Marine and terrestrial conservation planning – how different are they?

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ABSTRACT

There has been much discussion about the difference between marine and terrestrial systems and appropriateness of applying terrestrial conservation methods to marine systems. To investigate these issues, 43 criteria were assessed for magnitude of difference and implications for conservation planning. Results suggest that despite distinct differences in the ecology of marine and terrestrial systems, many of the conservation concepts applied in terrestrial systems are relevant and readily transferable to marine systems. Concern that marine systems may be too open and variable to support area-based conservation approaches is quickly abating. This initial misconception was influenced not only by real differences in ecology and scale of the two systems, but also by historic biases in our knowledge and use of these systems. In broad terms, as our understanding of these systems continues to develop, it is increasingly clear that both are subject to a similar suite of conservation issues requiring similar types of responses. In many regards the underlying conservation planning approaches currently applied in these systems are tending to converge towards a 'landscape' management approach incorporating on and off-reserve conservation techniques. Increasingly for marine and terrestrial systems, the most important conservation planning objectives include the establishment of secure systems of appropriately located, designed and managed protected areas, and to integrate their application with sustainable management and supplementary conservation management in the off-reserve matrix.

Key words: marine and terrestrial comparison, conservation planning, conservation management, protected areas, landscape conservation

Introduction

Some recent exercises in planning marine protected areas have drawn from ideas and methods developed in terrestrial environments (Ward *et al.* 1999; Airame *et al.* 2003; Leslie *et al.* 2003). Given the important physical and biological differences between marine and terrestrial systems, debate has arisen about the appropriateness of this transfer. Much of this concern is based on our understanding of the scales of variability, and environmental, ecological and evolutionary processes acting to determine biological diversity (Steel 1985; Carr *et al.* 2003). Adding to this complexity are real and perceived differences in ownership, human use, sustainability, regulation and access rights. Some have argued that the adoption of land-based approaches involving explicit goals can be beneficial in challenging entrenched misconceptions and biases (Gage 1997; Gell and Roberts 2002) and may introduce a higher level of accountability. Arguments against the adoption of a terrestrial model often refer to the dynamic nature of oceanographic processes, high natural variability, extensive movement of organisms in a system with few discrete boundaries (Hiscock 1997; Pullen 1997; NRC 2001). These factors have traditionally posed difficulties for fisheries managers and others working in the marine realm (Underwood 1981) as they contribute to uncertainties associated with an incomplete understanding and ability to predict population dynamics of fish, interaction among species and effects of environmental factors and human impact (NRC 1999). Consequently, concern was initially expressed about the limited role that permanent protected areas for biodiversity and fisheries management might play in such a system (Angel 1997; NRC 2001). As evidence supporting the value of marine protected areas continues to grow, discussion is beginning to focus on identifying the appropriate reserve selection and design criteria in order to meet the specific needs of conservation and management in a marine system (Carr 2003). Despite perceived differences, some aspects of planning protected areas are common to marine and terrestrial systems. In essence, conservation planning in both environments is faced with the same set of spatial problems. It requires, at the very least, a spatial representation of biodiversity – the set of features to be protected from threatening processes – and spatial decisions about the location, extent and configuration of protected areas (Pressey and McNeill 1996). Even aside from these fundamentals, the more specific differences between marine and terrestrial systems might have been overstated. Perhaps marine and terrestrial environments are more analogous, at least for the purposes of conservation planning, than is generally believed. To explore this question, I compared marine and terrestrial systems in relation to 39 themes (and 43 explicit criteria) relevant to conservation planning. These issues are grouped under 9 headings:

1. Biodiversity
2. Data on biodiversity
3. Regionalisations
4. Threats to biodiversity
5. Data on threats to biodiversity
6. Conservation goals
7. Regulatory framework
8. Coverage of existing conservation areas
9. Establishing new conservation areas

In the following sections each criterion is examined, with discussion on the degree of difference between the marine and terrestrial systems and the implications for conservation planning.

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Biodiversity

Dispersal of propagules

Marine and terrestrial organisms tend to have different dispersal strategies. A large proportion of marine organisms have an early planktonic phase during which propagules disperse, in some cases over long distances. Documented analogies in terrestrial systems associated with atmospheric dispersal of propagules or young are relatively uncommon, although recent advances in meteorological technologies have revealed, for example, the existence of atmospheric pathways of migrating insects between agricultural regions in south-central Texas (Westbrook *et al.* 1999). Other examples are generally restricted to wind dispersed spores, bacteria, viruses, pollen, seeds and some insects - such as juvenile spiders using silk runners as sails (Gage *et al.* 1999). The perception that marine populations operate in an 'open' system where long distance dispersal allows recruitment into patches of suitable habitat widely separated from the adult sources of propagules has been widely accepted. This is not always the case. In recent years there has been a radical reassessment of the open marine system in relation to propagule dispersal. We now know that despite high potential for long distance recruitment, dispersal of many marine species with early planktonic phases are constrained in their dispersal to distances as small as 1m by a variety of behavioural and physical mechanisms including eddies, active swimming, selective settlement on preferred habitat, and short pelagic duration of larval and egg stages (Olson 1985; Tegner 1993; Palmer *et al.* 1996; Shulman 1998; Swearer *et al.* 1999; Shanks *et al.* 2003). Many ecologically significant Australian seagrass species, including *Posidonia sinuosa*, are poor seed dispersers and instead rely on notoriously slow rhizome growth at rates less than 25 cm per year (Butler and Jernakoff 1999).

Implications for conservation planning:

- For a variety of marine organisms, severe disturbance of habitats is not followed by quick recovery through recruitment from "upstream" sources of propagules (Downes and Keough 1998; Butler and Jernakoff 1999; Jones *et al.* 1999; Warner *et al.* 2000). The persistence of these organisms, like many terrestrial species, can be promoted by permanent protected areas.
- Permanent protected areas can also be important to mitigate impacts on the marine environment by activities, such as trawling and dredging, that can render areas unsuitable for establishment of young over very large areas for decades, particularly when more stable habitats and biogenic structures (e.g. seagrass beds, soft corals, sponges and polychaetes hummocks) are disturbed (NRC 2002).
- Marine species subject to widespread threatening processes, including over-harvesting, can require protected areas that cover both larval source and settlement areas (Roberts 1998; Crowder *et al.* 2000; NRC 2001). Opportunities for applying one-way larval sink-source theory in terrestrial systems are rare, and uncommon in marine systems.

Endemism and spatial turnover of species

Narrow endemism (restriction of a taxon to a small geographical area) is relatively common in terrestrial organisms (Myers *et al.* 2000). It has generally been accepted that narrow endemism is less common in marine organisms due to greater dispersal of propagules and lack of geographic barriers. Some marine organisms, however, are poor dispersers relative to the spacing of suitable habitats or occur only in very restricted habitats. Consequently, there are a growing number of examples of marine endemism associated with oceanic islands, seamounts, hydrothermal vents and cold seeps, and also with more ubiquitous but discontinuous habitats like embayments, basalt pebble beaches, estuaries and coastal lagoons (McAllister *et al.* 1994; Ormond and Roberts 1997; Phillips 2001; Ponder 2003). It remains unclear to what extent some apparent narrow marine endemism is the result of under-recording (Elmgren and Hill 1997; Chapman 1999). However, endemism may also have been overestimated by under-recording in terrestrial regions (Myers *et al.* 2000). The generally higher levels of narrow endemism in terrestrial regions correspond to generally higher rates of turnover between separate occurrences of the same habitats (i.e. gamma diversity). For example, in the diverse marine gastropod genus *Conus,* turnovers of sub-tidal and intertidal species of 55% and 39% respectively, have been recorded over 1000 – 2000 km, while terrestrial communities often demonstrate turnovers of 100% over 100 km (Kohn 1997).

Implications for conservation planning:

- Marine and terrestrial areas with narrow endemics become fixed points in the design of representative systems of protected areas.
- In both marine and terrestrial regions, centres of narrow endemism (i.e. biodiversity "hotspots") that are also exposed to high threat often become priorities for conservation action (Myers *et al.* 2000; Hooper *et al.* 2002).
- Due to limited data on biodiversity in both terrestrial and marine environments, distinctive abiotic features that are likely to harbour narrow endemic species require protection until their biota can be documented.
- In general, it might appear sufficient to have more widely spaced replication of habitats in marine than terrestrial systems to deal with gamma turnover of species. However, underlying this generalisation, there is likely to be much variation between regions in both terrestrial and marine environments, including localised occurrences of endemism.

Community Genetics

Recent advances in genetic analysis techniques (e.g. mitochondrial DNA) are suggesting two important patterns. Firstly, dramatic spatial and functional discontinuities are being revealed between previously unrecognised marine populations (Reeb and Avise 1990; Neigel 1997; Reeb *et al.* 2000). For example, in the case of the sessile American oyster *Crassostrea virginica*, a dramatic spatial boundary was identified between two populations in a coastal region that appeared to be a zone of almost continuous habitat with no obvious barriers to dispersal (Reeb and Avise 1990; Neigel 1997). Even though the populations appear to be almost morphologically identical, it is clear that their genetic evolution would have required separation over about one million years, and that their genetic boundary remains so complete that it is assumed that there continues to be no viable larval exchange between two populations (Neigel

1997). The swordfish *Xiphius glandius* provides a similar example in a pelagic species. Where previously there was assumed to be a single homogenous stock, genetic analysis has identified two distinct populations (Reeb *et al.* 2000). Despite having overlapping ranges, these populations have been found to be genetically distinct due to their reproductive isolation by separation of their spawning grounds. Within both of these commercial species, plans are required to manage each population as a discrete fisheries stocks. A better understanding of intra-specific genetic variability, particularly in the high volume harvest of commercial species, is a fundamental requirement for achieving ecological sustainability.

Secondly, heritability of genetic variation within individual marine or terrestrial species has community and ecosystem consequences that extend well beyond the population itself (i.e. extended phenotype - Whitham *et al.* 2003). The effects of genetic variation within a dominant species may not only result in different traits within that species, but those traits have been shown in come cases to influence community structures and possibly ecosystem processes (Whitham *et al.* 2003).

Implications for conservation planning:

- Intra-specific variation between populations occurs in both marine and terrestrial regions, and its extent and significance may be underestimated. Until better information is available, these uncertainties should be reflected in the application of the precautionary principle including replication of protected areas and the adoption of conservative thresholds for sustainable management practices.
- For marine and terrestrial regions, there is a need to consider and protect genetic variation, particularly within dominant (or keystone) species (Whitham *et al.* 2003).
- For marine and terrestrial regions, there are real weaknesses associated with the conservation of individual species rather than communities or ecosystems (Simberloff 1998; Hutchings 2003; Whitham *et al.* 2003). Protected areas should be used to protect community and ecosystem viability rather than individual species, although the location of protected areas may be influenced by the conservation requirements of a threatened or vulnerable species.

Geographically separate life-history stages

Life histories of marine species often involve extensive movement among a variety of quite different habitats (Lindeman *et al.* 2000). Examples include: the movement of juvenile stages of the blue groper *Achoerodus viridis* between estuarine and coral reef habitats (Gillanders 1997), and the Caribbean spiny lobsters *Panulirus argus* with a pelagic larval phase prior to settlement and the use of a variety of benthic habitats including mangroves, reefs, seagrass post settlement (Acosta 1999). Comparable separation of life-history stages is uncommon in terrestrial environments. An example includes the hatching of monarch butterflies followed by migration to very different environments in Mexico (Bojorquez-Tapia 2003).

Implications for conservation planning:

- For both marine and terrestrial regions, life history stages of some species can depend on small patches of critical resources (e.g. fish spawning grounds, seabird rookeries, overwintering habitat for monarch butterflies). These areas are priorities for protection because their reduction or elimination can threaten the persistence of even widespread and abundant species.
- For both nearshore (i.e. neritic) marine and terrestrial regions it may be necessary to protect representatives of all habitats necessary for life history stages of species, where they are known.
- For both marine and terrestrial regions, where critical habitats for all life history stages are not known, the best approach is to represent the full range of habitat diversity in a system of protected areas. As information on the requirements of species improves, it might be necessary to refine the types, extent and distribution of critical habitats reserved in order to ensure that each is adequately protected.
- As both marine and terrestrial environments support a mix of species with different life-history requirements, applicable at a variety of scales, large reserves are likely to protect a greater range of habitats and life-history requirements than smaller reserves. While it might be desirable to maximise reserve size at fine to medium scales, networks of protected areas may be required to satisfy life-history requirements at coarser scales.

Factors influencing species distributions

Organisms interact with their physical environments in a variety of ways that contribute to their eventual distribution and survival at a variety of scales. By understanding these relationships it is possible to apply well-defined abiotic patterns to help predict community distribution patterns in both marine and terrestrial systems (Emanuel *et al.* 1992; Schoch and Dethier 1996; Zacharias *et al.* 1999; Roff and Taylor 2000). Despite fundament differences in their ecology, terrestrial and near-shore marine ecosystems are essentially similar in that ecological processes are often dominated by the size and location of physical structures (Holling *et al.* 1995; Hyrenbach *et al.* 2000). For example, fixed abiotic structures (e.g. mountains, islands, reefs or coastline) interact with dynamic abiotic features (e.g. wind, cloud, current or swell) to contribute to the maintenance of persistent ecological processes (e.g. rain-shadows, depositional environments, up-welling zones and larval retention eddies) that can be mapped for a given location at an appropriate scale and level of predictability (Denny 1995; Fox *et al.* 1999; Moller 2003).

For marine and terrestrial systems, biotic factors such as recruitment success, predation and competition tend to be expressed in biotic distribution at finer scales and over shorter time frames than abiotic factors (Holling *et al.* 1995; Mann and Lazier 1996). While there is a fundamental need to understand the relationship between biotic patterns and ecological processes at various scales, the relationships are often very complex, poorly understood and difficult to predict in both systems. Within this dynamic mix of biotic and abiotic diversity, conservation planners tend to utilise regular or persistent patterns to delineate convenient biodiversity surrogates, such as habitats. As a significant amount of diversity occurs at different scales within-habitat (i.e. alpha) or between-habitat (i.e. beta), in both marine and terrestrial systems, habitats alone are unlikely to adequately describe the full range of biological diversity (Gray 1997a).

A fundamental requirement in planning for area-based conservation, or sustainable resource use in both marine and terrestrial environments, is the delineation of habitat boundaries in a consistent classification (Roff and Taylor 2000). In both systems, habitat classifications are regularly defined using a combination of geophysical features (e.g. climate, oceanography, physiography) and biotic data (Wessel *et al.* 1999; Roff and Taylor 2000; Day *et al.* 2003). Where available, biotic data in the form of species occurrence records or maps of dominant community features (e.g. mangroves, seagrass, marine algae or coral) are often integrated into habitat classifications or applied as separate complementary data sets. While planners in both systems experience limitations in the availability of biotic data, this problem is possibly more extensive in marine environments due to the logistical and economic difficulties in accessing timely biotic data.

Implications for conservation planning:

- In the absence of ideal biotic data, abiotic information may provide a basis in both regions, for delineating habitats and ecosystem so that the development of a protected area system is not delayed;
- For both marine and terrestrial regions, persistent or repeating patterns in spatial distribution of communities or their surrogates provide a basis for defining and planning area based conservation action.
- For both marine and terrestrial regions, habitats alone are unlikely to describe diversity occurring at other scales, either within-habitat or between-habitats. Conservation planning should consider diversity at multiple scales.

Regular movements of organisms

There are many marine and terrestrial species that undertake predictable migrations to, or aggregate at, specific locations in response to seasonal temperature variation, food availability or life history requirements (e.g. recruitment or breeding). Better known examples from marine and terrestrial regions include annual migrations and aggregations of seals (e.g. elephant seal *Mirounga leonina*), whales (e.g. humpback *Megaptera novaeangliae*), fish (e.g. orange roughy *Hoplostethus atlanticus*), lobsters (e.g. rock lobster *Panulirus ornatus*, spiny lobster *P. argus*), sharks (e.g. grey nurse *Carcharias taurus*), insects (e.g. bogong moth *Agrotis infusa*), penguins, migratory wader birds, seabirds, bats and quadrupeds (e.g. caribou *Rangifer tarandus*). For species with large predictable movements, the conservation options are essentially the same for marine and terrestrial regions: establish fully protected areas at vulnerable aggregation sites within a context of comprehensive biodiversity protection; introduce selective protection for species or habitat at vulnerable sites; or apply species selective regulation independent of location. Marine reserves have, for example, been located to protect key habitat of the Caribbean spiny lobster *Panulirus argus* to prevent overfishing and local extinctions (Acosta and Robertson 2003)

Home range movements raise another series of issues, reserve design and the need for off-reserve conservation. Many species in both systems roam over relatively predictable home ranges at a variety of spatial scales that are often associated with the distribution of favourable habitat. It is generally accepted that species with small restricted home ranges are more likely be effectively protected by a reserve than wide ranging species that forage beyond the reserve boundary. However, significant benefits have been identified for a number of marine species that seasonally migrate well beyond the reserve into deeper off-shore waters (Gell and Roberts 2002; Halpern 2003). Similar benefits are assumed for mobile fauna in terrestrial systems, although apparent benefits may be due to habitat loss off-reserve and a preference for remnant habitat inside the reserve.

Implications for conservation planning:

- For marine and terrestrial regions, protected areas may protect vulnerable aggregation sites for species that migrate regularly to predictable locations.
- For marine and terrestrial regions, careful reserve design and large reserve size to protect the home range of a larger number of resident species, and developing boundaries that utilise natural barriers (Barrett 1995).
- Protected areas in both regions are likely to require complementary off-reserve action for those species that move beyond the reserve boundary.
- In both regions, protected areas may provide benefits for many species that move regularly beyond the reserve boundary. The degree to which this is due to species protection or habitat protection is unclear.

Irregular changes in distributions and abundances of organisms

Irregular movements are apparent in both marine and terrestrial species in response to spatio-temporal dynamics of resources (e.g. "nomadism" of birds, movements of pelagic fish). Approximately 26% of Australian land birds (Breckwoldt 1983), most water birds and many insects are considered to be nomadic as they move about the landscape in response to variable climatic events and feeding opportunities. These apparently irregular movements are similar in many regards to those of pelagic fish whose distribution is often influenced by oceanographic patterns and related feeding opportunities. For example, the distribution of planktivorous seabirds has been associated with oceanographic fronts that reflect concentrations of available prey. Alternatively, some piscivorous seabirds have distributions closely tied to that of schooling surface-feeding tunas (Spear *et al.* 2001). Pelagic tuna and squid distribution have long been linked with oceanographic features, such as thermoclines and up-wellings (Rockford 1981; Lu *et al.* 2001; Ichii *et al.* 2002). Even the distribution and frequency of these apparently irregular oceanographic features occur with a certain level of predictability as they are often associated with the major interaction of reoccurring currents, landmasses and broad-scale climatic event such as *El Nino* and *La Nina*.

Implications for conservation planning:

- The conservation response for vulnerable nomadic birds and pelagic fish is similar and may involve species-specific regulation or protection beyond the protected area boundary.

Causes and patterns in ecological heterogeneity

Heterogeneity occurs at a variety of spatial and temporal scales due to interaction between organisms and their physical environment. Any detailed investigation of the causes of species distribution in either marine or terrestrial systems requires an understanding of the fundamental relationship between ecological pattern, process and scale (Cale and Hobbs 1994; Gardner 1998; Underwood and Chapman 1998a, b). While it is often very difficult to determine the causes of ecological pattern in either system (Gardner 1998), some general trends are evident and may be used to guide conservation decisions.

At a broad regional level in both marine and terrestrial environments, heterogeneity is dominated by evolutionary rather than ecological processes, and is often related to broad-scale environmental gradients and long-term dispersal barriers. Climatic and oceanographic processes tend to maintain persistent ecological patterns at a broad-scale over the long-term (e.g. years) even through they may have significant and highly variable short-term localised effects (e.g. days). At the local level, physical heterogeneity and biological–physical interactions contribute more significantly to community and habitat heterogeneity in both environments. Similarly, at fine levels biological interactions (e.g. competition and avoidance) play a significant role in determining species heterogeneity (spatial and temporal) within-habitats (Gray 1997a).

In general, for nearshore (i.e. neritic) marine environments of continental shelf regions, many processes are dependent on the geographic location and physical patterns of the coastline and sea floor, and hence behave in a manner comparable with terrestrial systems (Holling *et al.* 1995). However, in a true broad-scale pelagic system only regional level factors tend to be linked with geographic location, while the local to fine level factors are dependent on the properties of the water body independent of geographic location (Angel 1997).

Implications for conservation planning:

- For both marine and terrestrial systems, important ecological patterns occur at every spatial and temporal scale. An area that appears homogenous at a broad level may be heterogenous at a finer level.
- For both marine and terrestrial systems, the variation due to relatively small-scale physiographic heterogeneity (e.g. gully versus ridge line in terrestrial vegetation communities, or swell exposed versus swell protected sides of shallow reefs) often exceeds that of broad-scale zoogeographic variation (Underwood *et al.* 1991; Emanuel *et al.* 1992).
- As a general rule, physically heterogeneous areas support a wider range of ecological communities than homogeneous areas (Cramer and Willig 2002). If the conservation objective is to protect the widest range of ecological communities, it is desirable to protect physically heterogeneous marine and terrestrial areas.
- Permanently located protected areas are appropriate for terrestrial and nearshore marine environments.

Role of habitat structure (biotic and abiotic)

The effects of abiotic and biotic structure on biodiversity are apparent in both marine and terrestrial systems. The term habitat structure applies to both abiotic and biogenic structures over a range of scales and complexities, although humans tend to focus on habitat structure at scales relevant to their interests and requirements. Important structures in marine systems are analogous to many terrestrial systems and include spaces between sediment and soil substrata, boulder fields and scree slope, polychaete hummock and hollow tree, kelp forest and closed forest, algal beds and ephemeral pasture, and reef systems and hills. These structures may provide a range of functions including protection, habitat for a more diverse community or interaction with physical conditions (sunlight, drainage, current, climate) to influence the performance (recruitment, growth and survival) of individuals and communities (Lenihan 1999).

Implications for conservation planning:

- For both marine and terrestrial systems it is generally desirable to maximise heterogeneity of biotic and abiotic structures at as many scales as practicable. Understanding the distribution of habitats at a variety of spatial scales is an important part of identifying complexity.

Data on biodiversity

Catalogues of described species

Catalogues of described marine and terrestrial species are far from complete. Even estimates of total numbers of insects species, one of the best studied groups with over 750,000 species described, range widely between 3 to 30 million (Gaston 1991; Groombridge 1992). Comparable estimates for the number of undescribed species in the deep sea are range between 0.5 to 10 million (Grassle and Maciolek 1992; May 1992). Even in Australia's relatively well-studied coastal, continental shelf and slope waters, it is estimated that only 10-50% of macro-fauna have been described (Zann 1996). Sensible estimates for micro-organisms (i.e. viruses, prokaryotes and protists) have yet to be formulated.

Larval, juvenile and adult life-history stages and their distribution vary significantly in many marine species leading to difficulties in relating the different forms to a single taxon. Once described, individual field records should incorporate life-history stage as an essential requirement in determining the viable zoogeographic range of marine species as many propagules disperse well beyond their viable range. These problems are uncommon in terrestrial regions.

Implications for conservation planning:

- Catalogues of described species are far from complete in both marine and terrestrial systems hence conservation planning decisions should not be made solely on the basis of species records.
- The problem of sibling species is likely to more extensive in the marine environment. That is, without having a complete knowledge of the full sequence of life forms in the development of a particular species, different life history stages of the same species may be temporarily miss-classified as separate species.

- Unless the viable range for a species is known and their life history stage recorded, estimates of viable zoogeographic range may be over estimated. This is likely to be a more extensive problem in the marine environment where many juveniles are transported beyond their viable range.

Spatial coverage of biological sampling

The spatial coverage of biological sampling data (i.e. point records of species occurrence) in both systems are often patchy and biased in their coverage due to factors including the study objectives, location and subject preference, extent of study area, ease and cost of field access, and resolution and design of the sampling effort. Biases in spatial coverage factors, combined with issues of data reliability and currency, often limit the suitability of biological data for application to conservation planning in marine and terrestrial regions (Pressey and Ferrier 1995; Maddock and Du Plessis 1999; Vanderklift and Ward 2000). These problems of coverage are accentuated in marine systems by high ecological variability, and practical and financial difficulties in conducting timely field surveys in marine environments. Hierarchical habitat classifications are widely regarded as useful complementary mechanisms for describing biodiversity distribution, by overcoming some of the limitations in biological sampling data (Noss 1990; Schoch and Dethier 1996; Ward *et al.* 1999; Roff and Taylor 2000).

Implications for conservation planning:

- The problem of patchy and biased biological records is common to both marine and terrestrial systems, although they may be accentuated in marine systems due to greater access difficulties.
- In both systems, species distribution records should not be used in isolation from other information sets when making conservation planning decisions, and then only when the nature of the biases are fully understood and enunciated.

Mapping of habitats

Habitat mapping (e.g. vegetation, soil landscape, geology and topography) as a basis for delineating patterns in biodiversity distribution is far more extensive and detailed on land than it is in the marine realm. While terrestrial mapping often fails to provide fine level information of species and condition, it is still sufficient to develop fundamental conservation priorities across the landscape. Broad-coverage marine habitat mapping (e.g. vegetation, substrate) of a scale appropriate for conservation planning is increasingly being developed for estuarine, intertidal and the shallow near-shore environments of 0-30 metres depth (West *et al.* 1985; Roob 1999; Barrett *et al.* 2001; Jordon *et al.* 2001; Kirkman 1996; Banks and Skilleter 2002). Significant advances in high resolution broad-cover remote sensing technologies (e.g. side-scan sonar and airborne laser depth sounders) are expensive, but are being applied increasingly to map marine habitats in both nearshore and deeper waters.

Habitat mapping in both regions not only provides a valuable tool for describing biodiversity distribution, but also provides a mechanism for describing the distribution of habitat related resources and resource use. For example the mapping of vegetation, soil landscapes, geology, elevation and slope are equally valuable to natural resource use activities such as agriculture, mining and forestry as they are to conservation planning. In many cases it has been the economic value of such datasets that has enabled mapping programs to take place. While this is also true for marine systems, it is only relatively recently that the incentives for resource mapping have begun to coincide with the needs of conservation planning. In particular, growing legislative requirements for fisheries management to focus on fish habitat and ecosystem management is providing increasing incentive to map marine habitats and their use patterns (Fox *et al.* 1998, 1999; NRC 2002). Similarly, recent interest in deep seabed resources combined with an impending deadline for signatories of the Law of the Sea Convention to make claims for an Extended Continental Shelf has resulted in significant mapping effort being applied in deeper waters along and beyond the Australian continental shelf break.

Implications for conservation planning:

- For both marine and terrestrial systems, habitat maps can provide a dual benefit to conservation planning and resource planning.
- Terrestrial habitat mapping is more extensive than marine habitat mapping due to the relative ease of data capture (i.e. satellite imagery and aerial photography) and its history of data compatibility with terrestrial resource use activities. Marine habitat mapping is often patchy, difficult and expensive, but increasingly it is being undertaken as a basis for conservation planning, fisheries management and seabed exploration as new, primarily vessel-based, remote sensing technologies are developed and applied.

Spatial surrogates for ecological and evolutionary processes

Spatial surrogates have been widely applied in both marine and terrestrial systems and validated as an effective default method to maximise the representation of species diversity in the absence of detailed data on species distribution (Ward *et al.* 1999; Zacharias *et al.* 1999; Wessels *et al.* 1999). However, the biodiversity representation approach is rather simplistic in both realms and fails to deal with the underlying ecological processes that ultimately determine the structure and viability of communities (Denny 1995; Lenihan 1999; Peterson *et al.* 2000; Pinnegar *et al.* 2000). An understanding of ecological processes allows conservation planners and managers to better assess the sensitivities of communities to threats, and ultimately helps develop effective conservation decisions including the setting of conservation priorities and improving reserve design.

Implications for conservation planning:

- For both marine and terrestrial systems, ecological and evolutionary processes are often poorly represented by conventional spatial biodiversity surrogates.

Understanding mobile/ephemeral species

There is an incomplete understanding of the dynamics and requirements of mobile and ephemeral species (i.e. those that exhibit large spatial and temporal variation in distribution and abundance) in both marine and terrestrial environments. The cost and practical difficulty of simultaneously sampling fine resolution spatial and temporal variability over broad areas in order to resolve ecological patterns in either system is often prohibitive.

Implications for conservation planning:

- For both marine and terrestrial systems, an understanding of the distribution and frequency of ecological patterns in mobile and ephemeral species provides a basis for more effective conservation action, but lack of such understanding should not be used as a basis for postponing or avoiding conservation action.

Regionalisations

Types of boundaries (criteria used to distinguish regions)

Australia's terrestrial and marine bioregions have been defined using similar types of broad-scale information including 'static' physical criteria (e.g. substratum, topography, depth, altitude), 'dynamic' physical criteria (e.g. regimes of air temperature, sea-surface temperature, rainfall and currents) and spatial-turnover in species composition. In both cases bioregions provide a useful regional planning framework as a basis for prioritising the collection and assessment of the finer-level information required to make on-ground conservation decisions. This is particularly true for regions requiring collaboration between state or national jurisdictions. Even though finer resolution data will invariably contradict the original regional boundary position due to differences in scale-dependent pattern or differences in data criteria, bioregional boundaries should continue to play a role in high level planning and reporting.

Implications for conservation planning:

- For both marine and terrestrial systems, bioregion boundaries provide a coarse level framework for implementing conservation assessment and planning programs across national and state jurisdictions.

Problems with setting targets for whole regions

Regional conservation targets have played an important role in drawing attention to the broad-scale biases in the distribution of biodiversity conservation effort between regions in both marine and terrestrial systems. However, targets set at the level of regions have no bearing on conservation requirements for biodiversity at finer scales within a region. Regional targets often fail to acknowledge the varying effectiveness of different conservation measures applied (Pressey 1996). For example, a terrestrial reserve that allows mining or a marine reserve that allows commercial and recreational fishing, clearly provides less biodiversity protection than a highly protected 'no-take' or 'no-mining' reserve. However, both may be recorded as contributing equally to the overall conservation target unless reserve types are appropriately categorised – see *Types of Reserves* later in this chapter.

Regional targets may also fail to acknowledge the varying levels of vulnerability experienced by individual biodiversity features (e.g. species, communities and habitats) within a region (Pressey 1996). In both marine and terrestrial systems there is a tendency to establish reserves in locations that impact least with competing economic and social interests, rather than locating reserves to protect the most vulnerable features. In general, the use of regional targets may lead to *ad hoc* placement of reserves, reservation bias towards residual areas of low economic value, over representation of non-vulnerable features, failure to protect the most threatened features, poor spatial replication and inadequate configuration of reserve boundaries (Pressey 1996).

Ideally, a bottom-up approach is required where conservation targets are set for each feature of known distribution based on their respective conservation values and their vulnerability to specific threatening processes operating within the region. Armed with this knowledge it is possible to allocate conservation measures (e.g. fully protected area, habitat protection zone, trawling exclusion zone, temporary closure or species specific regulation) that meet the minimum conservation requirements of a specific feature. Furthermore, by considering the conservation requirements of the full suite of biodiversity features (e.g. rare and common species and communities, representative habitats) at the same time it may be possible to meet their combined conservation requirements in a more efficient and effective manner.

Implications for conservation planning:

- For both marine and terrestrial systems, percentages of regions required for conservation management can only be judged by planning to achieve biodiversity targets (eg. for habitats and species) and allocation of appropriate forms of protection.

Problems with prioritising regions for conservation action

For both marine and terrestrial systems, conservation priorities set at a regional level may misdirect urgently required conservation action away from highly vulnerable habitats or species that lie within low priority regions. For example, the Succulent Karoo Biome, home to the world's richest succulent flora, is divided into 12 bioregions. With three bioregions presently containing large provincial reserves, regional level priorities suggested that reserves be established in the nine remaining bioregions prior to establishing more reserves within the three partly reserved regions. However, in conducting a finer level conservation assessment, Lombard *et al.* (1999) found that the existing reserves poorly represented the diversity within their regions and that regional priorities had missed important areas defined at finer scales. The finer level assessment established priorities that better addressed the endemicity and threats within each region. This finer information also provided the opportunity to create new reserves more efficiently by targeting only those priority areas within each region.

A contributing factor is that regional level priorities are often based on the level of regional representation within the reserve system, where these reserves have historically been located in an *ad hoc* or biased manner (Pressey 1996). Consequently, even well reserved regions are unlikely to protect the most vulnerable habitats and species in the region. The effect of historical bias in reservation is well established in terrestrial regions and occurs to a lesser extent in marine systems.

Implications for conservation planning:

- For both marine and terrestrial regions, regional level priorities may misdirect urgently needed conservation action away from highly vulnerable species and communities that lie within low-priority (i.e. well reserved) regions.

- To be effective, the analysis of conservation priorities in marine and terrestrial systems must be applied at a finer level than regions (e.g. to habitats, communities and species).

Threats to biodiversity

Direct conversion to human use

Permanent habitat alteration and habitat loss associated with urbanisation, infrastructure development, mining and agricultural activities are common issues in terrestrial environments. Similar problems in marine systems tend to be less common and restricted to the coastal fringe, although in the future off-shore mining of seabed resources (e.g. beach sand replenishment, construction sands and heavy mineral extraction) is likely to become a reality as terrestrial resources become depleted and commercial feasibility of mining in marine areas increases. In both environments, direct conversion activities present a significant threat to biodiversity. However, they often occur with a degree of predictability that allows pre-emptive conservation action to be taken for these vulnerable habitats.

In both environments, the greater the economic or social benefit of a conversion activity, the more difficult it is to achieve an effective conservation outcome. While a variety of regulatory planning mechanisms may exist to ensure sensitive habitats are protected and ecologically sustainable development objectives are met, the assessment of individual development proposals often fails to reflect their cumulative effect. In this regard, regulation often fails to protect vulnerable habitat from direct conversion. A common terrestrial conservation response to this problem has been to protect samples of vulnerable habitats within a reserve system.

Bottom trawling is one of the most destructive and widespread forms of disturbance to marine seabed habitat (Engel and Kvitek 1998; Norse and Watling 1998), and is analogous to vegetation clearing in terrestrial environments (Watling and Norse 1998). Both may result in temporary to permanent decrease in habitat complexity and biodiversity.

Implications for conservation planning:

- For both marine and terrestrial systems the establishment of protected areas to protect ecosystems from their direct conversion to human use is an effective conservation mechanism. However, direct conversion activities are far more extensive in terrestrial systems and are currently restricted to the coastal fringe in marine systems.
- For both marine and terrestrial systems, changes in economic feasibility due to advances in technology, increased demand or depletion of alternative resources may create new threats to biodiversity in the future.

Harvesting native species

The harvesting of native species is an extensive issue in both marine and terrestrial regions and include activities such as wildlife harvesting, grazing on native rangelands, selective logging of native forests, kelp harvesting and fishing. Terrestrial hunting practices for food or medicine, for example, have been occurring in terrestrial regions for tens of thousands of years. As habitats have contracted and the relative demand for food has increased, over-harvesting has had a devastating impact on terrestrial biodiversity (Bennett 2002; Rosser and Mainka 2002). For example, over-exploitation has resulted in the current listing of 2313 species of birds and mammals as being either vulnerable, endangered or critically endangered on the IUCN red list (Rosser and Mainka 2002).

In both marine and terrestrial ecosystems, the selective harvest of species or the associated physical impact of harvesting equipment often leads to a wide variety of indirect impacts on non-target populations, habitats and ecological relationships at a site (Roberts 1995; Hardwood 1998; Watling and Norse 1998; Hall 1999; Pinnegar *et al.* 2000). While direct impacts tend to be more obvious, indirect impacts tend to be poorly understood or acknowledged (Hall 1999; Langton and Auster 1999). Consequently, even if they were to be managed sustainably, protected areas that accommodate native harvest activities such as fishing and forestry are likely to provide a much lower level of biodiversity protection than a fully protected reserve, hence their contribution towards conservation targets for the representation of biodiversity features (e.g. habitats and species) should be scaled down accordingly. Failure to distinguish between these different levels of reserve protection (e.g. fully protected sanctuary versus general-use zone that accommodates commercial fishing) will lead to an over-estimate of the total area effectively protected, a phenomenon termed cryptic under-representation.

Native harvest activities in marine and terrestrial systems differ in their pattern of distribution. While harvest activities in terrestrial systems are extensive, they tend to occur in discrete areas (e.g. State forests), strongly influenced by land tenure boundaries and hence well suited to the protected area approach. Native harvest activities in marine systems are rarely confined permanently to a particular area, however they are often concentrated in specific fishing grounds or habitats (NRC 2002).

While perception of the uncontrolled exploitation of the common property resource in marine systems (Hardin 1968) is a little exaggerated, an excessive focus on maximising sustainable yields, combined with inadequate science, overcapacity and inappropriate management has lead to extensive over-exploitation. Current estimates suggest almost 70% of marine fisheries are either fully or overexploited (FAO 1994; Mace 1996; Hall 1999). Global estimates suggest that large predatory fish biomass today is about 10% of pre-industrial fisheries levels (Myers and Worm 2003). In response, fishery managers are beginning to adopt more precautionary approaches based on risk minimisation with a greater emphasis on maintaining ecological relationships between fisheries and fish habitats (Henne 1998; Hall 1999; Peterson *et al.* 2000; Rosenberg *et al.* 2000).

Implications for conservation planning:

- Impact of harvest of native species on biodiversity continues to be a significant issue in both marine and terrestrial conservation, but may be more important in marine regions relative to direct conversion in terrestrial regions.

- For both marine and terrestrial regions, conservation solutions are often intertwined with resource management and socio-economic issues. Solutions are likely to involve a combination of regulation (i.e. of harvest method, harvest volume and access), protection, and a balance between the competing issues of harvest impact, livelihoods and food security, and the development of alternative sources (Davies 2002).
- Marine protected areas can contribute to both the conservation of marine biodiversity and the sustainable management of fisheries (NRS 2001; Gell and Roberts 2002).
- For both marine and terrestrial systems, reserves that allow the harvesting of native species will invariably provide a lower level of biodiversity protection than fully protected reserves, hence their contribution towards conservation targets should be scaled down accordingly.

Impacts of off-site activities on reserves

Marine and terrestrial reserves are rarely isolated from processes occurring beyond their boundaries (Allison *et al.* 1998; Parks and Harcourt 2002). Consequently, biodiversity located within most reserves is subject to a range of threats derived from outside the reserve. While the potential for impact from external sources is perceived to be greater in marine regions, this difference is possibly overstated (Simberloff 2000). For example, the potential magnitude of the impact of exotic species and disease is very significant for both marine and terrestrial reserves. The real difference may be due to our lack of knowledge of marine communities and poor capacity to respond effectively to exotic invasions in marine systems (Simberloff 2000).

In coastal marine systems, particularly estuaries, the threats posed by activities in adjacent catchments may be extensive. In particular, the major externally derived threats to marine reserves include chemical pollution, sedimentation and introduction of exotic pests (Pollard and Hutchings 1990a & b; Zann 1996; Gray 1997b; Pullen 1997). Hence, the need to adopt a broader approach to biodiversity conservation incorporating more effective management of fishing, shipping and land-use activities.

In general, there is a growing realisation in both marine and terrestrial circles that reserves are only part of the solution, and that to be effective biodiversity conservation must also be applied beyond the reserve in the off-reserve matrix (often referred to as 'landscape conservation' in terrestrial systems). In terrestrial regions, conservation programs are increasingly applied in a landscape context in order to complement biodiversity protection, introduce ecologically sustainable land-use practices and to restore general ecosystem health both on and off-reserve. Landscape conservation programs are increasingly addressing issues such as environmental river flows, sustainable water use, and sustainable vegetation clearing and its subsequent impact on top soil loss, water quality decline and groundwater salination. At a local level, cooperative pest and fire management arrangements, for example, act to mitigate threat of predation on threatened species, invasion of exotic weeds and modified community structures due to increased fire frequencies. Concepts such as multiple-use marine protected areas provide a useful model for both marine and terrestrial systems through their integrated management of park use, and application of buffer zones to protect core sanctuary areas. However, this level of integrated management is rarely applied effectively beyond reserve boundaries in marine systems.

Implications for conservation planning:

- For both marine and terrestrial regions, good reserve management alone will not provide total protection of biodiversity within its boundaries. Reserves must be managed in a landscape context where the impact of activities outside the reserve may be mitigated.
- Careful placement of terrestrial reserves (including buffer zones around no-take sanctuary areas) and appropriate land management practices will minimise potential threats to marine and terrestrial reserves.
- Many off-site threats to terrestrial reserves are spatially restricted by catchment or landscape providing greater opportunity to predict and mitigate against potential impacts.

Data on threats to biodiversity

Data on direct conversion to human uses

Direct conversion to human use in terrestrial and coastal marine environments can readily be assessed through remote imagery. These data not only enable reasonably accurate determination of existing location and extent of direct conversion activities, such as clearing and land-filling, but also introduces a capacity to predict what types of habitats and locations are likely to be affected in the future.

Implications for conservation planning:

- For marine and terrestrial regions, data that provides capacity to predict the distribution and vulnerability of habitats can provide for timely application of appropriate protection mechanisms.

Data on distribution and effects of harvesting

Relative to the distribution of harvest data for terrestrial activities such as forestry and grazing, marine harvest data are poor, while data on harvest intensity and effect on non-target species, communities and ecosystem function are very incomplete for both marine and terrestrial regions. With few exceptions, marine harvest data are collected with poor spatial and method-target resolution. For example, the first reliable estimates of commercial and recreational fish harvest became available in NSW from the early-1990s, however they continued to provide a low spatial resolution of ocean harvest activity relying on broad reporting areas such as 'port of landing' and 'catch zones' up to 120 km apart (Pease and Grinberg 1995; Steffe *et al.* 1996). This type of coarse harvest data has traditionally been used in stock based fisheries management and is consistent with the traditional perception that it is not feasible to delineate persistent fish distribution patterns in an open marine systems. This approach has failed to detect valuable information on the variation in harvest effort and site productivity within zones. Recent advances in both marine habitat mapping and global positioning technology are now making the capture of far finer harvest distribution data possible (see NRC 2002 for marine example). Ideal harvest data should provide three basic datasets of value to resource managers and conservation planners in both marine and terrestrial regions: i) delineation of harvest method (e.g. demersal trawl versus fish trap) as different types of harvest method may have significantly different impacts on species and habitats; ii) spatial distribution of harvest activity (including harvest volume and effort); and iii) the spatial distribution of habitats. With these data it is possible to assess and regulate the impact of each harvest method on particular habitats and species. Good spatial resolution provides improved capacity to estimate stock abundance, interpret ecological processes, determine location of productive and vulnerable sites, and determine ideal positions for closures and protected areas to meet the complementary needs of sustainable harvest and biodiversity conservation.

Implications for conservation planning:

- Similar classes of harvest data are required by resource managers and conservation planners in both marine and terrestrial regions (i.e. resolution of harvest method and their impacts, harvest distribution and habitat and species distribution).

Data on impacts of off-site activities

The distribution of impacts of off-site activities is reasonably well known in terrestrial regions (e.g. altered flow regimes in rivers, dry-land salinity, spread of invasive species), as it is for a range of terrestrially-derived impacts on coastal marine systems (e.g. sewage out-falls, coastal development and industrial ports). However, the distribution of impacts in marine regions is less well known (e.g. fishing, pollution, siltation and invasive species).

The effects of off-site activities on biodiversity is poorly understood in both marine and terrestrial systems. Both regions experience problems determining subtle and indirect effects on biodiversity.

Implications for conservation planning:

- Poor data on distribution of impacts of off-site activities in marine regions, reduce capacity to implement site based mitigation.
- Poor data on the effects of off-site activities on biodiversity in both marine and terrestrial regions, requires a precautionary approach to regulation and reserve design (i.e. larger core reserve size, buffer zones and replication).

Conservation goals

Representation of biodiversity pattern

Representation of biodiversity pattern is a long-established goal for terrestrial reserves, and is a relatively recent phenomenon in marine regions. Representations of biodiversity patterns at the levels of regions, habitats or species, is increasingly being used as a rationale for the establishment of marine protected areas (ANZECC/TFMPA 1999; GBRMPA 1999; MPA 2001). Coarse regional level biodiversity patterns (e.g. bioregions) are generally defined for most marine and terrestrial systems using coarse broad-coverage data sets. Although more extensive in marine systems, both systems are faced with challenges in defining finer habitat or species level patterns. Where ideal data are not available, intermediate solutions are often devised using best available data. In western New South Wales, for example, soil landscape mapping has been used in the absence of appropriate vegetation mapping.

In marine and terrestrial systems, biodiversity patterns are increasingly being mapped and assessed at finer levels as better data become available. There is an increasing realisation in marine and terrestrial regions that such data are valuable in supporting both conservation and resource management decisions (Pickrill and Todd 2003). Increase in the availability of marine habitat data is supported by dramatic improvements in remote sensing technologies, growing economic incentives to evaluate seabed resources and an increased emphasis on ecosystem-based fisheries management (Fox *et al.* 1998; Fox *et al.* 1999; NRC 2002). In addition there are an increasing number of examples where marine habitats have been mapped primarily as a basis for selecting locations for marine protected areas (Roob 1999; Barrett *et al.* 2001; Jordan *et al.* 2001; Banks and Skilleter 2002).

Implications for conservation planning:

- For both marine and terrestrial systems, the application of a biodiversity representation approach is limited by our capacity to delineate and map biodiversity patterns. Inevitably biases in the type, resolution and extent of the biodiversity features mapped will impact decisions on where and how much to reserve.
- For both marine and terrestrial systems, appropriately developed broad habitat units may act as effective surrogates for the distribution of a proportion of species, but are unlikely to be good surrogates for all species, particularly those that are rare, endangered, have limited geographic ranges or are associated with specialised habitats not defined by the broad habitat units. Consequently, a more comprehensive representation of biodiversity patterns may be achieved using a combination of broad habitat units and species distribution (Ward *et al.* 1999; Lombard *et al.* 2003).
- As remote mapping technologies continue to develop and their full potential for dual application in conservation and resource management gains recognition, more comprehensive mapping programs are likely to occur in marine regions.

Persistence of biodiversity processes

Persistence of ecological processes is an important goal in terrestrial regions. Traditionally this has been addressed through considerations of reserve management and reserve design criteria (i.e. size, location, connectivity and spatial context) in order to meet the requirements of viable populations. Increasingly, persistence is being addressed through the integration of these concepts with off-reserve conservation action. Persistence in terrestrial reserves is often affected by poor reserve design caused by conflicting reservation priorities and the availability of suitable land. For example, mammal extinctions in terrestrial protected areas have been shown to be greater in both small reserves and reserves located in areas of high human density or adverse surroundings (Parks and Harcourt 2002). As opportunities for establishing new reserves decrease, there is an increasing need to integrate representation priorities with those of reserve design to ensure that reserves are adequately connected and buffered. In many terrestrial regions this can be achieved through both the engagement of complementary off-reserve conservation measures and habitat rehabilitation.

Objectives of effective reserve design and management apply equally to marine regions. With ownership issues less likely to constrain optimum reserve design, concepts such as multiple-use marine reserves (e.g. networks of core sanctuary areas buffered by habitat protection zones and linking key habitats at both local and regional scales) provide an ideal opportunity to maximise persistence of marine biodiversity within the reserve system. In some regards the multiple-use concept provides a model for terrestrial landscape conservation plans.

Implications for conservation planning:

- For both marine and terrestrial reserves, persistence of biodiversity processes is dependent on reserve management, design and the landscape context within which the reserve is located.
- The development of reserve networks of buffered core sanctuary areas linking habitats at local and regional scales is increasingly a goal for both marine and terrestrial reserves. In marine regions there is greater capacity to manage the distribution of competing activities to achieve ideal reserve designs using concepts such as multiple-use reserves. To a lesser extent, similar concepts are beginning to be applied through complementary off-reserve conservation mechanisms in terrestrial regions.

Refugia as sources for harvesting outside

The concept of refugia is rarely applied in terrestrial regions to benefit harvesting outside reserves. Where they have been applied, they are often focused on achieving localised persistence. For example, drought refugia incorporating permanent water sources are incorporated into a reserve system so that in times of severe drought mobile species may contract back to these core areas, then radiate out to replenish surrounding areas once the drought conditions have alleviated. In marine regions the concept has long been discussed as a technique to enhance harvesting outside reserves and to provide a safeguard against poor fisheries management decisions outside the reserve (NRC 2001; Gell and Roberts 2002). This safeguarding role is diverse, but may include the reserve acting as either a source for larval export or mature 'spill-over' as a basis for sustaining fisheries. While these are often clearly stated objectives for many reserves, their efficacy remains uncertain.

Implications for conservation planning:

- The objectives for establishing reserves in marine and terrestrial regions may differ. The ideal location and designs of marine reserves may differ depending on whether the reserve is established primarily for fisheries enhancement (e.g. larval export or 'spill-over') or biodiversity conservation.

Regulatory framework

Jurisdictions

Government jurisdictions have an important influence on the application of conservation actions. In Australia, two main marine jurisdiction systems exist. State governments are responsible for the narrow strip of costal waters out to 3 nautical miles while the Federal government controls the large expanse of coastal waters from 3 – 200 nautical miles off-shore. In many cases there is a relatively clear geographic separation of State and Federal roles across what is ecologically a non-existent boundary.

Extension of Federal powers into State waters are limited and usually occur in relation to issues of national or international significance including defence and international shipping (Tsamenyi *et al.* 2003). In contrast, terrestrial regions are mostly under direct State control in Australia, with very little land under Federal control. Boundaries between States are well defined politically and while far less open biologically than their marine counterparts, are still not impervious to many impacts including modified river flows and invasive pests.

Implications for conservation planning:

- Despite differences in jurisdictional arrangements, marine and terrestrial regions are faced with similar problems in dealing with cross jurisdiction issues, although these problems are likely to be more extensive in marine regions. Examples include problems associated with the capture of consistent data and the implementation of complementary resource management and conservation actions across jurisdictional boundaries.

Separation of agency roles for conservation and commercial management

The separation of agency roles for conservation and commercial resource management is a problematic issue in both marine and terrestrial systems. In both cases a balance is required between providing sufficient separation to ensure unbiased assessment of conservation, economic and social priorities, while trying to integrate their application through appropriate planning. In marine regions, conservation and commercial roles are generally poorly separated relative to terrestrial regions.

Separation of commercial management roles from high order biodiversity conservation decisions such as those relating to development of permanent fully protected areas and threatened species regulation is desirable and likely to minimise negative effects on conservation. For example, commercial interests in both regions may impact on the effectiveness of protected area systems by influencing the classification and assessment of conservation priorities, by underestimating the impact of activities on ecological process, by influencing the location and extent of protected areas to avoid economically productive areas and through the implementation of inappropriate reserve management arrangements that allow economic activities to occur in areas where they should be excluded.

Implications for conservation planning:

- For both marine and terrestrial regions, failure to separate conservation and commercial management usually leads to commercial interests significantly compromising conservation outcomes.

Co-ordination of planning processes

Marine regions generally have fewer agencies involved in the coordination of planning processes, but just as many stakeholders. As a consequence, there are generally fewer competing interests between agencies, clearer requirements and better coordination of planning processes that determine where conservation mechanisms are applied and how competing activities are separated in the landscape. This increases the potential for successful application of integrated landscape planning (e.g. multiple–use protected areas) that satisfy the fundamental objectives of conservation and resource management by separating incompatible uses, allow compatible uses to co-exist and locating management zones to create complementary effects (e.g. networks, corridors, and buffers). In contrast, terrestrial planning is poorly coordinated as a consequence of the large number of agencies and management programs involved (eg. Regional Vegetation Committees, Catchment Management Boards, National Salinity Action Plan, Western Regional Assessments, Comprehensive Coastal Assessment).

Implications for conservation planning:

- The difficulties associated with introducing integrated landscape planning is generally more difficult in terrestrial than in marine regions.

Ownership and use rights

There are major differences in private ownership between marine and terrestrial regions that constrain where conservation actions are applied in the landscape. The establishment of a terrestrial reserve for example requires the often difficult voluntary purchase of privately owned lands and leases, or the negotiated transfer of publicly owned lands, whereas marine reserves very rarely require the acquisition of the seabed or water column. Consequently, the location and design of a terrestrial reserve system is often constrained by the availability and cost of suitable land. These constraints place a greater reliance on the application of complementary conservation mechanisms in the off-reserve matrix, and rehabilitation of unsuitable land in order to achieve effective reserve designs. The opportunities for locating and designing the ideal theoretical reserve system in a marine region are almost unconstrained by ownership issues.

Regardless of this underlying issue, both systems are subject to similar categories of user rights. Examples include those rights that are unlikely to be extinguished by conservation action (e.g. shipping and terrestrial access corridors, marine and terrestrial utility easements, Navy anchorages and defence installations, mineral exploration licences, native title claims, protected areas), those that may be extinguished with appropriate compensation (e.g. grazing permits, apiary permits, aquaculture leases, commercial fishing licences, water extraction licences, vegetation clearing permits), and existing use activities which may be extinguished or regulated without compensation but for which the relevant stakeholders are provided opportunities to respond through consultation or political processes (e.g. recreational fishing, charter boat operators, horse riders, off-road vehicles users and hunters). As demand on marine systems has increased, there has been a need to separate competing interests. With recent advances in global positioning systems, it has been possible for marine planners to introduce the terrestrial approach of assigning explicit boundaries to facilitate area-based regulation of user rights. This trend is reflected in the increasing demand for a marine cadastre to define the boundaries of all registered interests including leases, jurisdictions, shipping channels, infrastructure easements, fisheries closures, protected areas and other management zones.

Implications for conservation planning:

- The opportunities for locating and designing the ideal theoretical reserve system in a marine region are almost unconstrained by ownership issues.
- Both marine and terrestrial regions are subject to complex use and access rights that overlie ownership tenure that may be defined in cadastral boundaries. These complexities are generally more extensive in terrestrial regions.

Common access for harvesting

Regulation of common access harvesting rights in third world countries tends to be poor in both marine and terrestrial regions. In highly regulated countries, such as Australia, there is generally extensive regulation restricting the opportunities for harvesting of native terrestrial flora and fauna. In marine regions tighter regulation continues to be imposed on commercial and recreational harvest activities to manage the increasing demands on marine resources. In the early-1990s, recreational fishers for example had relatively unrestricted access to all but 400 hectares of NSW coastal waters. By the early-2000s, the total recreational fishing free area had increased to 17,653 hectares with more proposed, the first reliable data on the size of the recreational harvest had been gathered (Steffe *et al.* 1996), a recreational fishing licence system had been introduced and a number of dedicated recreational fishing reserves had been established.

In many countries throughout Africa, South America, and Asia, common access for harvesting remains culturally and legally acceptable in both terrestrial and marine regions despite clearly being unsustainable. Trade in bush meat for example is regarded as the single largest threat to wildlife populations in many areas of the world (Barnett 2000). Introduction of appropriate regulation in underdeveloped countries is made more difficult where harvest activities form a significant component of a community's food and income base.

Implications for conservation planning:

- Common access harvesting is generally extensive in most marine regions as it is in many unregulated terrestrial regions. Poor regulation can lead to unstainable resource use and significant impacts on biodiversity conservation outcomes.
- In most native harvest situations, a successful conservation outcomes often involves i) social and economic solutions including the provision of alternative food and income sources to balance a reduction in harvest, ii) an accurate estimate of ecologically sustainable yields of target species, and iii) an understanding of the broader impacts and vulnerabilities of target and non-target species and their habitats.

Coverage of existing conservation areas

Extent of reserves in terrestrial and marine regions

Quantitative comparisons with terrestrial reserves show the generally smaller individual areas, and lower overall extent, of marine reserves (except for The Great Barrier Reef Marine Park). In the past decade the total area of marine reserve has increased significantly in Australia due to the development of a Federal strategic plan of action for the establishment of a national system of marine protected areas (ANZECC/TFMPA 1999). Currently, less than 1% of the world's oceans are in reserves, yet many of these are still subject to limited forms of extractive use, including commercial fishing (Carr *et al.* 2003). Also see later section - *Types of Reserves*.

Implications for conservation planning:

- In Australia, the total extent of marine reserves (i.e. take and no-take) is currently less than that of terrestrial reserves, but is increasing at a rate greater than for terrestrial systems.

Types of reserves

Multiple-use reserves are much more extensive in marine regions. This is partly a consequence of the less complex ownership and planning arrangements in marine systems which allow a variety of different reserve categories to be applied in a single planning process. This provides significant potential to develop a complementary matrix to better manage competing uses and achieve ideal reserve design concepts (e.g. buffers, networks, connectivity). Terrestrial reserves are generally dedicated to biodiversity conservation. While many are fully protected there is an increasing trend to apply informal categories (e.g. State Conservation Areas) that support a wider range of potentially conflicting recreation and resource use activities, such as mining, horse riding and four-wheel driving.

Implications for conservation planning:

- For both marine and terrestrial regions there is a spectrum of conservation reserve categories available, from fully protected to low biodiversity protection areas, allowing harvesting or mineral extraction.
- For both marine and terrestrial regions, appropriate reserve categories can be applied in response to the relative conservation values and vulnerabilities of a site (i.e. sites containing features of high conservation value and high vulnerability should be afforded high levels of protection).
- When calculating progress towards reservation goals for both marine and terrestrial reserves, area representation figures should reveal the contribution of each reserve type based on its capacity to protect biodiversity (IUCN 1994). Failure to identify the contribution of each reserve category may lead to cryptic under-representation.

Adequacy for representation and persistence of species

Adequacy for representation and persistence of species is poorly understood in most marine and terrestrial regions. In terms of reservation, the assessment of adequacy requires good data on the distribution of species, as well as a knowledge of their biological and ecological requirements, their sensitivity to threatening activities and processes, and the ability of various management regimes to protect them against these activities and processes. In general, adequacy requirements for species, and their implications for reserve design, are better understood in some terrestrial environments due to enhanced distributional data and more extensive studies on requirements for persistence.

Where reliable species distribution data are available, they may be applied in conjunction with data on the distribution of other biodiversity features (e.g. community and habitat) as a basis for assessing their representation within a reserve system. Ultimately, the coverage of reserves and reserve adequacy will be influenced by data quality and conservation goals. Factors include the accuracy of data in representing real patterns in the distribution of biodiversity, the level of subdivision of environmental domains (e.g. species, habitats, ecosystem or bioregion) and the conservation goals (e.g. target thresholds) applied to each feature (Pressey and Logan 1994). To an extent, finer biodiversity domains are likely to better represent the heterogeneity of natural systems and improve capacity to achieve adequate species representation. However, finer data may require the reservation of a greater total area to sample all domains (Pressey and Bedford 1991). Consequently, in marine regions where very coarse grained domains are generally available, conservation goals based on their representation are likely to be met in a smaller total reserve area, but a reserve system based solely on these domains is likely to be inadequate in protecting the full range of species particularly those that are geographically restricted.

Implications for conservation planning:

- For both marine and terrestrial regions, poor knowledge of adequacy requirements for reservation requires a greater emphasis on generic principles, such as the precautionary principle.
- Marine and terrestrial reserves established for the adequate protection of a wide range of species and habitats are likely to require larger and more connected reserve coverage.
- For marine and terrestrial regions, a high level of protection within the reserve is required in order to meet the minimum requirements of the most vulnerable species represented.
- For both marine and terrestrial regions, the adequacy of reserves in protecting species within their boundaries is dependent on species' behaviour and the management of potential threats. Consequently, adequacy within reserves is influenced by the reserve design (e.g. size, location, configuration), the management regime of the off-reserve matrix within which the reserve is located (Parks and Harcourt 2002) and the management regime within the reserve itself (e.g. reserve category and regulation of activities).

Biases in reserve coverage relative to commercial potential

Terrestrial reserves are typically biased toward areas with least potential for commercial use. The main reasons are lands with high potential for commercial use are often locked-up in private ownership. Opportunities for reservation are often restricted by prohibitive property prices and the unwillingness of the owner to sell. Similarly, commercial interests have been backed historically by effective lobby groups with influential arguments against reservation based on potential commercial or social impacts. As a consequence, larger terrestrial reserves have tended to be established in areas of low commercial potential, often in rugged and infertile landscapes (Pressey *et al.* 1996) with smaller less effective reserves being established in areas where biodiversity is most vulnerable such as in areas of high local human density (Parks and Harcourt 2002).

With the exception of ownership restrictions, marine reserves tend to be biased in a similar way. For example, the distribution of no-take zones within multiple-use reserves have traditionally been located on reef habitats to avoid productive soft bottom trawl grounds. This imbalance in the representation of habitats is beginning to be addressed in Australia through the adoption of representative reservation principles. However, biases in the coverage of marine reserves continue to be expressed in other ways. For example, reserve design principles are often compromised with the size and placement of no-take zones applied to avoid areas favoured by commercial or recreational fishers. Similarly, the total level of effective biodiversity protection achieved is often over-estimated (i.e. cryptic under-representation) for many multiple-use marine reserves when low level protection zones, that allow commercial harvest activities, are counted alongside no-take zones in the overall assessment of the reserves contribution towards representation goals.

Implications for conservation planning:

- For both marine and terrestrial regions, the coverage of reserves is biased towards areas with least potential for commercial, or to a lesser extent, recreational use. Although expressed in different ways the conservation consequences are similar. Bias may result in failure to protect species, communities and habitats that are often the most vulnerable, and may make the task of developing an adequate and representative reserve systems more expensive (Pressey 1994).
- For both marine and terrestrial regions, the protected areas category (IUCN 1994) provides a basis of avoiding cryptic under-representation. This is particularly relevant for multiple-use marine reserves.

Establishing new conservation areas

Design considerations

The development of reserves in marine or terrestrial regions often involves a similar set of design considerations (e.g. size & shape, connectivity and configuration, location context and replication) although their application may vary significantly depending on the particular reserve objectives. While terrestrial reserves are often established for biodiversity conservation, they may be established for a variety of other purposes (e.g. recreation amenity, cultural heritage conservation). Consequently, criteria for design will vary in relation to the objectives of the reserve, and the specific requirements of a site. The requirement to vary reserve design depending on reserve objectives applies equally in marine regions. Marine reserves established for biodiversity conservation for example require a different set of reserve design goals than those established for fisheries management (Hastings and Botsford 2003).

The theory underlying reserve design is reasonably well developed in terrestrial systems. While still in its infancy in marine regions, there have been significant advances in the understanding of reserve placement and design in the past few years (Botsford *et al.* 2003; Gerber *et al.* 2003; Lubchenco *et al.* 2003; Roberts *et al.* 2003). Despite the lack of empirical evidence, given the magnitude of ecological difference between marine and terrestrial regions it is reasonable to expect significant differences in the fundamental requirements of reserves designed for specific species (Carr *et al.* 2003). However in both realms, general patterns are evident for biodiversity conservation reserves; larger reserves are more effective than small reserves, and nearly any habitat can benefit from appropriately placed reserves (Carr *et al.* 2003; Halpern 2003; Parks and Harcourt 2002).

Reserve efficiency (i.e. maximising reserve benefits within the smallest practical area) is an important objective in both marine and terrestrial reserve planning and may be expressed in a number of ways. The development of integrated marine and terrestrial reserves can provide synergistic benefits for conservation (Pullen 1997), or the development of reserve designs that meet the needs of conservation and fisheries (Hastings and Botsford 2003).

Implications for conservation planning:

- For marine and terrestrial regions, there is no single answer to the problem of designing the ideal reserve. Design criteria will depend on the objective of the reserve, and the characteristics of the site.
- For marine and terrestrial regions, larger reserves are likely to be more effective than small reserves, and nearly any habitat can benefit from appropriately placed reserves.

Planning tools

There are an increasing number of terrestrial planning processes guided by special-purpose planning software underpinned by explicit conservation targets and large spatial data sets. These have generally been applied to identify the potential reserve sites based on concepts including irreplaceability and complementarity. Increasingly, as better spatial datasets have become available, a number of examples of marine applications of terrestrial planning software are occurring (e.g. New South Wales, Jervis Bay work by CSIRO, Great Barrier Reef, KwaZulu-Natal, numerous US examples; Leslie *et al.* 2003).

Where systematic conservation planning tools have been applied to re-assess existing marine or terrestrial reserve systems that had been initially developed through ad hoc reserve selection processes, significant deficiencies have been found. For example, South Australia's marine reserve system was found to represent biodiversity no better than a randomly selected reserve system. Ad hoc approaches are likely to be less efficient and may even compromise fundamental biodiversity conservation outcomes (Stewart *et al.* 2003).

The application of explicit targets for biodiversity features is a fundamental characteristic of systematic conservation planning in both marine and terrestrial systems. Feature targets may be customized to reflect previously defined conservation objectives in order to provide direction for conservation planning decisions, while also providing accountability and defensibility in the planning process (Pressey *et al.* 2003).

However, distinction should be made between generic targets and feature specific targets. The use of generic percentage targets for geographic areas, such as 10% of each bioregion, habitat, or 20% no-take protection within a multiple-use marine protected area, fail to reflect the on-ground conservation requirements of the species and communities present. In reality there will be species, for example, that may require greater (or lesser) levels of protection than that suggested by a generic feature target. Consequently, feature specific targets are likely to provide for more effective on-ground conservation outcomes (Pressey *et al.* 2003).

Implications for conservation planning:

- For both marine and terrestrial systems, conservation planning software can provides a flexible mechanism for analysing large quantities of complex data, and a useful support when deciding which areas to protect.
- For both marine and terrestrial reserve systems, failure to utilise systematic planning tools may lead to less efficient reserve systems and greater likelihood of compromised conservation outcomes.
- For marine and terrestrial systems the formulation of appropriate feature targets is a contentious aspect of any planning process, but this should not be used as an argument for avoiding systematic conservation planning and the benefits that it provides.
- For marine and terrestrial systems, customised feature specific biodiversity targets are likely to provide for more effective on-ground conservation outcomes than generic targets for geographic areas.

Planning for off-reserve conservation

Many reserves in both marine and terrestrial regions are limited in their capacity to provide adequate long-term protection for all species and communities within their boundaries. Reasons include social and economic constraints that often prevent reserves from being established in a timely and effective manner, or that once established, reserves may provide insufficient protection from external factors acting on the features inside the reserve. In these cases, off-reserve conservation provides an important supplement to reservation in both systems. Off-reserve conservation is well-established in marine regions through the multiple-use model in which no-take zones are buffered by lower category conservation zones in order to minimise edge effects. Increasingly, marine conservation is focusing on catchment management as a means to reducing the impact associated with land-use (e.g. chemical pollution, siltation, and acid sulphate soil run-off). Also requirements for sustainable harvesting are resulting in greater emphasis on ecosystem management and the role of fisheries refugia as a means of complementing traditional fisheries regulation.

In terrestrial regions, there has been an historic emphasis only on core reserves. With increasing realisation that local extinctions are continuing to occur inside reserves due to the effect of external influences greater emphasis is now being applied to off-reserve mechanisms. Examples include greater reliance on alternative site based protection (e.g. private conservation agreements, community stewardship programs and environmental protection zones), and improved regulation of water resource allocations and vegetation clearing activities on private land.

Implications for conservation planning:

- Regardless of the quality of reserve design and management, effective conservation is likely to require complementary off-reserve conservation action (Jameson *et al.* 2002)
- The effectiveness of a reserve in providing protection within its boundaries is significantly influenced by human processes outside its boundary (Parks and Harcourt 2002)

Implementation issues

A key issue for implementation in terrestrial regions is scheduling of conservation action because of limited resources relative to the scale of the task and ongoing loss and degradation of biodiversity. Constraints on the implementation of reserves include the availability of land for purchase, resistance by those with commercial interests (e.g. forestry) to giving up resources on public land, the rising cost of land acquisition and decreasing reservation options as the habitats continue to be cleared. Often the consequences of not conserving may be loss of biodiversity. Scheduling of conservation action in terrestrial regions can be achieved by placing the greatest urgency for reservation on areas containing biodiversity features that have high conservation value and high vulnerability. Scheduling is also important in marine regions but mainly where ownership (e.g. along the coastal fringe) and use rights (e.g. in commercial fishing zones) limit the rate of implementation.

Implications for conservation planning:

- In marine and terrestrial regions, there is an increasing reliance on conservation in the unreserved matrix beyond the reserve boundary (Franklin 1993).
- There is likely to be an increasing reliance on rehabilitation in terrestrial regions.
- Development of conservation priorities and conservation scheduling is more critical in terrestrial regions.

Results

A summary of the magnitude of differences between marine and terrestrial regions and their implications for conservation planning are presented in Table 1. Results suggest that a large difference exists between marine and terrestrial systems for 31 of the 43 criteria examined. In general terms, the greatest differences relate to: their fundamental ecology and progress towards documenting biodiversity (i.e. 'biodiversity', 'data on biodiversity'); the types of threatening process acting on the two systems (i.e. 'threat to biodiversity'); and the 'regulatory frameworks' that have evolved to influence access and ownership patterns. These issues in turn have influenced the types and extent of the existing reserve systems (i.e. 'coverage of existing conservation areas'), and contemporary priorities and objectives for establishing new reserves (i.e. 'establishing new conservation areas').

A small magnitude of difference between the marine and terrestrial systems was recorded for the remaining 12 of the 43 criteria. This relative similarity related to: the role of bioregional frameworks and their limitations in developing local level conservation priorities (i.e. 'regionalisations'); common objectives in achieving biodiversity persistence through reservation and sustainable management, and the

Table 1. List of main headings (and number of criteria)

	Magnitude of difference		Implications for planning	
Themes	**Small**	**Large**	**Similar**	**Different**
* Biodiversity (9)	1	8	9	-
* Data on biodiversity (5)	1	4	5	-
* Regionalisations (3)	3	-	3	-
* Threats to biodiversity (3)	-	3	3	-
* Data on threats to biodiversity (5)	3	2	4	1
* Conservation goals (4)	2	2	3	1
* Regulatory framework (6)	1	5	4	2
* Coverage of existing conservation areas (4)	1	3	2	2
* Establishing new conservation areas (4)	-	4	3	1
Totals (43)	**[12]**	**[31]**	**[36]**	**[7]**

challenges associated with mapping ecological patterns and processes as a basis for conservation planning and resource management (i.e. 'conservation goals'); and the poor understanding of the nature of threatening processes and their impacts on species, communities and ecological processes (i.e. 'data on threats to biodiversity').

Regardless of the magnitude of the difference observed between marine and terrestrial systems, results suggest that their implications for conservation planning are relatively similar. Of the 43 criteria examined, 36 had similar planning implications. Conservation planning responses were most similar for issues relating to: patterns and causes of biodiversity distribution (i.e. biodiversity); method of describing ecological patterns, and their inherent biases (i.e. data on biodiversity); requirements for setting conservation priorities at sub-regional levels (i.e. regionalisations); and impacts of direct habitat conversion, harvesting of native species and pervasive off-reserve processes (i.e. threats to biodiversity).

Of the 43 criteria examined, only 7 required a different planning response between marine and terrestrial systems. Many of these differences would appear to be related to the history of regulation and use, and their subsequent influence on the types and extent of new and existing reserves. The major differences in planning response in marine and terrestrial systems relate to: the distribution of impacts (i.e. data on threats to biodiversity); application of reserves as refugia (i.e. conservation goals); capacity to coordinate planning processes, and the complexity of ownership and use-rights (i.e. regulatory frameworks); application of multiple-use reserves (i.e. coverage of existing conservation area); and scheduling of conservation action (i.e. establishment of new conservation reserves).

Conclusions

Despite fundamental ecological differences, many conservation planning issues and their required responses are similar for marine and terrestrial systems. Many terrestrial conservation techniques, such as area-based management and reserve selection methodologies, are increasingly being applied to marine systems. This transfer has been assisted in recent years with the increasing emphasis in marine systems on ecosystem-based management and advances in technologies for describing the distribution of marine biodiversity. In many regards there is also a convergence in both systems toward planning processes that treat biodiversity conservation (on and off-reserve) and sustainable resource management in an integrated 'landscape' context. This approach has long been applied in a limited form in marine systems through the multiple-use marine protected area model and is increasingly being applied to address terrestrial issues relating to land and water degradation. Consequently, perhaps the two most important conservation planning objectives for either system relate to the establishment of a secure system of appropriately located, designed and managed protected areas (in most situations this involves full protection); and the application of effective ecologically sustainable management regimes and supplementary conservation mechanisms within the off-reserve matrix.

Determining the best reserve location and design in either system is dependent on the reservation goal. A reserve established for fishery enhancement may differ from one established to protect a rare marine polychaete, just as a reserve established for the conservation of migratory monarch butterflies will differ from a reserve established for the conservation of a common terrestrial vegetation community. Despite differences in objectives, both within and between systems, reserve selection and design criteria are similar. These generally include: size (i.e. larger reserves protected more diversity); habitat heterogeneity (i.e. complex habitats support greater biological diversity); representation of common as well rare and unique biodiversity features; protection of vulnerable habitats and species; replication of reserves to guard against catastrophes; and development of reserve networks with appropriate levels of connectivity. In order to assess these criteria in either system, a sound knowledge of the diversity and distribution of species, communities and their habitats is required.

For both marine and terrestrial systems, conservation priorities must be established in order to schedule conservation action and prioritise areas for protection or management. If the goal is biodiversity persistence, priority for conservation action is generally given high conservation value features (e.g. rare species) that are most vulnerable to threatening processes. Consequently, effective allocation of conservation action in both systems requires a sound understanding of the distribution of threatening processes and the nature of their impact on species, communities and their habitats. This knowledge may also assist resource managers to better understand the impacts of their activities on ecosystem services, hence assist them in attaining ecologically sustainable resource use.

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Appendix 1. Differences between marine and terrestrial systems.

Criterion	Difference	Magnitude of difference	Implications for planning
Biodiversity			
Dispersal of propagules	Larger proportion of marine species have wide dispersal of propagules.	Large, quantitative	Similar, but some marine species require protection of both source and settlement areas.
Endemism and spatial turnover of species	Smaller proportion of marine species are narrow endemics.	Large, quantitative	Similar
Community genetics	Greater potential for under-estimation of intra-specific genetic variation in marine populations.	Large, potentially	Similar
Geographically separate life-history stages	Larger proportion of marine species have geographically separate life-history stages.	Large, quantitative	Similar
Factors influencing species distributions	Factors influencing distribution in an atmospheric versus aquatic environment are very different	Large, qualitative	Similar
Regular Movements of Organisms	Common in both marine and terrestrial systems, but more extensive in the marine environment	Large, quantitative	Similar
Irregular changes in distribution and abundance of organisms	Common in both marine and terrestrial systems, but more extensive in the marine environment	Large, quantitative	Similar
Causes and patterns in ecological heterogeneity	Causal factors may differ, but principles determining ecological patterns are often similar in both marine and terrestrial systems	Large, qualitative	Similar
Role of habitat structure (biotic & Abiotic)	Similar	Small	Similar
Data on biodiversity			
Catalogues of described species	Incomplete in both systems, but the number of undescribed macro-species is potentially greater in the deep marine environment	Large, quantitative	Similar
Spatial coverage of biological sampling	Patchy and biased in both systems but accentuated in marine system	Large, quantitative	Similar
Mapping of habitats	More extensive in terrestrial, but increasing application in marine systems	Large, quantitative but converging	Similar
Spatial surrogates for ecological and evolutionary processes	Common concern that biodiversity surrogates often fail to represent underlying ecological processes	Small, qualitative	Similar
Understanding mobile/ ephemeral species	Understanding of mobile and ephemeral species remains incomplete in both systems but the problem is more extensive in the marine system.	Large, quantitative	Similar
Regionalisations			
Types of boundaries	Bioregional boundaries have been applied in marine and terrestrial systems using similar criteria	Small, qualitative	Similar
Problems with setting targets for whole regions	Similar problems in setting regional level targets in both systems.	Small	Similar
Problems with prioritising regions for conservation action.	Similar problems in prioritising regions for conservation rather than biodiversity features	Small	Similar

Criterion	Difference	Magnitude of difference	Implications for planning
Threats to biodiversity			
Direct conversion to human use	Extensive in terrestrial systems but currently restricted to the coastal fringe in marine systems.	Large, quantitative	Similar
Harvesting native species	Extensive in marine and terrestrial systems, but more important in marine systems relative to direct conversion	Large, quantitative	Similar
Impact of off-site activities on reserves	Potential for impact more widespread in marine regions	Large, qualitative	Similar
Data on threats to biodiversity			
Data on direct conversion to human use	Data is reasonably accurate for terrestrial and coastal fringe	Small, qualitative	Similar
Data on distribution and effects of harvesting	Poor data on effects of harvest on non-targets species and communities	Small	Similar data categories required
	Poor data on harvest distribution in marine regions, but improving	Large, but converging	Similar data categories required
Data on impacts of off-site activities	Distribution of impacts	Large, quantitative	Different, capacity to implement site based mitigation
	Effects of impacts on biodiversity	Small	Similar
Conservation goals			
Representation of biodiversity pattern	Increasing application in marine systems as biodiversity maps are become available	Large, but converging	Similar
	Maps used to represent biodiversity pattern are valuable for both natural resource management and conservation planning	Small	Similar
Persistence of biodiversity processes	Within reserves, dependence on management, design and landscape context	Small, qualitative	Similar criteria, but different application
Refugia as sources for harvesting outside	Refugia rarely applied in terrestrial regions	Large, qualitative	Different objectives and criteria may apply
Regulatory frameworks			
Jurisdictions	Different arrangement of State and Federal jurisdictional boundaries	Large, quantitative	Similar types of response
	Problems created by jurisdictional boundaries possibly more extensive in marine regions	Large, quantitative	Similar type of response
Separation of agency roles for conservation and commercial management	Problems created by failing to separate roles common in both regions	Small, convergence	Similar issues
Co-ordination of planning processes	Better coordination in marine regions and greater potential to apply coordinated planning processes.	Large, qualitative	Different
Ownership and use rights	Ownership and use-rights are more complex in terrestrial regions.	Large, quantitative	Different
Common access for harvesting	Extensive in marine areas, but becoming more regulated in developed countries	Large, but converging	Similar response.

Criterion	Difference	Magnitude of difference	Implications for planning
Coverage of existing conservation areas			
Extent of reserves in terrestrial and marine regions	Reserves are less extensive in marine regions	Large, quantitative	Similar response
Types of reserves	Multiple-use reserves are far more common in marine regions, but a spectrum of reserve type are available in both regions	Large, qualitative	Different application, but similar issues
Adequacy for representation and persistence of species	Poorly understood in most marine and terrestrial regions, but better understood in terrestrial regions	Large	Different application, but similar issues
Biases in reserve coverage relative to commercial potential	Biases experienced in both regions.	Similar	Similar
Establishing new conservation areas			
Design considerations	Design criteria are dependant on reserve objectives and ecological characteristics that vary both between and within marine and terrestrial regions	Large, qualitatively	Similar
Planning tools	Increasingly being applied in marine systems	Large, but converging	Similar
Planning for off-reserve conservation	Off-reserve conservation is an increasing objective in terrestrial regions, and is reasonably well established in marine regions	Large, but converging	Similar
Implementation issues	Development of conservation priorities and scheduling of conservation action is more urgent in terrestrial regions	Large	Different