Applying Sustainability Science

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Many of our most serious environmental problems are the direct or indirect result of applying narrow technical expertise to complex natural systems. Local and international examples demonstrate the need for a radically different approach. Recognition of the problem has produced the move toward sustainability science. As well as explicitly recognizing the complexity of natural systems, sustainability science involves researchers working with the wider community to specify the problem, collect and evaluate data, develop and refine theories, and propose new responses. Sustainability science also requires new approaches, such as working back from identified unacceptable outcomes to determine better trajectories of development. Some examples of the approach will be given, ranging from protection of the Great Barrier Reef to setting greenhouse gas emission targets for the city of Brisbane. sustainability science offers a practical way of moving toward the only type of development which is morally defensible, a path that explicitly aims to sustain the natural systems on which we depend.

Introduction: Sustainability Science

The report GEO 2000 said that the world's present development path is not sustainable [UNEP 1999, xxix]. We are trying to meet the needs of a growing population in a globalising, unequal and human-dominated world. Our efforts are exerting unsustainable pressures on the Earth's essential life-support systems. The complexity of the challenges ahead is clearly evident in the worrying interactions of climate change, loss of biological diversity, increasing poverty and growing inequality [Kates et al 2001]. Meeting fundamental human needs while preserving the life support systems of Earth will require significant changes. The human population is likely to increase by 50 per cent or more before it stabilises. We can also expect per capita demand for goods and services to continue to increase. There are still about 1 billion people without clean drinking water and nearly 3 billion without adequate sanitation, while about half the people alive have never made a telephone call or ridden in a car. So future demand for goods and services for the human population could well be double the present level, which is already stretching the capacity of natural systems.

The Amsterdam Declaration and the recent IGBP report raised the possibility that we could see significant disruption resulting from the present level of human consumption. The declaration said [inter alia] that global change is real and is happening now, warning that human activity could inadvertently trigger abrupt changes to Earth System dynamics “with severe consequences for Earth’s environment and inhabitants”[IGBP 2001]. It continued:

*In terms of some key environmental parameters, the Earth System has moved well outside the range of the natural variability exhibited over the last half million years at least. The **nature** of changes now occurring **simultaneously** in the Earth System, their **magnitudes** and **rates of change** are unprecedented.*

In response, the declaration called for both a new "ethical framework for global stewardship" and "strategies for Earth System management". While the need for a new ethical framework is indisputable, I am not alone in questioning the hubris of the idea of "Earth system management". As the IGBP report said [Steffen et al 2004]:

Attempts to manage the functioning of the Earth System itself are fraught with difficulties, perhaps insurmountable. Systems theory suggests that complex systems can never be managed; they can only be perturbed and the outcomes observed. Furthermore, many of these outcomes will be unpredictable, even with a vast amount of information on the system, leading to unintended and potentially severe consequences…There is a further problem. Humans and their societies and institutions are embedded in and are an integral part of the Earth System. Humans cannot fully stand outside the human-environment system as they attempt to analyse it, and thus cannot be in a position to manage the Earth System in any objective fashion. Humans cannot be dispassionate observers [or] objective managers.

This awareness led to the development of the field of **sustainability science**. It recognises that our understanding of nature-society interactions is still limited. There have been substantial advances in recent decades through work in the environmental sciences that factors in human impacts, and work in social and development studies that takes account of environmental influences, but we still have to accept that modern science can be described as islands of understanding in oceans of ignorance. We are constantly engaged in land reclamation, but there is no chance of filling in the oceans. So we need to set some broad priorities for our limited scientific effort. At the top of the list should be the urgent need for a better general understanding of the complex dynamic interactions between society and nature. That will require major advances in our ability to analyse the behavior of complex self-organising systems, as well as developing better understanding of the irreversible impacts of interacting stresses. We need to work at multiple scales of organisation and consider the impacts on natural systems of various social actors with different agendas, ranging from environmentalists standing in front of trees to bulldozer drivers pushing them over and Cabinet ministers telling us it is justified because it promotes economic growth.

Case studies from all the inhabited continents have shown that many of our serious environmental problems are the direct result of applying narrow specialised knowledge to complex systems [Kates et al, op cit]. Agronomists have advised farmers on fertiliser use to improve pasture, but the changes have put unacceptable nutrient loads on waterways. Expert advice has allowed fishing vessels to catch more seafood, leading to depletion of fisheries. Irrigation systems have made it possible to grow new crops, but have also deprived streams of the flows needed to maintain riverine ecologies. Species introduced to control one pest have driven other native biota to extinction. Coal-fired power stations provide cheap electricity, but their carbon dioxide emissions are now changing the global climate. All these serious problems resulting from applying narrow specialised knowledge are present in Australia, as well as biodiversity loss and large scale salinity as a result of land clearing. So it is evident that great damage can be done by the application of narrow, specialised science without an appreciation of the complexity of natural systems. The first Australian state of the environment report concluded that the serious problems are the combined effect of various pressures: population growth and distribution, lifestyle choices, the technologies we use and the demands they make on natural systems [SoEAC 1996, ES-4]. The report also said that complex environmental problems have only been successfully solved by a systematic approach, combining all facets of the complex issue. Failures were usually piecemeal efforts that focussed on one aspect of the problem to the exclusion of other, equally important, aspects.

We need to address these issues through integrated scientific efforts that focus on the social and ecological characteristics of particular places or regions. There is an initial set of core questions for sustainability science [Kates et al, op cit]. These address the fundamental character of nature-society interactions, our ability to guide those interactions along more sustainable trajectories, and ways to promote the social learning needed to navigate a transition to sustainability. By structure and by content, sustainability science must differ fundamentally from most science as we have known it. The traditional scientific method was based on essentially sequential phases of scientific inquiry such as conceptualising the problem, collecting data, developing theories and applying the results. These familiar forms of developing and testing hypotheses have run into difficulties as we study complex non-linear systems with long time lags between actions and their consequences, complicated by our inability to stand outside the nature-society system. So we have to accept that our engagement with complex natural systems cannot be based on the old model for rational objective science. The traditional sequential steps must become parallel functions of social learning, additionally incorporating the elements of action, adaptive management and policy as experiment. Sustainability science therefore needs to employ new methods such as semi-quantitative modelling of qualitative data and case studies, or inverse approaches that work backwards from undesirable consequences to identify pathways that avoid those outcomes. Scientists and practitioners need to work together to produce trustworthy knowledge that combines scientific excellence with social relevance.

Meeting the challenge of sustainability science will also require new styles of institutional organisation to foster inter-disciplinary research and to support it over the long term, to build capacity for that research and to integrate it into coherent systems of research planning, assessment and decision support. The present approach is too haphazard and piecemeal. It is chastening to remember that the two crucial pieces of research that identified the problem of ozone depletion both failed to attract support through the conventional peer-review process [Lowe 1989, 27]. That science was only done because the researchers concerned – James Lovelock and Sherwood Rowland - had access to discretionary funds. We can't afford to leave such important issues to chance – especially in a world where fewer and fewer scientists have discretionary funding that allows them to follow where the science leads. We need a better process to involve scientists and practitioners in setting priorities, creating new knowledge, and testing it in action.

Protecting the Great Barrier Reef

The Great Barrier Reef is the world's largest connected system of coral reefs. As well as being an outstanding natural asset, it is the basis of a large tourist industry which generates billions of dollars each year [GBRMPA 1998]. The system faces a range of threats: run-off of nutrients and sediment from agriculture and grazing on the coastal land, the impacts of fishing and trawling, climate change and the effects of large-scale tourism. Recent studies involving reef scientists, fishing interests, the tourist industry and users of coastal lands have identified trends which are not sustainable. So a range of response measures has been devised, including an environmental levy on reef tourism to fund research, prohibiting fishing in one-third of the GBR marine park, new codes of practice for tourist activity and strategies to reduce run-off from the mainland [GBRMPA 2003]. The scientists worked together with users of the natural system to define the problem, identify limits and develop policy responses which will now be monitored to determine whether the identified unacceptable outcomes are actually being avoided.

The aspect of the problem which has not yet been tackled in any systematic way is climate change. The science now predicts that coral bleaching could occur in virtually every year by 2030, leading to widespread loss of coral and subsequent devastating impacts on the whole ecological system [Hoegh-Guldberg 2004]. The Australian government is still refusing to ratify the Kyoto protocol on climate change, even though the Senate has now passed the Kyoto Protocol Ratification Bill. All the good work to develop new approaches to protecting reef systems could be undone by the failure to slow down global warming.

Protecting Brisbane's outstanding natural assets

The city of Brisbane is growing. Pressure to release land for housing, economic production and community services is causing the loss of natural areas. The City Council supported a process to identify and list the outstanding natural assets. Residents were invited to nominate possible inclusions, at all scales from individual trees to entire islands or creek systems. Consultant scientists reviewed the nominations to rank them according to ecological and social significance. As a result, about 1000 of the proposals were accepted for inclusion in the Brisbane Conservation Atlas, ranging from the whole of Moreton Island to a rock face of geological importance. The public listing of the outstanding assets has successfully diverted development pressures in other directions, using land that was already degraded or on which endemic species had been supplanted by introduced species.

Developing a greenhouse gas emission target for Brisbane

I was commissioned by Brisbane City Council to help develop a greenhouse gas emission target. This involved developing an inventory of current emissions, collecting projections of expected trends, and identifying realistic strategies to curb growth or effect real reductions. The study found that greenhouse gas emissions in Brisbane were similar to the average for Australian cities, ranking among the highest per capita emitters in the world. Brisbane City Council had already set a target for its own operations. My report showed that it was feasible to go beyond the internal goal and set a target for the city's total emissions of greenhouse gases. The task has been made more difficult for Brisbane by its recent growth. Total annual emissions in 2000 were estimated to be about 45 per cent above levels in 1990, the base year for the Kyoto treaty. The "business as usual" projection for Brisbane would see emissions in 2012 a massive 65 per cent above the 1990 base year. The study found that a politically uncontentious target for the city of Brisbane would be to hold emissions 20 per cent below the business-as-usual figure, or return emissions to the 1997 level by 2012, despite the growth in population and economic activity. This would require co-ordinated action but no net public expenditure by the Council; in fact, the target would involve reducing some of the planned expenditure on transport infrastructure which would have facilitated dramatic growth in vehicle use. So this would have been a "no regrets" approach. The principal policy priorities involved support for "green power", energy efficiency in buildings, use of solar hot water through planning powers and moral suasion, and initiatives already identified in the city's "Travelsmart" initiative to improve the fuel efficiency of transport. Greater reductions could be achieved by more aggressive measures to discourage inefficient use of transport systems, such as road pricing or extensive use of HOV lanes in peak hours. The City Council eventually resolved to set a less ambitious target of returning emissions in 2012 to the 2000 level.

The Murray-Darling basin

Australia is both the driest inhabited continent and the continent with the most variable rainfall. The largest river system, the Murray-Darling basin, drains about one-sixth of the continent, but has relatively small water flows by comparison with similar catchments on other continents. The Mississippi-Missouri basin and the Amazon basin cover comparable areas and have respectively about ten times and about a hundred times the average annual flow of the Murray-Darling system. Increasing extraction of water for irrigation has resulted in about 80 per cent of the median flow of the Murray-Darling being diverted, with devastating effects on ecological systems, ranging from the River Red Gum forests to native fish and birds. There are also consequences for human society, with a recent report concluding that reduced flows and increased salinity would lead to Adelaide's water supply failing WHO standards within twenty years [Wentworth Group 2002]. An informal grouping of leading environmental scientists developed a proposed response in consultation with water users [Ibid], proposing to cut water extraction by 1500 Gigalitres a year, about a 20 per cent reduction, arguing that even this major change would have only "a 'moderate' chance of restoring the Murray to a healthy working state". The policy package envisaged a transition over three years to a new water trading regime, including water property rights and pollution licences, together with incentives for improved water management. The report noted that there are clear market failures in the historic approach. The irrigators in the upper reaches of the catchment derive economic benefits for the use of water, while the costs of degradation are borne by downstream users, the natural environment and future generations. While the proposed new system would provide significant benefits at marginal or zero long-term cost, there will be some transitional costs and some reductions in the present uncharged benefits obtained by some irrigators. So there has been political opposition to the approach, reinforced by jurisdictional issues: the basin includes four States and the Australian Capital Territory. At the time of writing, it appeared likely that the outcome would be a "compromise" approach of accepting the policy framework but reducing extraction only by 500 Gigalitres, a figure unlikely to solve the ecological or social problems.

Some general lessons

Integrated approaches are needed to tackle complex problems, which always require the knowledge and skills of different traditional disciplines, as well as often needing various forms of local or traditional knowings. They require spatial and temporal integration, not only to ensure that solving the current problem in one place does not create new problems at other places and later times, but also to ensure that the local solutions recognise regional and global considerations. They also require functional integration, taking account of the different interests and perspectives of the various people and groups involved. We have gradually evolved from seeing problems as mainly technical, through a transition period of seeking win-win or at worst no-regrets solutions, to recognise that there will always be uncertainties in complex situations and that changes to those situations will usually involve trade-offs, between economic objectives and social or environmental goals, or between different interest groups, or sometimes between local interests and wider concerns of regional or global communities.

This analysis suggests some principles which are necessary, though not always sufficient. There needs to be agreement about the nature of the problem and the desired outcome(s). The process must draw on all the skills and knowledge needed to comprehend the problem and explore alternative responses. Where there are significantly different interests, such as farmers and foresters, or fishers and tourist operators, those competing interests need to be involved. The process must be managed by people with the intellectual and personal capacity to inspire respect, must provide opportunities for productive interaction and must include mechanisms to resolve conflicts. Finally, those involved need to recognise the uncertainties involved and the nature of trade-offs. As an example of uncertainty, the Inter-governmental Panel on Climate Change now acknowledges that we can't know the future pattern of greenhouse gas emissions, but also accepts that even if we did know the emissions, we could still not predict with complete confidence the changes to the climate; there would still be error-bars on the estimates of temperature, sea level, rainfall and so on [IPCC 2001].

As an approach to handling the tension between different desired outcomes, the Australian Resources Assessment Commission used a system of setting out three separate analyses of a proposal: economic benefits, social costs and benefits, environmental risks [RAC 1991]. This allows open and explicit discussion of the overall costs and benefits to the whole community, deciding whether the expected economic and social benefits justify the environmental and social costs. The final choice involves values, but there are clear advantages in a transparent approach. Developing alternative scenarios is also a very useful way to focus attention on the various costs and benefits of different approaches.

Conclusion

Scientists need to work together with the users of research to find ways of interacting sustainably with natural systems. This means cooperating to identify the scope of the problem, collect data and find practical solutions. Sustainability science also recognises that these responses can only ever be provisional, subject to revision in the light of experience. In other words, we have to see policy initiatives as **experiments** and continually review their impacts, because there are often unexpected responses when complex systems are perturbed. So we also need structures that promote social learning. It is no exaggeration to say that the survival of human civilisation depends on our ability to respond to this challenge. It is not just a challenge to the scientific community, but also to our political institutions, which have been shaped by the age of heroic certainty.

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