Values: drivers for planning biodiversity management

Ken J. Wallace a,b,*

a Department of Environment and Conservation, Locked Bag 104, Bentley Delivery Centre, WA 6983, Australia
b Future Farm Industries Cooperative Research Centre, The University of Western Australia, 35 Stirling Hwy, Crawley, WA 6009, Australia

ABSTRACT

Policy and operational outcomes in biodiversity management are compromised by inconsistent logic and lack of clarity in key terms such as sustainability, environmental quality and resilience. This is due in part to their poor linkage with human values, an essential component of a coherent planning framework. At the same time, the poor definition and classification of planning elements, such as threatening processes, hampers effective use of quantitative decision tools in planning. This paper outlines a framework in which the planning components are linked through cause–effect relationships and driven by human values. When combined with effective classification of planning elements, this framework resolves the issues outlined above and provides a sound basis for planning the management of biodiversity.

Crown Copyright © 2011 Published by Elsevier Ltd. All rights reserved.

1. Introduction

Biodiversity continues to decline worldwide in response to powerful threatening processes, many of which are anthropogenic in origin (MEA, 2005). At the same time, management resources are manifestly inadequate to counteract this trend and must therefore be wisely allocated through effective planning and priority setting (Gregory and Keeney, 2002; Moore et al., 2004). However, despite the extensive literature on planning for biodiversity management, policy and operational outcomes are often compromised by inconsistent logic and lack of clarity in key terms. For example, sustainability is a commonly used term and may be construed as a goal (Prato and Fagre, 2005). Yet Newton and Freyfogle (2005, p. 24) have persuasively argued that sustainability “has grave defects as a conservation goal and ought to be replaced...sustainability is not a freestanding goal so much as an attribute of the means used to achieve a goal”. That is, sustainability itself is not a goal, although it may be a desirable property of an ecosystem being managed to achieve a goal. A similar argument applies to comparable terms that may be written as goals including ecosystem health, condition and resilience. These examples raise questions concerning the logic underlying the use of such terms and the adequacy of planning frameworks to support goal definition in both policy and operational spheres.

Difficulties with these terms arise partly because they lie at the boundary between science, politics and policy, and their interpretation is strongly influenced by human values (Lackey, 2001; Hull et al., 2003). Furthermore, as Sarewitz (2004) has contended, the values underlying environmental matters must be clearly described and resolved through political means before science itself may be effectively applied to environmental decisions. This reasoning is extended below to planning for biodiversity outcomes in general. In particular, it is argued that explicit linking of values into the planning
process is essential not only to clarify terms, but also to drive the logic of planning and ensure that political aspects of decisions are dealt with appropriately.

The important role of human values in planning the management of natural resources is widely acknowledged (Rogers and Biggs, 1999; Decker et al., 2001; Gregory and Keeney, 2002; Shields et al., 2002; Lindenmayer and Burgman, 2005; Prato and Fagre, 2005; Lockwood, 2006). However, the link between values and other planning components is imperfectly developed in these and many other descriptions of planning (e.g., Margules and Pressey, 2000; Groves, 2003; Knight et al., 2006; Pierce and Mader, 2006; CMP, 2007; TNC, 2007). As shown below, this has important implications for specifying goals, biodiversity assets and management actions. Exacerbating this situation is that, as planning becomes more quantitative and a range of decision and analytical techniques are applied at policy and operational levels, the poor definition and classification of planning elements may lead to a range of problems including double-counting and inappropriate trade-offs in decisions. This is best demonstrated by double-counting, including the mixing of means and ends, in the classification of ecosystem services (Boyd and Banzhaf, 2007; Wallace, 2007).

This paper describes a planning framework that deals systematically with these closely related problems. The framework defines and links five planning components (human values, goals, biodiversity assets, ecosystem processes, and management actions) in a sequence driven by the values that humans place on biodiversity (Fig. 1). Although presented in a linear sequence, actual planning proceeds in an iterative manner with knowledge from one component potentially forcing planners to revisit and revise earlier components. Separation of values from other planning steps helps to partition the most socio-political aspects of planning decisions from those that are more science based. Combined with the coherent classification of planning sets, such as sets of values and sets of processes, this framework provides a sound basis for planning policy and operational outcomes. The next section describes each of these components focusing on the pivotal role of values in planning, but also explores other issues including the classification of planning elements. In Section 3, the definition and application of terms such as ecosystem health, integrity and resilience are examined through the planning framework. Finally, a number of unresolved issues are described in a conclusion (Section 4). Throughout the paper the term biodiversity is taken to include all life forms, including their genetic, taxonomic, structural and community diversity.

2. Planning components

Planning proceeds by asking questions about the desired endpoints (effects) one wants to achieve, then determining what is required to achieve them (causes) – that is, working from left to right in Fig. 1. Operational management works in the opposite direction, implementing actions to achieve the desired effects. Human values are the ultimate, desired endpoints or effects of management in this framework.

2.1. Human values

Human values are enduring beliefs concerning ultimate, preferred end-states of existence (adapted from Rokeach, 1973). They comprise the total set of end-states needed for
human well-being including those essential to human survival and reproductive success (Wallace, 2007). Definition and classification of human values is difficult (Lockwood, 1999; Shields et al., 2002). Classifications in current use include those developed for assessing the total economic value of biodiversity or other natural resources (MEA, 2005; OECD, 2006) and those developed in the context of planning or explaining the management of biodiversity (Lindenmayer and Burgman, 2005; Lockwood, 2006). Value sets from the social sciences, which frequently focus on welfare or quality of life (Sen, 1999; Abdallah et al., 2008), or on some psychological aspect of values (Maslow, 1970; Rokeach, 1973) are also relevant.

The value set described here (Table 1) is drawn from these and similar publications with an emphasis on values that may be derived from natural resources. At the same time care has been taken to avoid redundancy among the sets to minimize double-counting and clarify synergies and trade-offs in decisions. This approach uses the ultimate, preferred end-states of existence themselves (such as adequate resources and categories of health) to represent values. The classification (Table 1) provides an adequate basis for the discussion here, although it requires significant further development. The items in the table are separated into the ultimate, preferred end-states of existence and examples of the specific benefits (e.g., food, shelter and energy) that deliver those values. Those interested in the relationship between ecosystem services and values should refer to Wallace (2007), including comments in the Appendix; however, the classification in that paper has been revised for use here.

The relative priority accorded to values and the benefits required to supply them will vary among individuals and cultures. Ranking values and making decisions concerning the relative allocation of resources is a subjective process (Sarewitz, 2004; Brown and Sax, 2005) within the province of politics, but potentially informed by science. In this context it is essential that those planning policy and operational decisions work to a clearly articulated value or set of values established through a political process involving, ideally, all key stakeholders. The points in the planning process where stakeholders should be involved, and the processes for doing so, are important matters but beyond the scope of this paper. For government officers in democracies, statutory

<table>
<thead>
<tr>
<th>Table 1 - Values and related ecosystem benefits.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valuesa</td>
</tr>
<tr>
<td>Adequate resources</td>
</tr>
<tr>
<td>Health: Protection from other organisms</td>
</tr>
<tr>
<td>Health: physical and chemical environment</td>
</tr>
<tr>
<td>Esthetics</td>
</tr>
<tr>
<td>Recreation</td>
</tr>
<tr>
<td>Spiritual and philosophical contentment</td>
</tr>
<tr>
<td>Socio-political fulfillment</td>
</tr>
<tr>
<td>Sub-categories of values (examples)</td>
</tr>
<tr>
<td>Protection from other humans</td>
</tr>
<tr>
<td>Protection from predation</td>
</tr>
<tr>
<td>Protection from disease and parasites</td>
</tr>
<tr>
<td>Benign environmental regimes of temperature, moisture, light (e.g., circadian rhythms) and chemical factors</td>
</tr>
<tr>
<td>Benign global climate regime</td>
</tr>
<tr>
<td>Access to resources for:</td>
</tr>
<tr>
<td>Passive recreation</td>
</tr>
<tr>
<td>Active recreation</td>
</tr>
<tr>
<td>Biodiversity ethic</td>
</tr>
<tr>
<td>Land stewardship ethic</td>
</tr>
<tr>
<td>Commercial/material ethic</td>
</tr>
<tr>
<td>Etc</td>
</tr>
<tr>
<td>A benign social group, including mates and being loved (sense of belonging)</td>
</tr>
<tr>
<td>Meaningful occupation</td>
</tr>
<tr>
<td>Justice</td>
</tr>
<tr>
<td>Opportunity benefits, capacity for cultural and biological evolution including knowledge/education resources and genetic resources</td>
</tr>
<tr>
<td>Ecosystem benefits (examples)</td>
</tr>
<tr>
<td>Food (for energy, structure, etc.)</td>
</tr>
<tr>
<td>Oxygen/air</td>
</tr>
<tr>
<td>Water (potable)</td>
</tr>
<tr>
<td>Light (e.g., manufacture of vitamin D)</td>
</tr>
<tr>
<td>Energy (e.g., for cooking, warming covered below)</td>
</tr>
<tr>
<td>Building materials for shelter against predators or disease vectors</td>
</tr>
<tr>
<td>Abundance of disease organisms below specified thresholds</td>
</tr>
<tr>
<td>No critical vectors/predators within area of interest</td>
</tr>
<tr>
<td>Building materials for shelter against wind, rain, etc.</td>
</tr>
<tr>
<td>Plant and animal fibers for clothing</td>
</tr>
<tr>
<td>Warmth through burning wood, etc</td>
</tr>
<tr>
<td>Carbon sequestration as temperature control</td>
</tr>
<tr>
<td>Access to adequate sunlight</td>
</tr>
<tr>
<td>Appropriate environmental composition and structureb</td>
</tr>
<tr>
<td>Appropriate environmental composition and structureb</td>
</tr>
<tr>
<td>Appropriate environmental composition and structureb</td>
</tr>
<tr>
<td>Appropriate environmental composition and structureb</td>
</tr>
</tbody>
</table>

Adapted from Wallace (2007).

a Values are represented by the ultimate, preferred end points of existence.

b Note that the last four value categories demand a particular structure and composition of natural and cultural ecosystem elements depending on the specific aspect of the value required.
instruments reflect the values sought by governments on behalf of their communities of interest, the electors. However, the links between statutory and related policy documents and values are not always clear, or in terms that may be unambiguously applied in planning. Scientists and other disciplinary experts involved in decisions have a responsibility to openly acknowledge in decision contexts whether they are acting as objective advisers or as advocates for a particular value.

From the above it can be seen that isolating values as a component within the planning framework helps separate political matters, as far as practicable, from those planning components which entail a much greater proportion of science. Nevertheless, socio-political issues may arise at any point during planning. Analyses of values in our own work have revealed the diversity of views in small groups, and in turn this provides an opportunity to resolve, or at least acknowledge, fundamental issues early in the planning process.

As noted in Section 1, the importance of human values in planning the management of biodiversity is widely acknowledged, but the links between values and other planning components are poorly developed. Yet the value or mix of values selected as the goal of management may have a profound impact on the composition and structure of biota required and the related management operations. For example, consider a system of contiguous, extensive woodlands and forests. To deliver spiritual/philosophical values centered on one of the ethical concepts for biodiversity conservation outlined by Hay (2002) from such a system, management would focus on maintaining a structure and composition of biodiversity that, at the least, was likely to ensure that all native taxa and genetic variants persisted and evolved with a minimum of human intervention. However, if the management focus was on esthetic values, then management will focus much more on maintaining the mature woodland and forest structures favored as scenery (Shelby et al., 2005). A second example is that analysis of stakeholder values in a Western Australian catchment revealed that, in addition to managing for spiritual/philosophical and opportunity values, catchment stakeholders considered that the biodiversity assets in the catchment should also be managed to better protect downstream environments and their values from, for example, flooding and excess salt (DEC, 2007). However, to achieve these additional values requires a much greater area of biodiversity to be conserved. As the impacts of this unfolded through the planning process it became clear that it was not feasible to manage for all three priority values identified. This forced a change in the goals of management – a point which emphasizes the iterative nature of planning.

It is unclear why explicit linkage of values into planning is so uncommon in the literature. From the management strategies described by authors it appears that some aspect of biodiversity ethics (Table 1) is often driving planning. This is not inherently a problem provided it is made explicit and the limitations this may impose on the delivery of other values is acceptable. Managing for a single value will almost certainly limit the capacity to meet a more extensive set of values. In turn, this may reduce or marginalize community interests in biodiversity management. Thus, to plan effectively one needs to know for which values one is managing. Also, Minteer and Miller (2011) have noted that it is increasingly important to make trade-offs in decisions more explicit to help reconcile conservation disputes. Describing priority values in the context of a complete set of potential values is an important step in this regard. However, in planning biodiversity management it is not sufficient simply to describe the desired values, they must be explicitly linked to goals to avoid ambiguity concerning the outcomes of management and thus misunderstanding among those participating in policy and planning processes.

2.2. Goals

Goals, not distinguished here from aims or objectives, are universally acknowledged as critical to effective planning. Definitions have in common that goals give direction to management and express a desired outcome (e.g., Margules and Pressey, 2000; Shields et al., 2002). It is less common for the goal to be expressed in both spatial and temporal terms, although both constraints are necessary to drive later components of the planning process such as risk assessment (Wallace, 2006). Following from this, a goal is defined here as the desired outcome of management constrained in both space and time. Under this framework goals are expressed in terms of the desired end-states of existence (values). That is, the outcome expressed in the goal identifies the primary values desired as the endpoint of management. An example of the type of goal proposed is: “to make the ethical and recreational values of biodiversity in the Banksia National Park accessible to the local and state communities for the next 25 years”. In some cases goals may be stated in terms of the biodiversity assets required to deliver the values – but the connection to values should be made explicit. Complex planning tasks may involve multiple goals arranged as a hierarchy as outlined by Shields et al. (2002).

Although it is possible to express goals in terms of processes, Wallace (2007, pp. 239–240) outlines technical reasons against this before concluding that “humans measure their well-being either in terms of tangible benefits, such as food, water, property, gold, luxury goods; or in terms of abstract benefits such as a sense of being loved, or contentment. In both cases the benefits are expressed in terms of quantity, not in terms of whether the nitrogen or carbon or political cycles are working adequately. If we are to engage a wide range of people…then the measures used to evaluate options must be in concrete terms that are overtly relevant to the daily lives of people”. From both policy and operational perspectives, it is particularly important to plan for outcomes using a language that, as far as practicable, is unambiguous and meaningful for a wide range of stakeholders.

It will generally be necessary to expand goals such as that stated above in at least two ways. Firstly, a description of the communities of interest (Duane, 1997; Harrington et al., 2008) who have ownership or interest in the goal will normally be important. This will provide guidance as to who should be involved in the planning process. Although ideally all communities of interest should be included at the outset, complex planning tasks usually involve increasingly wider consultation as new stakeholders are identified. Secondly, more detailed explanation of the values to be delivered will be
required. For the goal listed above, it is necessary to state in more detail the desired recreational uses, and the acceptable level of each use.

Operational management may need to extend beyond the spatial boundary of the goal. For example, where a goal is spatially defined to encompass values from wetland biodiversity assets in a catchment dominated by agriculture, then the scale of management may be the whole catchment. Nevertheless, the goal will still be expressed in terms of the wetland biodiversity assets. Here, it is sufficient to acknowledge that although the goal will refer to the delivery of values from a specified area, achieving this goal may require a much wider area of operational management. Failure to discriminate between the spatial scale of the goal and the spatial scale of management may cause confusion in policy development and operational management. Explicit linkage of goals to biodiversity assets helps to avoid such confusion and ensures that biological targets are tied to values, the ultimate desired endpoint of management.

2.3. Biodiversity assets

Just as the priority values drive the specification of the goal, the goal defines the biodiversity assets that must be restored or maintained (Fig. 1). These are the specific biodiversity assets, detailed in terms of their composition and structure, required to meet the goal and deliver the priority values. Using the previous example of a system consisting of extensive woodlands and forests, to deliver biodiversity ethic values from such an area would generally require that, at a minimum, the existing taxa in viable population numbers (that is, a specific biological composition) are maintained. Alternatively, if esthetic and recreational values are preferred from the same woodland, then structure, particularly a higher percentage of mature trees, would be of greater importance but some taxa (compositional elements) may not be required.

Biodiversity assets are described in numerous ways, but typically as genes, taxonomic units, biological communities, various combinations of biological communities (e.g., those within a single protected area), and biomes. Once the goal is specified and the related composition and structure of biodiversity assets defined, the next step in the planning framework (Fig. 1) is to ask: What ecosystem processes must be managed to ensure a composition and structure of biodiversity assets that will achieve the goal and thus deliver the priority value(s)? This leads us to a consideration of processes, the focus of operational management.

2.4. Ecosystem processes

Ecosystem processes are the interactions (events, reactions or operations) among biotic and abiotic elements of ecosystems that lead to a definite result (adapted from Tirri et al., 1998). Such processes can be, and are here, taken to include human social, political and economic processes. Humans are another animal in any system being managed and much is gained by considering all processes in a system as a whole. Those processes that must be managed to deliver a goal are defined here as key processes. They are broadly equivalent to ‘threatening processes’; however, this latter term is ambiguous, often poorly linked to spatially and temporally defined goals, and, in my experience of natural resource planning, may unnecessarily alienate stakeholder groups whose primary interest is not conservation of biodiversity for ethical reasons (Table 1).

The importance of specific processes to management varies depending on the goal, including the temporal and spatial scales over which processes are analyzed. For example, the potential impact of a slowly invading weed species will vary considerably depending on whether the time scale is five years or 50 years, and whether over an area of 5 ha or 50,000 ha. Thus, analysis centers here on key processes which, by definition, are attached to a goal bound in time and space. In an operational sense, management is the application of human resources to influence the rates of processes to achieve a goal.

A central question is how best to describe and classify key processes for biodiversity planning? There are two main issues. Firstly, there is debate concerning the definition and classification of processes into the sources of stress on organisms (such as policy processes leading to a power plant using stream water for cooling) and the actual stresses on organisms (such as increasing water temperature downstream of cooling water discharge). One part of this debate concerns whether sources should be separated into one or two categories, and how they might be classified (Salafsky et al., 2008, 2009; Balmford et al., 2009). This is a comparatively simple issue to resolve where the focus is solely on planning operational management. Consider the set of causal relationships (Fig. 2) that might lead to a toxin poisoning waterbirds where the birds are the biodiversity asset. It is clear from even this simplified description that there are many sources (events) contributing to poisoning of waterbirds. In this example the poisoning of the waterbird is the key process, or ultimate stress, causing death. All preceding events are sources. From the perspective of planning management there is little point in trying to place these multiple sources into one, two or even three categories for analysis. Rather, it is preferable to fully model events to provide a more complete understanding or hypothesis of cause-effect relationships. This also identifies multiple points at which operational and policy instruments may be applied.

The second issue is how best to classify ecosystem processes that directly affect organisms. Existing classifications are generally organized by categories of human activity – such as mining, agriculture, recreation – plus categories that typify a common approach to operational management – such as invasive species management, pollution, or disease (e.g., Coates and Atkins, 2001; Zacharias and Gregor, 2005; Burgman et al., 2007; Halpern et al., 2007). In addition, some classifications include some natural processes, such as volcanism (Salafsky et al., 2008; Balmford et al., 2009; CMP, 2010). None of the classifications examined used less than two organizing principles. Even with effort it is very difficult to avoid significant overlap between categories (redundancy) when classifications are structured on a mixture of two or more organizing principles (Table 2).

Exacerbating this situation is that categories reflecting similarity of operational management invariably encompass different processes. For example, from a management
viewpoint, control methods for introduced animals have much in common irrespective of whether the key process involved – from the perspective of the organisms being managed – is predation, direct trampling, habitat destruction, or competition for resources. Thus, while such groupings of processes generally focus on commonality of management techniques, the actual key processes encompassed vary considerably.

These are important issues. Avoiding overlap among categories is critical to enable quantitative priority setting and to assess feasibility of policy and operational interventions. For example, one method of calculating management feasibility is to quantify the probability of all key processes combined causing goal failure. A logically coherent classification system is essential for this and other quantitative approaches. A solution is to categorize key processes according to a single principle, and to concentrate on one point in the linear sequence of cause–effect relationships. The most logical focus is on those factors that directly affect the survival and reproduction of organisms paying particular attention to avoiding redundancy. An example of this approach (Table 3) is provided here. Once the factors directly affecting the organisms of interest are identified, the related processes requiring management may be described. Similarly, the potential impacts of a change in processes may be assessed. For example, in work currently being prepared for publication, the potential impacts of changing hydrological processes on the biota of a wetland were evaluated by an expert group using a set of factors drawn from Table 3. It was found that significant risks included chemical factors (excess salinity) and drought (water as a resource). Using a set of factors (Table 3) provided greater clarity in comparison with similar, previous work employing classifications of processes (Table 2).

Whatever method is used to classify processes, it is essential that the underlying principles are clearly stated, redundancy minimized, double-counting avoided, and the categories cover all possible key processes. These attributes are particularly important where analyses aim to assess the feasibility of goal achievement and the relative importance of management interventions, whether at policy or operational levels. Management actions are themselves a sub-set of ecosystem processes, and determining the most appropriate set of management actions and their feasibility is a vital component of effective planning.

2.5. Management actions and feasibility analysis

Within this planning component the aim is to identify those actions that will most efficiently and effectively ensure key processes deliver the goal. The categories of action available to bring about change were classified by Prescott (1995) as legislation/regulation, new technology (or research and development), economic instruments and communication/education. In addition to these, groups with an on-ground, operational capacity are also able to take direct action – for example, by eradicating introduced plants. To determine what actions are required, it is essential to have an adequate model of the system affecting the target biodiversity assets. For example, the conceptual model in Fig. 2 highlights the points at which action might be taken in relation to a specific key process, poisoning of waterbirds. If it is decided that reduction in fertilizer use is the appropriate approach, then the decision

---

Fig. 2 – Event tree hypothesizing cause–effect relationships leading to waterbird deaths due to botulinum toxin.
Table 2 - Categories of ecosystem processes. Note the difficulty of removing redundancy among categories.

<table>
<thead>
<tr>
<th>Category of ecosystem processes</th>
<th>Potential key processes (examples)</th>
<th>Examples of redundancy</th>
</tr>
</thead>
</table>
| 1. Altered biogeochemical processes                                    | ● Hydrological processes  
● Altered nutrient cycles  
● Altered climate processes                                                                                                                                                                                                   | Altered nutrient cycles could be deleted and items separated into categories (3–5) and (8) with which this group overlaps                                                                                                                                                  |
| 2. Regimes of physical disturbance                                     | ● Fire regimes  
● Cyclone regimes  
● Drought regimes  
● Erosion  
● Volcanic eruptions  
● Landslides/avalanches  
● Seismic activity/tsunamis                                                                                                                                                               | Overlap between erosion in general, and water erosion under hydrological processes needs to be managed to avoid redundancy                                                                                                                                                 |
| 3. Impacts of pollution (often, but not necessarily, anthropogenic)    | ● Herbicide/pesticide spraying  
● Entanglement in or ingestion of anthropogenic debris  
● Spillage of oil and other chemical spills  
● Atmospheric, land and water chemical pollution  
● Noise pollution  
● Thermal pollution  
● Anoxia  
● Oil spills                                                                                                                                                                                                 | Need to avoid redundancy with biogeochemical processes and other categories within (3), anoxia overlaps with (8)                                                                                                                                                    |
| 4. Impacts of introduced plants and animals                            | ● Environmental weed invasion  
● Predation, herbivory, parasitism, competition, etc, by introduced animals                                                                                                                                                       | Hunting and collecting by humans, a predator, is potentially redundant with components in (7) and (8)                                                                                                                                                                   |
| 5. Impacts of problem native plants and animals                        | ● Expansion of native plant species  
● Predation/herbivory, competition, etc. by native animal species                                                                                                                                                                      |                                                                                                                                                                                                                       |
| 6. Impacts of disease                                                  | ● Initiation and spread of animal diseases  
● Invasion and spread of plant pathogens (e.g., fungal diseases)                                                                                                                                                                         | Hunting and collecting, etc. may be redundant with items in (4) and (8). Habitat destruction included in (8) below, but may be redundant with (7)                                                                               |
| 7. Impacts of human activity                                           | ● Recreation  
● Consumptive uses  
● Illegal actions  
● Hunting and collecting  
● Harvesting of native species for commercial use                                                                                                                                                              |                                                                                                                                                                                                                       |
| 8. Production of ecological and genetic resources to maintain viable populations | ● Food production  
● Water production  
● Shelter production  
● Oxygen production  
● Reproduction (access to mates)  
● Genetic fitness                                                                                                                                                                                                 | Vegetation clearing, urban and other infrastructure development, mining/quarrying, sea floor dredging, other habitat degradation (many listed above – important not to double count any one, specific key process) |

needs to be made as to which action, or combination of actions are likely to be most effective. Regulation, education and economic incentives are all likely to be important. Specific techniques for assessing actions may be required, for example, where public and private benefits are both involved (Pannell et al., 2012).

Conceptual and numerical models are thus fundamental to describing current knowledge of cause–effect relationships which will, in turn, underpin the selection of policy and operational interventions. Where adequate data is available, complex numerical models may be applied (e.g., Tremblay et al., 2004; Millsapugh and Thompson, 2009). However, a wide range of techniques including event trees and cognitive mapping (e.g., Hobbs et al., 2002; Özesmi and Özesmi, 2004; Burgman, 2005; CMP, 2007) allow useful conceptual models to be developed based on expert knowledge alone. These models document ideas about interactions within systems and identify opportunities for undertaking policy and operational actions. For example, it is clear from the event tree describing waterbird poisoning (Fig. 2) that there are many opportunities for intervention including policies to alter farm fertilizer use, diverting summer flows, and so on. Also, once events are described in a logical framework, the hypothesized interactions are overt, thus encouraging debate and capture of alternative views. Models not only help identify management actions, but they also provide a basis for calculating the likely success of management where, for example, probabilities of events can be incorporated.

Having identified a set of management actions to deliver a goal, it is generally unwise to proceed if success is unlikely. That is, if management feasibility is low. Feasibility is defined here as the quality of being practicable to accomplish or carry out (adapted from the Oxford English Dictionary). There are several questions that need to be answered to assess feasibility (Wallace et al., 2003). Firstly, is there adequate knowledge and technical capacity to implement the proposed
actions? That is, is the science supporting the project models sufficiently understood to give confidence that the management goal will be delivered with an acceptable probability of success? In addition, are the technical tools – equipment and operational knowledge – sufficiently well developed to ensure effective implementation of proposed management actions? If the answer to either of these questions is negative, then managers have three options. They can either undertake the necessary research and/or technical development to overcome the capacity deficit, change the project goal and/or values to ensure the goal may be achieved with an acceptable probability, or abandon the project, at least for the foreseeable future.

Secondly, what will the project cost to implement in financial terms? Given the comparatively small amount of funds expended on biodiversity management in developed nations, absolute lack of financial resources is rarely an impediment to achieving goals. Rather, it is the relatively small allocation of resources through socio-political processes that is the impediment to successful biodiversity management. Thus, this item could be included with the next. However, there are advantages in calculating costs separately. In particular, where proposed management actions prove to be expensive, efforts to improve knowledge and technical capacity to reduce costs are encouraged.

Finally, does the proposed project have sufficient socio-political support from stakeholders to ensure allocation of adequate resources for project success? This may entail support from any one or more of specific individuals, local and regional communities, or national and global communities depending on the type of support required. This potentially engenders a third scale of management. That is, a project will often have different scales in terms of goal specification, operational management, and communities of interest. If a project has inadequate socio-political support, there are again three options: undertake the necessary endeavors – such as communication and political lobbying – to overcome the deficit in socio-political support, change the project goal or values to ensure the goal may be achieved with an acceptable probability, or abandon the project, at least for the foreseeable future.

Monitoring, evaluation and reporting, well described in the current literature, are essential activities once a project is considered feasible and implementation begins. They may be aimed at any planning component (Fig. 1) depending on the question being investigated. However, ultimately the success
of management will be assessed in terms of whether priority values have been achieved. Given that values, taken together, represent human well-being, this provides an important opportunity to inform policy and political discussions. The planning framework outlined above provides the context within which the specification of terms such as sustainability, an issue raised in Section 1, may be resolved.

3. Ecosystem properties

Terms such as sustainability and ecosystem health are defined here as ecosystem properties, which are attributes belonging to an ecosystem or its individual elements or processes. Thus, properties are attributes of the abiotic or biotic elements of an ecosystem, or related processes, considered singly or collectively, or as a whole system. For example, resilience is “a measure of a system’s capacity to cope with shocks and undergo change while retaining essentially the same structure and function” (Walker et al., 2009, p. 1). Thus, resilience is neither the elements of an ecosystem nor the related processes, but a measure of a system’s capacity to maintain itself under specific circumstances. The above definition of properties is consistent with that of chemical and physical properties of systems and their elements, such as steepness, aridity, hardness, acidity, and so on; and is also broadly consistent with use of the term by Jax (2010).

Terms such as sustainability, resilience, and ecosystem health – all ecosystem properties – may be problematic. With respect to sustainability, goals developed as described above specify what values are to be sustained, for how long, and from what specific area. Expressed in this way a goal effectively renders the term sustainability unnecessary in planning. If inter-generational equity is an issue, then the timescale of the goal should be extended to cover the desired number of generations.

A similar argument applies to system properties such as environmental quality, health, integrity, and condition. If the values and goals that drive planning are explicit as described in Section 2.2, then these terms may be unnecessary. Presumably if a goal is achieved, then 100% of the environmental quality or condition has also been achieved. The only exception might be where there is an even more demanding aspirational goal, but in that case once the aspiration is constrained in space and time, 100% of condition or quality has again been described. At the very least, ecosystem properties such as health, condition and integrity need to be closely linked to a goal (and thus values) for them to be useful in policy development or operational planning.

Other ecosystem properties – such as resilience – are useful concepts that encompass helpful tools for measuring and analyzing aspects of ecosystems. Nevertheless none are, in themselves, the values arising from ecosystem management. All are descriptive terms or means to ends. Applying Gregory and Keeney’s (2002) “why” test, not one of the ecosystem properties listed is the ultimate (or penultimate) endpoint for a “why” question, although all may be important properties of ecosystems delivering one or more values. Thus, in biodiversity planning ecosystem properties are generally given substance by a management goal.

A common planning error is to mix two or more of values, assets, ecosystem properties and ecosystem processes at the same level of classification. For example, the Australian Government required regional natural resource management groups to address ten targets (Australian Government, 2003). The ten targets were:

1. Land salinity.
2. Soil condition.
3. Native vegetation communities’ integrity.
4. Inland aquatic ecosystems integrity (rivers and other wetlands).
5. Estuarine, coastal and marine habitats integrity.
7. Turbidity/suspended particulate matter in aquatic environments.
8. Surface water salinity in freshwater aquatic environments.
10. Ecologically significant invasive species.

Of these targets (1), (6), (7), (8) and (10) are ecosystem properties or elements depending on how they are defined, and all are closely related to key processes; (2–5) are ecosystem properties; and (9) consists of biodiversity assets. Thus, the list is not exhaustive for any one of its constituents (assets, properties and processes). At the same time, there is redundancy among the constituents. For example, all the properties listed may affect the one asset type mentioned, and all the properties listed may relate to community or system integrity. It is therefore not surprising stakeholders had difficulty applying the targets in regional planning. This underlines the importance of classifying planning elements using logically coherent sets that follow three criteria (adapted from Burgman, 2005). These are that each classification set should:

i. Be exhaustive, in that there is a classification category for each element to be classified;
ii. Contain no redundancy among categories. That is, each element to be classified fits only within one classification category; and
iii. Be readily understood by those applying the classification system.

The above example also underlines the difficulties that policy makers invite if they use ecosystem properties as management goals, difficulties that are substantially magnified where values are not appropriately defined and incorporated into planning.

4. Conclusion

Human values are used to drive the biodiversity planning framework developed above. The specific values selected as the outcomes of management profoundly affect the goals of management, and these in turn determine the particular composition and structure of biodiversity assets required to meet the goal at the end of the planning period. Once these
aspects, the ends of management (Fig. 1) are clear, the actions required to achieve them can be established through describing key ecosystem processes and modeling the relevant system. Feasibility analysis can then be used to assess whether the proposed actions are likely to achieve the goal. At any point in the planning process new information may drive planning back to an earlier point — that is, the planning process is iterative. Planning frameworks contain a number of elements, such as values and ecosystem processes, which must be coherently classified, particularly where quantitative analysis is intended.

This planning framework directly addresses the issues raised in Section 1, in particular, the inconsistent logic and lack of clarity in key terms, including the definition of goals. The direct linkages between the planning components and the statement of values at the outset encourage clarity throughout the planning process and discourage the mixing of means and ends (see Section 3). Applying the planning framework in conjunction with the concept of ecosystem properties ensures that terms such as sustainability, ecosystem condition and resilience may be effectively defined. Separation of values as a component of planning helps to partition the most political components of planning decisions from those that are more science based, which resolves some of the difficulties outlined by Sarewitz (2004) and Juntti et al. (2009) concerning the contribution of science and evidence to policy decisions.

The planning framework outlined here could be improved by developing a more robust classification of values, an endeavor that will require significant cross-disciplinary work. While acknowledging that value sets will vary depending on context, core aspects will be common across planning situations, and the elucidation of these will improve discussions of trade-offs and synergies in decision processes. Although science cannot make socio-political decisions, it can help ensure that decisions are well-informed with trade-offs and synergies clearly stated.

Other areas requiring development are the quantitative and qualitative methods for exploring, documenting and evaluating values, assets, key processes, and actions. Effectively engaging the appropriate communities of interest in deliberative processes (Frame and O’Connor, 2011) and cost-efficiently evaluating the feasibility of proposed management actions also continue to provide important challenges. In closing, it is instructive to recall Orr’s (2009, p. 1350) retrospective comment “...that all of us working for a habitable planet should have focused more clearly on politics and on the question of how good ideas move across the chasm from being right to being effective in the conduct of our public and international business”. If this paper contributes positively to that process, it will have achieved its aim.

**Acknowledgements**

Discussions with many colleagues and critiques from reviewers have been an essential component of testing and developing the ideas in this paper. In particular, discussions with, and comments from: G. Barrett, J. Bartle, D. Coates, P. Drake, J. Higbid, R. Lambeck, D. Pannell, A. Rowles, P. Ryan, M. Smith and R. Vogwill have been very helpful. Referee comments were valuable, and significantly improved the paper. Work on this paper was funded by the Department of Environment and Conservation; however, it also contributes to departmental commitments to the Future Farm Industries Cooperative Research Centre.

**References**


MEA (Millennium Ecosystem Assessment), 2005. Ecosystems and Human Well-being: Biodiversity Synthesis. World Resources Institute, Washington, DC.


