a variety of approaches to collaborative research. In doing so, she ranks them in increasing order of integration and complexity as – multidisciplinary, pluridisciplinary, crossdisciplinary, interdisciplinary and transdisciplinary. Under this typology, interdisciplinarity is understood to involve significant integrative effort, "... centered on a common problem-solving purpose ..." (Klein 1990, p.69). This suggests a somewhat more holistic character than appears to be allowed by Nicolescu. Transdisciplinarity, in being described as signifying "... the interconnectedness of all aspects of reality, transcending the dynamics of a dialectical synthesis

to grasp the total dynamics of reality as a whole" (Klein 1990, p.66), is here too set in contrast to interdisciplinarity in terms of its scope of application.

Whether interdisciplinarity ought to be characterised following Nicolescu and others, or Jantsch, Klein and others is immaterial to the purpose of this thesis. What *is* material is that transdisciplinarity is understood to be distinct from other forms of integrative work across disciplines. In this thesis, an attempt is made to distil the essential components of a transdisciplinary approach so that they can be incorporated within a new approach to dealing with complex environmental problems. In so doing, it is intended to develop a methodology that is consistent with the demands of ecological economics, i.e. to be transdisciplinary. To this end, the discussion now returns to further exploration of transdisciplinarity as an organising principle for systematic research.

As noted by Bourguignon, Nicolescu has adapted the related concepts of *levels of reality* and the *logic of the included middle* from quantum physics. Along with complexity, he argues that these are the "three pillars of transdisciplinarity", and that they "determine the methodology of transdisciplinary research" (Nicolescu 1998a). Moreover, although these concepts from quantum physics might be foreign to many ecological economists, they nevertheless form an important part of contemporary thinking of transdisciplinarity. The "Charter of Transdisciplinarity" adopted at the First World Congress on Transdisciplinarity in 1994 has as its second article the declaration that:

> The recognition of the existence of different levels of reality governed by different types of logic is inherent in the transdisciplinary attitude. Any attempt to reduce reality to one single level governed by a single form of logic is incompatible with transdisciplinarity.
>
> (CIRET 1997, p.1)

Nicolescu's (1985 and 1998b) explanation of the meaning of these concepts is extended and outside the scope of the present work. However, a key argument that he makes based upon the concepts of *levels of reality* and *logic of the included middle*, is summarised in the following statement: "Transdisciplinarity is the transgression of duality ... (it) is transgressed by the open unity which encompasses both the universe and the human being" (Nicolescu 1998b, p.6).

Nicolescu invokes complexity as one of the three pillars of transdisciplinarity. Essentially, he is referring to a complex evolving Nature, as opposed to the view that Nature is mechanistic, a view that he asserts has led to "... the disappearance of the concept of Nature from the scientific field" (Nicolescu 1998b, p.8). His view of a transdisciplinary evolving Nature is one

that demands a new methodology, a "... transdisciplinary methodology" (Nicolescu 1998b, p.10).

This linking of evolution with transdisciplinarity is a theme also pursued by Laszlo (1997) who proposes that the acceptance of evolution as a basic principle could lead to effective transdisciplinary unification within the sciences. Whereas Nicolescu directly links the study of living nature with a transdisciplinary methodology, Laszlo fails to make this link explicit. Nevertheless, their arguments are both at least supportive of the use of a transdisciplinary approach when environmental issues are concerned.

The International Centre for Transdisciplinary Studies and Research (CIRET: Centre International de Recherces et Études Transdisciplinaire), is an organisation set up in 1987 to advance transdisciplinary study. The aims of that Centre are included in a document entitled "Moral Project" (CIRET 1997b), and this document gives a straightforward statement of the nature of transdisciplinarity:

> By its very nature, transdisciplinarity rejects all globalising projects, all closed systems of thought, utopian ideas, any enslavement to an ideology, religion or philosophical system no matter what. Its aim is not the unification of all branches of knowledge; a goal that would be absurd and illusory. More modestly, *transdisciplinarity will try to bring us closer to reality by the linked study of nature, the imaginary, the universe and man, so as to permit us better to meet the challenges of our epoch.*
>
> (CIRET 1997b, emphasis added)

The text in italics essentially describes an holistic, systems-based approach. Moreover, the way that transdisciplinarity is intertwined with the understanding of nature, makes it reasonable to connect this approach to problems of environmental management and ESD. In the first chapter of this thesis, it was noted that this thesis is a "...focused attempt to develop a methodology to support holistic approaches to environmental management". It is in this context that the work of CIRET and Nicolescu is of relevance because they both make a strong link between transdisciplinarity and the environment, and also give a basis for articulating a transdisciplinary (and thus holistic) methodology.

The Union of International Associations is another group that has explored transdisciplinarity. They publish the *Encyclopedia of World Problems and Human Potential*, which defines transdisciplinarity as:

> The coordination of all disciplines and interdisciplines on the basis of a generalized axiomatics (introduced from the purposive level) and an emerging epistemological

> pattern. In the successive steps of cooperation and coordination between disciplines, transdisciplinarity defines an organizational principle for a hierarchical system of multiple levels, having multiple goals, and in which there is coordination of the whole system toward a common goal.
>
> The essential characteristic of a transdisciplinary approach is *the cooperation of activities at all levels* of the education/innovation system. This depends not only on a common axiomatics (derived from coordination toward an overall system goal) but also on the mutual enhancement of epistemologies. With transdisciplinarity, the whole education/innovation system would be coordinated as a multilevel, multigoal system, embracing a multitude of coordinated interdisciplinary two-level systems.
>
> (Union of International Associations 1994-95, web page http://www.uia.org /uiademo/kon/c0796.htm, emphasis added)

Pointing to cooperative activity as the essential characteristic of a transdisciplinary approach (cf. Footnote 2 in this chapter where the point is made that synergy too depends on cooperation), they identify the need for a set of common axiomatics. To support the notion that ecological economics could, at least in principle, be transdisciplinary, it is possible to identify some axioms that could apply. The following generalised axioms are suggested as potential candidates:

- unless economic activity is constrained within ecological limits, the entire human economic system will collapse (i.e. it would be unsustainable);
- entropy provides a natural limit to activity;
- environmental problems must be viewed from a systems stance;
- risk and uncertainty are key elements of environmental problems; and
- market model approaches to analysis of environmental problems are unsatisfactory.

Whereas the above axioms could become a generally accepted part of ecological economics, the issue of whether the field can grow into a genuine transdiscipline in both theory and practice is another matter. Before this can happen, there is a need to move from approaches to policy predicated upon disciplinary foundations, to ones that explicitly "... bring us closer to reality by the linked study of nature, the imaginary, the universe and man, so as to permit us better to meet the challenges of our epoch" (CIRET 1997b). This challenge for policy-making is addressed in the following quote from the *Encyclopedia of World Problems and Human Potential:*

> The real challenge for policy-making in relation to the crises of our times is to provide people with tools to counter the imaginal deficiency from which we collectively suffer when dealing with complexity. The texty, linear-environment of speeches, messaging and documents has a poor track record. Eminent experts, with suitable budgetary encouragement, can now be found to negate the importance of any problem (or corresponding policy), whether over-population, acid rain, low-level radiation exposure, or smoking. Their 'facts' are no longer a reliable basis for action.
>
> (Union of International Associations 1994-95, web page http://www.uia.org knowledg/33itran.htm)

This points to the need for an alternative approach; one which moves beyond the confrontational and argumentative adversarial style portrayed above. However, alternatives are not easy to identify. There are today many advocates for 'holistic' and/or 'integrated' approaches to environmental problems, and indeed such approaches have been explicitly included in strategic policy and legislation (e.g. the New South Wales *Catchment Management Act 1989*). However, there is risk in such practices. The potential for a 'naïve holism', one which has the potential to dilute seriously the effectiveness of efforts at integration and cooperation must be recognised. The creation of an integrating perspective as a competing alternative to a fragmented framework might only result in a new form of "... part/whole polarization when what is required is a more insightful way of dealing with polarization" (Union of International Associations 1994-95, web page http://www.uia.org/knowledg /33itran.htm).

The adoption of 'naïve holism' within the context of sustainable development, can lead to non-sustainable outcomes. The allure of concrete, short-term gains can blind decision makers to the longer term implications of their decisions. It is for this reason that care must be taken when implementing holistic approaches to environmental management. There are suggestions in the literature for ways to overcome this problem of 'naïve holism', including the use of computer mapping techniques in conjunction with cross-stakeholder dialogue. The methodology being proposed in this thesis has been developed under recognition of the dangers of 'naïve holism', and includes techniques designed to mitigate against them.

Judge (1991) is critical of attempts to achieve effective cross-disciplinary research, and notes the non-development of an effective transdisciplinary methodology. He describes "structurally crude" approaches to multidisciplinary work in which disciplines are "... focused in a star-formation around the problem, or treated as a basket of resources which can be called upon in

response to a problem" (Judge 1991, p.7). He is critical of such approaches because they have no way of:

- structuring a pattern of checks and balances between the advocates of different methodologies,
- constraining efforts at domination by one (or more) and
- ensuring the contributions of minority views.

(Judge 1991, p.7)

He notes that at the extreme, such approaches lead to programs in which interdisciplinarity "... is only evident in the binding together of the individual disciplinary contributions in a single report of the initiative" (Judge 1991, p.1).

Judge describes a token approach to cross-disciplinary study in which integration, if any, is left to the initiative of the individual reader of the report. This contrasts with a transdisciplinary approach that includes an intentional attempt to capture system synergies and thus to achieve effective integration.

This critique by Judge, which brings out the failings of discipline-bound approaches to generate genuine integration, provides further perspective on the nature of genuine transdisciplinary research. In the next section, these ideas of Judge's, as well as others reviewed in this section, are brought together in a coherent structure with the intention of codifying transdisciplinarity.

Another perspective on transdisciplinarity is the possibility that metaphors could form the basis for effective practice. This is another approach to understanding what it means to 'do' transdisciplinarity. The Macquarie Dictionary defines *metaphor* as "... a figure of speech in which a term or phrase is applied to something to which it is not literally applicable, in order to suggest a resemblance" (Delbridge and Bernard (eds) 1994, p.607). The idea that metaphor can be a legitimate tool for policy and research has been made by various authors. Judge (1994b, p.4) notes that "In recent years there has been considerable interest in the cognitive function of metaphor as fundamental to the development and maintenance of cognitive and experiential frameworks"; the general use of metaphor has been discussed by Lakoff and Johnson (1980); the possibility that the entire discipline of Physics is based on metaphor has been put by Jones (1983); while the use of metaphor in social policy has been addressed by Schon (1979). Within the context of metaphor, one must consider what type of metaphor(s) might be appropriate for transdisciplinary practice. Judge (1994b, pp.4-5) asserts that it should

be "... holistic and transdisciplinary" and that the framework must be able to handle "Inconsistency, incommensurability and paradox" (Judge 1994b, pp.4-5).

Judge relates the idea of metaphor to that of the "conceptual scaffolding" needed to support transdisciplinary work. This conceptual scaffolding is essentially a systems framework of understanding. Within this context, he makes a clear link with problems of sustainable development, emphasising that the use of metaphor is very important.

Along with the suggestion that the use of metaphor needs to be a part of transdisciplinary research, Judge identifies recent advances in computer technology as potentially enabling in this respect. He points to the possibility that "... visual displays could be used as surfaces through which to interrelate insights in new ways" (Judge 1994b, p.10), such that "... participants can responds to an integrative representation of the range of points made ... (and suggests that) ... This is a software challenge for the immediate future" (Judge 1994b, p.14). He also makes the point that this type of software was not presently available (in 1994).

Clearly, Judge was not aware of the study of System Dynamics (see Chapter 3), nor of software such as *ithink* (High Performance Systems 1994 and 1997), which is designed with just such a task in mind. The methodology developed in this thesis involves harnessing the power of cognitive mapping techniques (after Eden 1994) and *ithink* software to achieve the sort of integrative process suggested above. Cognitive mapping provides a sort of visual metaphor of the problem at hand, and is an effective way of developing conceptual scaffolding to support learning and understanding.

To draw this section of the discussion to a close, it is perhaps appropriate to turn to Nicolescu (1997, p.3) whose envisioning of a transdisciplinary approach includes "...the emergence of continually connected beings, who are able to adapt themselves to the changing exigencies of professional life, and who are endowed with a permanent flexibility which is always oriented towards the actualization of their interior potentialities". Maybe Nicolescu's vision of "continually connected beings" is utopian, but he nevertheless points to the way that transdisciplinary professionals need to function. Surely, such direction is necessary if transdisciplinarity is to become a serious methodological approach.

2.2.3 Transdisciplinarity Revealed?

The above review of transdisciplinarity provides a variety of pointers to that which distinguishes transdisciplinary work from multidisciplinary and interdisciplinary work. Whether these pointers are definitive is probably debatable, even though they have been identified from writers specialising in the articulation of transdisciplinarity. So far, they have not been explicitly applied within ecological economics, and thus lack critical review within that community. However, since one objective of this thesis is to articulate a transdisciplinary framework that could be applicable for ecological economics, the pointers identified above provide at least a starting point for such a framework.

Another use to which the pointers can be put, is to provide a basis for assessing whether particular attempts to implement an integrating methodology embody elements of genuine transdisciplinary scholarship and practice. By way of illustrating this application of the pointers, they will be used as the basis for analysing present practices in IRM (to be explored in Chapter Four). Further, the pointers will be used to assess the integrative decision making approach and its use as demonstrated in the case studies reported in Chapter Six. This analysis can be found at Section 7.2, where a simplified version of the pointers is proposed.

In order to facilitate these tasks, the pointers have been arranged as questions that can be used to determine whether a piece of research or applied work appears to be transdisciplinary. These indicator questions, as presented in Table 2.3, provide the basis for a systematic approach to the analysis of work to determine its transdisciplinary stance.

These indicators of transdisciplinarity represent a significant contribution of the present research to the field of ecological economics. Nothing similar to them has previously been proposed in the literature. Moreover, they provide a substantive basis for the development of an ongoing dialogue among ecological economists about the nature of transdisciplinarity.

The need for the adoption of a systems perspective within the transdisciplinary approach has been identified by CIRET (1997b), Gill (1997) and Nicolescu (1998). The following section provides a review of the literature on complex systems and the systems approach, while aspects of contemporary systems praxis are discussed in Chapter Three.

Table 2.3 Indicators of Transdisciplinarity

Criteria	Based on:
Does this work go beyond normal conceptions of scientific disciplines?	Costanza *et al.* 1991
Does this work attempt to integrate and synthesise many different disciplinary perspectives?	Costanza *et al.* 1991
Is there evidence of a synergistic alliance between and across conventional disciplinary boundaries? Is there an explicit attempt to capture synergy in the outcomes?	Gill 1997
Is there an attempt to make use of a language of universal transparency, or a common metaphor, in order to facilitate transdisciplinary communication?	Gill 1997, Judge 1991
Can the approach cope with philosophical and/or methodological diversity? *E.g. Anthropocentric and ecocentric positions ought to be accommodated.*	Gill 1997, Luks 1998
Is the approach problem-focussed rather than being constrained by disciplinary boundaries?	Costanza *et al.* 1991, Kesik 1996
Is there a systems perspective in which developing understanding about the links between system components is emphasised?	CIRET 1997b, Gill 1997, Nicolescu 1998
Is the work based firmly on a home discipline, where perspectives from other disciplines provide qualification for, or enrichment of, the focussed work within a particular discipline? *This would indicate multidisciplinarity.*	Nicolescu 1997
Is there evidence of the transfer of methods from one discipline to another? *This would indicate interdisciplinarity.*	Nicolescu 1997
Is there an attempt to reduce reality to a single level? *This is incompatible with transdisciplinarity.* Are there mechanisms to make more complex structures comprehensible?	CIRET 1997, Judge 1991
Is duality a key aspect of the work? E.g. yes/no, wrong/right, black/white etc. *Transdisciplinary work should transgress duality by focussing on system interrelationships and the "included third".*	Nicolescu 1998b
Are there any explicit or implicit generalised axioms that underlie the work? Is the work consistent with the generalised axioms of ecological economics suggested in Section 2.2.2?	Union of International Associations (UIA) 1994-95
Is there a mechanism to structure the work so that the different hierarchical levels of the work are systematically articulated? *Different hierarchical levels will have different goals. The overall system might also have goal(s) that are different to the individual levels.*	UIA 1994-95
Is the work predicated upon a confrontational and argumentative adversarial style, or an inclusive participative style. *The former might indicate protection of disciplinary borders, while the latter could suggest a transdisciplinary approach.*	UIA 1994-95
Is there a focus on concrete, short term gains? *A transdisciplinary approach (and thus by implication a systems approach) would also give significant weight to longer term dynamics and possible outcomes.*	UIA 1994-95
Is the integration left to the reader, or is it explicitly addressed in the project?	Judge 1991.
Are there checks and balances to ensure that no particular methodological approach dominates? Are minority views likely to be properly represented?	Judge 1991
Can inconsistency, incommensurability and paradox be accepted and dealt with in a meaningful way?	Judge 1994b

2.3 Complex Systems and the Systems Approach

The need to take a systems approach to environmental problems has been previously identified in this thesis. The ESD literature makes particular mention of the need for a systems approach to difficult environmental problems. The systems approach is seen as relevant to ecological economics in its pursuit of an integrated understanding of combined anthropo-ecological systems. A systems approach has also been advocated by many authors as the way to implement IRM (see discussion in Chapter Four). Following is a survey of some of the authors who have contributed to contemporary understanding about a systems approach.

In 1950, Ludwig von Bertalanffy wrote what has proven to be an important work in the development of systems theory. In this article, von Bertalanffy (1950) outlines the basic principles of a general systems theory, and it is his work (also see von Bertalanffy 1968) that is frequently cited by authors who contribute in this field. However, the idea of taking a systems approach to understanding complex problems did not originate with Bertalanffy. In his review of the origins of systems thinking, Churchman (1979, p.32) comments that to the best of his knowledge:

> ... the earliest document aiming at a systems approach to decision making was written in China in the second millennium B.C. This very early attempt ... is the *I Ching* or Book of Changes.

Churchman also identifies other historical contributors to systems thinking. One was Plato, who proposed the city-state as a whole system, and who noted that "The well-organized city-state will display a value greater than the sum of the values of the single components - a philosophy that sometimes goes under the label of *holism*" (Churchman 1979, p.37). Another important figure identified by Churchman in the history of systems thinking was Immanuel Kant, "... the great synthesizer who set the stage for the methodology we use today in the systems approach, which has its foundations neither in observation alone nor in reason alone, but in some kind of complex inquiring system built out of the connections between these two sources" (Churchman 1979. p.43).

Following von Bertalanffy (1950), there were a number of authors who made general contributions to the articulation and critique of a general systems approach. These include Boulding (1956), Mesarovic (1964), Phillips (1969), and Ackoff (1971). So, just what is the systems approach that these authors advocate? It has a number of characteristics that many of these authors agree on, and perhaps the most important of these is the concept of synergy.

Synergy, the idea that within a cooperatively functioning system the whole is greater than the sum of its parts, is fundamental to the systems view. So fundamental in fact, that where Churchman (1979, p.37) writes "...a value greater than the sum of the values of the single components – a philosophy that sometimes goes under the label of *holism*", he incorrectly identifies the concept as holism (which is itself a simile for *systems thinking*). The concept of synergy is perhaps best understood as an antithesis – the antithesis of reductionist and mechanistic thinking. Dillon (1976) adopts this line where he writes "...a system is an indivisible whole and, in contrast to the reductionist view, is more than the mere sum of its parts in the sense that the system's behavior is not deducible from the behavior of its elements considered in isolation" (Dillon 1976, p.30).

As the antithesis of synergism, reductionism and mechanistic thinking deny that the sum of the parts of a system can be anything other than the sum of the parts of the system. For example, Walmsley (1972, p.8) observes that the classical mechanistic metaphor implies "... the notion of a 'whole' that is completely equal to the sum of its parts, can be run in reverse, and which will behave in exactly identical fashion no matter how often the parts are disassembled and put together again". Dillon (1976, p.29) writes that "reductionism implie(s) reducing phenomena to their more basic (and hopefully independent) parts, analyzing these parts as independent entities to explain their behaviors, and then aggregating these explanations as an explanation of the phenomena under study".

These concepts of reductionism and mechanism can be seen as fundamentally opposed to a systems view in which synergy is recognised. Whereas the reductionist approach may have the advantage of breaking down a problem into manageable bits that can be subjected to intensive scientific scrutiny, it has no mechanism to understand the overall behaviour of the system in question. Ackoff (1974, p.14) observes that:

> Viewed structurally, a system is a divisible whole; but viewed functionally it is an indivisible whole in the sense that some of its essential properties are lost when it is taken apart. The parts of a system may themselves be systems and every system may itself be part of a larger system.

Following this idea, reductionist study is strictly concerned with the system as a divisible whole, and the study of the divided portions. However, the deconstruction of the system to enable study results in the loss of certain characteristics of the functioning system. Walmsley (1972) argues that although such an approach may facilitate the study of an idealised theoretical world, it falls short in its ability to describe the complexities of the real world.

Particularly in the context of environmental problems which are typically systemic in nature, and do not readily succumb to 'solutions' generated through idealised theoretic frameworks, it is important to understand the functioning of the overall system in order to develop appropriate responses. The need for such a systems approach is implied by Madala and Ivakhnenko (1994, p.1) where they write "very often the ability of the system to carry out its function (or alternatively, its catastrophically failing to function) is a property of the system as a whole and not of any particular component".

The above is not meant, and should not be taken, as an indictment of reductionist science or the use of mechanistic metaphors. Indeed, a large body of scientific and technological advance is directly attributable to the application of such approaches (Gell-Mann 1994 provides an interesting discussion of this issue). Furthermore, what is a system at one level of observation, may be the component pieces of a system at a higher level, and will contain its own component pieces at a lower level (cf. Ackoff 1994, p.14 above). This notion of hierarchies of systems itself receives quite a lot of attention in the literature (e.g. Allen and Starr 1982, Funch 1995, Giannakodakis 1994, O'Neill *et al.* 1986, and Simon 1973). It points to the idea that although reductionism and holism may be discussed as fundamentally opposing notions, there is nevertheless a continuum of understanding from the very reductionist and mechanistic to the holistic and synergistic. The Nobel Laureate, Murray Gell-Mann, recognised for his work with the fundamental sub-atomic particle the quark, proposes a connected structure of science that goes from the simple to the complex. He suggests that "The enterprise of science involves investigating ... (the scientific) laws at all levels, while also working, from the top down and from the bottom up, to build staircases between them" (Gell-Mann 1994, p.112).

This interdependency of the different levels of science, and the reliance of one level upon another level, is an idea that Nicolescu addresses in the context of distinguishing transdisciplinary from other modes of disciplinary endeavour. He argues that even though transdisciplinarity is seen to be radically different from disciplinarity, multidisciplinarity and interdisciplinarity, it would be unwise to make this distinction absolute since it would lead to the situation where "... transdisciplinarity would be emptied of all its contents and its efficacy in action reduced to nothing" (Nicolescu 1998a, p.3).

The point that is being made by Gell-Mann and Nicolescu is that *both* approaches to scientific endeavour are essential. Without the detail of disciplinary (reductionist) investigation, there would be no *substance* for systemic study, and without the relational insights provided by

systemic study, the *context* for reductionist study would be missing. This is an argument also implied by Giannakodakis (1994) in the context of transport planning.

Notwithstanding the above point about a continuum of scientific endeavour from the finely reductionist to the broadly holistic, there remains a fundamental distinction between the two; one disallows synergy while the other explicitly identifies it. Moreover, complex human-environmental systems violate the fundamental techniques of reductionist research, and thus cannot be adequately studied using such techniques (Costanza *et al.* 1993). Therefore, a systems approach that makes explicit allowance for synergy and the relationship between system components is required in order to make sense of the sort of complex problems encountered in the context of environmental management.

So far, this discussion has been about the systems approach as something that is distinct from reductionist approaches to gaining knowledge. To conclude this part of the discussion, it is important to address the questions; "What is a system?" and "What constitutes a systems approach?".

The Dictionary of Human Geography defines a system as: "A group of elements organized in such a way that every element is to some degree interdependent (directly or indirectly) with every other element" (Johnston *et al* 1994, p.614). This definition can be expanded so that the interdependence of elements is addressed in more detail, and the system characteristic of synergy is made explicit. Russell Ackoff has made various contributions to the development of systems theory (e.g. Ackoff 1971, Ackoff and Emery 1972, and Ackoff 1974), and has identified a number of characteristics that can be found in systems. These are:

1. The behaviour or properties of one system component has an effect on the behaviour or properties of the system taken as a whole.

2. The behaviour and properties of any particular system component and the effect it has on the whole, depend on the behaviour and properties of at least one other system component. No system component can affect the system in isolation from all other parts, and each component is affected by at least one other part.

3. Each and every subgroup of system components has properties one and two which means that each subgroup has a non-independent impact on the whole system. This necessarily implies that it is not possible to divide the whole system into independent subgroups.

Based on the above characteristics, Ackoff (1974, p.13) argues that "... a set of elements that forms a system always has some characteristics, or can display some behavior, that none of its parts or subgroups can". This leads him to conclude that "A system is more than the sum of its parts" Ackoff (1974, p.13).

Although the above two definitions give a good basic picture of a system, they fall short in that they do not address some of the other significant aspects of systems. In fact, the entry in the Dictionary of Human Geography (Johnston *et al* 1994) extends the above-mentioned definition by articulating some other aspects of systems. These are: it might be important to distinguish between closed systems (with no links or flows to or from their environment) and open systems (which do have such links or flows); feedback loops are also an important part of systems; these can be positive (or self-reinforcing) feedback loops, or negative (or goal-seeking) feedback loops; and there will be time lags between the action of a stimulus and the response of the system at various points. Madala and Ivakhnenko (1994) extend the definition and identify complexity, temporal dynamics and adaptation as further aspects of a system. These latter system aspects are important in the study of human-environmental systems which typically contain many non-linear feedback loops, change through time and to some extent are able to adapt to changes in their environment.

So far, the discussion has been about systems in general, with no specific reference to combined anthropo-ecological systems. Costanza *et al.* (1993, p.545) make the link to such systems, and observe that:

> Ecological and economics systems both independently exhibit these characteristics of complex systems. Taken together, linked ecological economics systems are devilishly complex.

The above addresses the question "What is a system?", and from this the following key points can be identified:

- a system has elements that are interrelated and, to a greater or lesser extent, interdependent;
- a system exhibits synergy;
- systems can be closed or open;
- feedback loops link various system elements;
- there will be lags between stimulus and various system responses;

- many system variables will be, *inter alia*, functions of time;
- systems can adapt to changes in their environment; and
- discontinuities and thresholds may exist.

Given these system characteristics, how then ought one study systems so that the methodology is properly aligned with the nature of the system? The *systems approach* is the generic way to deal with such problems. So what characterises a systems approach? Referring again to Ackoff (1974, p.14):

> The synthetic mode of thought, when applied to systems problems, is called the systems approach. In this approach a problem is not solved by taking it apart but by viewing it as part of a larger problem.

The "taking it apart" to which Ackoff refers is of course the reductionist approach, and here he makes explicit that this approach *should not* be used in the study of systems. Moreover, he makes the further point that "... piecemeal approaches to environmental problems are not likely to succeed because of the large number and complexity of interactions between different aspects of the environment and man's behavior in it." This, he argues, means that "... comprehensive, coordinated, and integrated planning, not isolated problem solving, is required if we are to bring about significant environmental improvements" (Ackoff 1974, p.174).

A further expansion of this general approach is provided by Walmsley (1972). He asserts that hard to quantify things like value judgements and behavioural phenomena "... are just as 'concrete' a part of the total situation as any other" (Walmsley 1972, p.25). He describes systems theory as focusing on "... understanding rather than explanation", and observes that "... the approach is synoptic rather than analytic in that it moves outwards from the problem to its contexts rather than inwards to its parts" (Walmsley 1972, p.25).

More recently, this general principle of an integrated approach has been extended in respect of the actual techniques that might be used. In the context of social systems, Radzicki (1990, p.60) points to the need for using non-linear equations, and simulation models that can deal with the complex systems specified using such equations. This point has also been made by Mosekilde *et al* (1983).

Finally, a general comment on the use of a systems approach as a way to link scientific endeavour and social activity, is that a systems approach can be used "... as a window through

which to view the dilemmas, paradoxes, insights and ambiguities which plague the use of any science or rational method in a social context" (Batty and Hutchinson 1983, p 3).

Following from the above, it can be seen that the systems approach is identified in the literature as effectively 'best practice' when it comes to dealing with complex problems in which humans and human activity is involved. However, not all authors are quite so sanguine about the systems approach. Phillips (1969), in his provocatively titled article "Systems Theory - A Discredited Philosophy", is highly critical of the whole concept of a systems approach. He lists the following problems with the approach:

1. the failure of systems theorists to appreciate the history of their theory;
2. the failure to specify precisely what is meant by a 'system';
3. the vagueness over what is to be included within systems theory;
4. the weakness of the charges brought against the analytic or mechanistic method;
5. the failure of general systems theory as a scientific theory.

(Phillips 1969, p.4)

Phillips was writing in criticism of the early general system theorists and particularly von Bertalanffy. His argument was that general systems theory was invalid because of a number of philosophical and practical problems. In particular, he identifies the concept of synergy as being based on a supposedly discredited "theory of internal relations". Whether or not Phillips' criticisms of systems theory are valid is beyond the scope of the present research. However, history seems to have vindicated the systems theorists as their ideas have persisted and developed, while criticisms such as Phillips' do not seem to be supported in the literature.

Another problem with a systems perspective is that it tends to select against the requirements of individual system components. Perrings *et al.* (1995, pp.24-25) argue:

> There is a sense in which a systems perspective privileges the requirements of the system above its individual components. This is, in fact, a widely held view in ecological economics. But it is not a value free view. It flatly contradicts the principle of consumer sovereignty which privileges the rights of the individual not only with respect to the collectivity, but also with respect to future generations ... the sovereignty of the present generation of consumers denies any role for the state in securing the welfare of future generations.

This particular issue is important from a perspective of liberalism and the rights and freedoms of individuals, and provides an interesting problem in political philosophy. Again, this is something that is outside the scope of the present work. No attempt will be made to deal with

this in detail, except to note that questions such as these need to addressed in the context of social choice; i.e. in the face of deepening environmental problems, what individual rights might have to be foregone so that a sustainable society can be achieved?

Finally, a significant problem with a systems based approach to non-trivial problems is that complex conceptual frameworks need to be articulated. Furthermore, analytical techniques fail because the non-linear feedback relationships make anything other than transient algebraic solutions impossible to find. Another problem is the lack of general theories that can be universally applied, due, not in small measure, to the fact that each system under study is fundamentally different. This problem has not escaped attention in the literature. Walmsley (1972, p.53) observes:

> One major problem with any systems-theoretic framework is the lack of characteristic methodology whereby it can be applied. ... One escape from this lack of techniques to handle interdependencies is to be found in simulation procedures that offer a means of applying systems theory. ... The simulation approach comprises two main stages: the development or synthesis of a model that adequately represents the system under study and the examination of the behaviour of the model in relation to changes.

As Walmsley has noted, a simulation approach provides a means of applying systems theory. Simulation involves the representation of a physical system on a computer. The purpose of doing this is "... to mimic the real system so that its behavior can be studied" (Sterman 1988, p.215). Following Morecroft (1988), a simulation model can be thought of as *microworld*, or a virtual laboratory in which to carry out experiments about the real system. The advantage of the microworld is that it enables the undertaking of experiments that might otherwise be "... impossible, unethical, or prohibitively expensive in the real world" (Sterman 1988, p.216).

The art and science of system simulation has been particularly developed within the field of system dynamics, and this is explored in Chapter 3. This does not imply that the only field that addresses system simulation is system dynamics. Indeed, even 25 years ago, McMillan and Gonzalez (1973) could comment that the literatures of every discipline report examples of simulations. Moreover, there are a number of simulation techniques including "... stochastic modeling, system dynamics, discrete simulation, and role-playing games" (Sterman 1988, p.216).

System dynamics is the methodology of choice for the present research because it is explicitly founded on a systems thinking framework that is consistent with that outlined above. Moreover, the contemporary system dynamics modelling software is designed in a way that is

intuitively straightforward, and this means that it is comparatively easy for just about anyone to follow the way that models are constructed and run. This means that simulation, which is essential as a tool in systems analysis, can be accessible not only to the specialists, but also to the larger community that might participate as stakeholders in the decision making process. This is in contrast to alternative system simulation techniques that rely on mathematical formulations and computer programming; two speciality areas that are most definitely *not* accessible to the community at large. The inclusion of stakeholders is a fundamental aspect of the methodology articulated in this thesis, and because system dynamics is amenable to this, it provides an appropriate basis for the study.

Before proceeding to the discussion on system dynamics, the concept of complexity as it applies to systems needs to be expanded somewhat. A large literature has developed in the last 20 years in the 'new sciences' of chaos and complexity, both of which are concerned with systems that exhibit non-linear feedback. The specific purpose for reporting on chaos and complexity in this thesis is to demonstrate cognisance of a field of study that is related to the systems concepts described above, and to search for any general principles that can be adduced from that field. With these objectives in mind, the following survey of the literature is provided.

2.3.1 Chaos

The notion that chaos exists in systems came about as meteorologists tried to predict the weather with increasing accuracy. The advent of powerful computers promised to increase the accuracy of predictions greatly, however only modest improvements have been achieved. Investigation by researchers has revealed that the dynamics of weather systems are such that it is fundamentally impossible to extrapolate very far into the future from a set of initial conditions. Small immeasurable perturbations in the system can result in large deviations from the predicted path. This is popularly known as *the butterfly effect*, in which it is suggested that the movement of a butterfly's wings in one place, can initiate a sequence of events that leads to a cyclone at some future time and some other place in the system. Technically called *sensitive dependence on initial conditions*, this effect is the reason for chaotic behaviour of systems. (Gleick 1987).

Following Gleick's (1987) explanation, chaos occurs in systems that are nonlinear. This is in contrast to linear systems which are based on linear equations that are solvable. For a linear system, a reductionist approach is legitimate because one can break the system into its parts,

study the parts, and then add the results up. It is the linearity that make these things possible. Conversely, in a non-linear system, there is generally no solution to the equations, and the non-linear system parts cannot be added together in a meaningful way. The non-linearity of systems is caused by feedback loops within the systems. That is, some given behaviour of the system causes a change in some other characteristic of the system, and this in turn changes the original behaviour in some way. In Gleick's (1987, p.24) words, "nonlinearity means that the act of playing the game has a way of changing the results".

In their review of chaos, Parker and Stacey (1995) identify some of the implications of chaos for the study and understanding of economics and management. They develop their argument from a foundation of a social system in which the behaviour of the individuals is both dependent on the behaviour of others, and affects the behaviour of others. They represent this feedback system as follows (refer to Figure 2.2). Individual or organisation X will make decisions about what actions to take, and these will be made in the context of previous actions by X, as well as previous actions of Y and Z (other individuals or organisations). By some means, X discovers (although imperfectly) what Y and Z have been doing, and then chooses some course of action based on this knowledge. However, actions by X affect the choices that Y and Z make about their actions, as they too seek to discover what previous actions X and each other have taken. Thus feedback loops affect the choices that X,Y and Z make. This result can be generalised to any groupings of individuals, organisations or nations, and in the same way their interrelated behaviour comprises a feedback system. Moreover, as the authors note, such social systems always involve nonlinear relationships.

As has been discussed previously, the systems approach to environmental management that is being advocated in this thesis, explicitly and necessarily involves the participation of a wide range of people. This means that it is, at least in part, a social system and thus subject to the feedback dynamics described above. This should not be taken to mean that the natural systems do not have nonlinear feedback relationships (they do, in fact chaos was first recognised within the natural sciences), but only to emphasise the fact that the involvement of the human dimension complicates the issue even further. Within the field of IRM, the discussion in Chapter Four and the exploration of the case studies in Chapter Six will reveal the existence of nonlinear feedback relationships, and the complex interactions of system stakeholders within the overall anthropo-environmental system. IRM thus provides a good context for the application of the methodology that is articulated in this thesis, since the latter has been developed to respond to these factors which are typical of nonlinear systems.

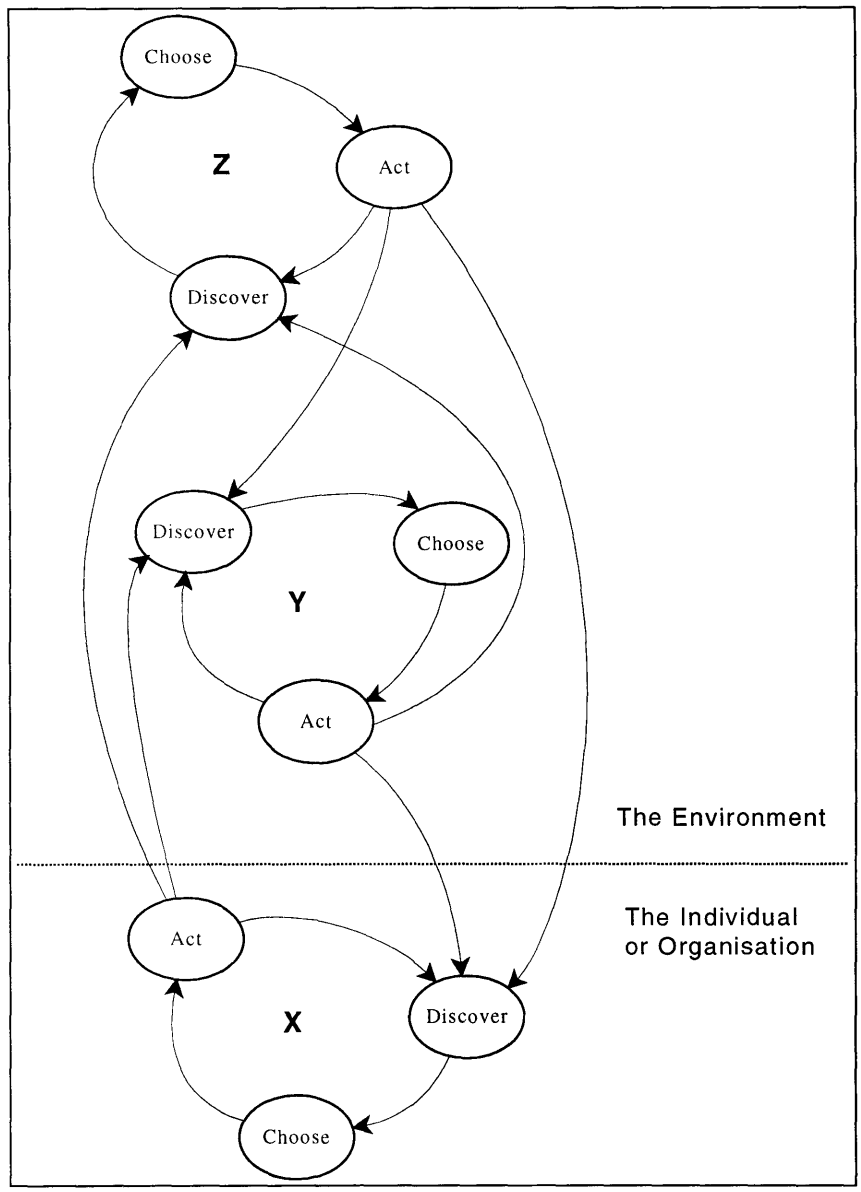

Figure 2.2 A simple feedback system (after Parker and Stacey 1995)

Parker and Stacey (1995) point to the fact that the existence of chaos means that prediction based on statistical techniques is likely to be highly suspect. This is due to the fact that small estimation errors can lead to huge divergences from the predicted path due to the butterfly effect. This has implications for the way that long-term management decisions are made. The authors note:

> Any system which attempts conscious design or planning of long-term futures will inevitably break down. Companies and economies require structures and institutions which encourage self-transformation. In terms of policy we should be focussing on means rather than ends, creating the conditions for change by designing systems that are capable of self-organising evolution.
>
> (Parker and Stacey 1995, p.76)

Elsewhere, Stacey (1993) has observed that within such feedback driven systems, and especially systems which have both negative and positive feedback modes of action, there is a tendency for the system to be inherently unpredictable. In this case, "... strategies can only emerge from the interaction between people" (Stacey 1993, p.14).

A major conclusion that Parker and Stacey (1995) draw, is the need for systemic learning to be an intentional and explicit part of the management of chaotic systems. Indeed, Parker and Stacey's conclusion points towards a major theme of this thesis – that ecological economics ought to be based upon an explicit learning methodology. This follows because ecological economics is about the management of environmental systems which, with the inclusion of human activity, can certainly be described as chaotic. The idea and implications of systemic learning will be explored further in Chapter Three.

2.3.2 Complexity

The study of complexity has evolved from the work on chaos. It has been described as the study of activity either at the edge of chaos, or at the border between order and chaos (Gell-Mann 1994, Waldrop 1992). It involves the study of complex adaptive and self-organising systems that evolve from less complex systems. In a complex world, self-organisation is where "... groups of agents seeking mutual accommodation and self-consistency somehow manage to transcend themselves, acquiring collective properties such as life, thought, and purpose that they might never have possessed individually" (Waldrop 1992, p.11). These "collective properties" are analogous to the concept of synergy discussed earlier.

Complex systems can be distinguished from systems that are either ordered or chaotic because "... all these complex systems have somehow acquired the ability to bring order and chaos into a special kind of balance". At this point of balance (often labelled *the edge of chaos*), there is a creative tension between order and chaos. It is here that "... new ideas and innovative genotypes ..." (Waldrop 1992, p.12) are formed, and where conservative attachment to old approaches is challenged and eventually overthrown.

Gell-Mann (1994, p.373) identifies examples of complex adaptive systems as "... biological evolution ... human thought, social evolution and adaptive computing", and notes that "... all these systems keep exploring possibilities, opening up new paths, discovering gateways, and occasionally spawning new types of complex adaptive systems" (Gell-Mann 1994, p.374). The

author observes that much research on these systems is being undertaken, and that this research indicates

> ... that such systems tend to settle into a well-defined transition zone between order and disorder, where they are characterized by efficient adaptation and by power law distributions of resources. Sometimes that zone is called, rather metaphorically, the 'edge of chaos'.
>
> (Gell-Mann 1994, p.374)

Gell-Mann concludes his 375 page treatise on complexity (in which he makes little reference to environmental matters *per se*) with a comment on the need to conserve nature and to safeguard biological diversity wherever possible. He notes that the context for dealing with these environmental issues includes consideration of "... the demographic, technological, economic, social, political, military, diplomatic, institutional, informational, and ideological problems facing humanity" (Gell-Mann 1994, p.375). He calls for greater sustainability, which, if it could be attained, would lead to a more desirable world, and wonders "... if paths can be sketched out that may lead to such a sustainable and desirable world, ... a world in which humanity as a whole and the rest of nature operate as a complex adaptive system to a much greater degree than they do now" (Gell-Mann 1994, p.375).

Thus, in bringing to a close his exploration of complexity, Gell-Mann links the ideas of chaos and complexity inextricably with questions of sustainability. In doing this, he provides the closure of the link that sees the systems world view along with the special and related considerations of chaos and complexity as being of fundamental importance when dealing with the problems of sustainability.

2.4 Concluding Comments

In this chapter, the topics of sustainability, ecological economics and transdisciplinarity have been discussed at some length. In each of these areas, the need to take a systems or holistic approach has been identified and discussed. In the previous section the nature of the systems approach has been explored, along with a cursory examination of the new sciences of chaos and complexity.

The purpose of the chapter has been to explore a range of literatures that are either directly relevant to, or can contribute to, the articulation of a transdisciplinary methodology to support the management of complex environmental problems. Throughout the chapter, there have been many recurring ideas, particularly relating to systems, their study and management. However,

as yet little has been said about the practical aspects of systems work. To redress this imbalance, systems praxis (as distinct from systems theory) is addressed in the next chapter.

IRM has also been referred to a number of times in this chapter. It has been noted that that literature identifies the need to adopt a systems approach in dealing with complex environmental problems, that it is exemplary of ESD in action, and that it involves the study of systems which exhibit nonlinear feedback relationships. Each of these attributes, along with others, will be addressed in greater detail in Chapter Four.