Scale mismatches, conservation planning and the value of social network analysis

ANGELA M. GUERRERO[1,2], RYAN R.J. McALLISTER[2], JONATHAN CORCORAN[3] and KERRIE A. WILSON[1]

[1] The University of Queensland, School of Biological Sciences, Brisbane, Qld 4072, Australia. a.guerrero@uqconnect.edu.au, k.wilson2@uq.edu.au

[2] CSIRO Ecosystem Science, PO Box 2583, Brisbane, Qld 4001, Australia. ryan.mcallister@csiro.au

[3] School of Geography, Planning and Environmental Management, The University of Queensland, Brisbane, Qld 4072, Australia. jj.corcoran@uq.edu.au

Correspondence should be addressed to: Angela Guerrero; email: a.guerrero@uq.edu.au; telephone: +61 421414856; fax: +61 07 33651655

Destined for *Conservation Biology* as a *Review Paper*

Running Title: Scale mismatches and conservation planning

Key words: conservation planning; scale mismatch; social networks; social network analysis; conservation implementation.

Word Counts: Text + Literature Cited – 7284; Figures – 2; Tables – 1

Abstract

Many of the challenges faced by conservation scientists and practitioners can be framed as a *scale mismatch*. The problem of scale mismatch in a conservation setting occurs when the planning for and implementation of conservation actions is at a scale that does not reflect the scale of the conservation problem being addressed. Managing this problem lies not in fitting conservation actions to a single scale, but rather in understanding and negotiating the multi-scale nature of conservation problems so that conservation actions operate at temporal, spatial and functional scales that are appropriate for the problem at hand. We review some of the challenges faced in conservation planning in the context of *scale mismatches*, with the objective of understanding the underlying issues and explaining how this problem can manifest and affect conservation outcomes. Networks link organizations and individuals across space (and time) which determines the collective scale of conservation actions. Social network analysis can be used to explore if these network structures constrain or enable key social processes, and how multiple scales of action are linked. Such issues underpin efforts to guide the meditation of scale mismatches in assessing, planning, implementing, and monitoring conservation projects.

Introduction

The concept of scale mismatch, also referred to as the 'problem of fit', has emerged in the broader natural resource management literature and refers to a mismatch between the extent and resolution of management actions and that of the ecological system of interest (Lee 1993; Young 2002; Cumming et al. 2006). The problem of scale mismatch in a conservation setting occurs when conservation actions are undertaken at a scale that does not reflect the scale(s) required to solve a target conservation problem. For example, scale

mismatches are common in the problem of successfully managing migratory species (e.g. Berkes 2006), and where the relatively short-time horizons of planners and politicians conflict with longer-term ecological and social changes (Folke et al. 1998b). Cumming et al. (2006) explored the concept of scale mismatch in the management of natural resources, explaining their causes and consequences. The authors highlight that scale mismatches are generated by a wide range of social, ecological, and linked social-ecological processes, and conclude that how best to resolve them remains an open question and a frontier for future research. An understanding of how scale mismatches transpire, and their likely consequences, can be valuable for those committed to attaining on-the-ground conservation outcomes, so that they can devise prompt strategies to deal with or ameliorate them.

Conservation planning is evolving from being primarily concerned with the systematic identification of protected areas for the conservation of species diversity (Margules & Pressey 2000), to a process of prioritizing, implementing and managing actions for the conservation of biological diversity and other natural values, both within and outside of protected areas (Wilson et al. 2009). Challenges that hinder the effectiveness of conservation planning include funding not being available or used to support only short-term projects, lack of consideration of ecological processes and dynamic threats that determine the persistence of biological diversity (Pressey et al. 2007), the limited extent to which science and research informs on-the-ground action (Balmford & Cowling 2006; Pressey & Bottrill 2009), along with unacknowledged diversity of value systems (Wondolleck 2000; Van Houtan 2006) and non-negotiated agendas that obstruct objective decision making (Biggs et al. 2011). Arguably, many of these challenges emerge as a result of scale mismatches, primarily because conservation problems often require multiple actions, each

associated with different ecological and management scales (Sarkar et al. 2006). The problem of scale mismatch lies not in fitting conservation action to the 'right' scale. Instead, the multi-scale nature of conservation problems needs to be understood and negotiated so that strategies and actions are developed and applied at appropriate temporal and spatial scales. Governance and management arrangements that have the capacity to alleviate mismatches across the range of actions are therefore required. However, there is often insufficient institutional diversity (structures or mechanisms) to adapt to the multi-scale nature of conservation problems and effectively manage across scales (Folke et al. 1998a; Young 2002; Wyborn 2011).

It is now recognized that conservation planning needs to include stages dedicated to understanding the social-ecological system in which conservation actions are to be implemented, including the cultural, economic and institutional contexts (Polasky 2008; Pressey & Bottrill 2008), and the norms, values and human factors that underpin opportunities and constraints for effective conservation action (e.g. Cowling & Wilhelm-Rechmann 2007; Guerrero et al. 2010; Knight et al. 2010). In this context the identification and involvement of stakeholders is key to effective conservation planning. It can facilitate the identification of new knowledge, opportunities for and barriers to implementation, engender trust and gain support for implementation (Pierce et al. 2005; Knight et al. 2006a; Pressey & Bottrill 2009).

The use of network theory has grown exponentially in the last decade in areas across the physical and social sciences and has been useful for explaining social phenomena across a diversity of disciplines (Borgatti et al. 2009). Networks link organizations and individuals across space (and time), and hence are critical in determining the collective scale of conservation actions, which in turns underpins the magnitude of mismatch in scales. In this

paper we apply the concept of scale mismatches to understand different challenges faced throughout the conservation planning process. We explore this issue across multiple scales associated with the different stages of conservation planning. We then discuss emerging conservation planning approaches that are useful in the face of potential scale mismatches, and end with a discussion on how social network analysis can be applied to help guide conservation practitioners who are managing scale mismatch problems.

Scale mismatches through the lenses of the conservation planning process

The process of planning and implementing conservation actions (Figure 1) involves continuous decision making, including conservation problem definition, the formulation of actions, and how they are to be implemented on-the-ground. Conservation problems are often complex involving competing objectives, multiple actors, and a diversity of possible conservation actions. Decisions can be made at spatial and temporal scales that are unlikely to match the scale of the ecological patterns or processes relevant to the conservation problem, creating a *scale mismatch.* For example, actions and strategies might be formulated at a regional scale while the conservation problem also requires action at a finer scale (Briggs 2001; Sarkar et al. 2006), or a plan might be formulated at an appropriate scale for action, but the operational capacity for implementation might be deficient.

Scale mismatches can manifest in diverse ways at each stage of the conservation planning process, including the assessment, action and strategy formulation, implementation and management, and review and adaptation stages. We show this by applying a modified version of Cumming et al. (2006) classification of scale mismatches (spatial, temporal and functional scale mismatches) (see Table 1). Spatial scale mismatches refer to differences in geographic extent, for example a fine scale, such as patches or

landscapes, compared to a broader scale such as regional or global scale (Cash et al. 2006). Temporal scale mismatches relate to different durations of processes (Cash et al. 2006). Both time and space scales also have 'grain', which refers to the resolution with which observations are made (i.e. data resolution). Functional scale mismatches refer to differences in the scope of processes covered by a system (Lee 1993; Folke et al. 1998b), for example a very narrow scale focusing on a few ecological features, compared to a broad scale that considers a diversity of ecosystems and threatening processes.

Assessment stage

One of the first decisions made when planning for conservation is defining the extent of the planning region. In some instances regions are defined based solely on institutional boundaries without accounting for ecological boundaries (see example in Table 1). This can result in plans that fail to appropriately define the conservation problem, or that only address part of the problem. A case in point is the Murray-Darling Basin in Australia. For over 100 years the Murray-Darling Basin, one of the most important river systems in Australia, has provided water for irrigation, stock and domestic use and other industries across four Australian states. The growing diversion of water fuelled by the expansion of the irrigation industry in the basin has resulted in a 40 percent reduction in water flow (Cosler et al. 2010). This has led to ecosystem collapses, detrimentally impacting natural features such as native fish, riparian vegetation and wetlands of national significance. Attempts to resolve these issues have been through diverse and unconnected institutions (e.g. separate state legislation), leading to a lack of effective governance of the basin as a whole. This can be interpreted as a spatial scale mismatch at the onset of the planning process where the planning region did not reflect the boundaries of the ecological systems of the basin and

instead was defined as the area of the basin occurring within each state. Linked to this was a functional mismatch, where the full scope of features and ecological processes, including patterns of river flow, and the health of wetlands, native fish, forest and water bird populations, occurring across the basin were not accounted for (Murray–Darling Basin Authority 2011). More recently, attempts to manage these scale mismatches include the creation of institutions operating at a Federal level such as the Commonwealth *Water Act 2007,* and the formation of the Murray-Darling Basin Authority. The Authority is responsible for the formulation of an integrated management plan to set the water diversion limits for the basin as a whole (Water Act 2007), and for the development of specific conservation programs in conjunction with state governments such as the Rivers Environmental Restoration program and the Native Fish Strategy program. The current challenge for the Authority is to formulate an integrated plan that sets water diversion limits in a manner that is consistent with the characteristics and needs of the entire social-ecological system (Young & McColl 2009; Cosler et al. 2010), not only at the whole-of-basin level but also across scales, whilst retaining a local-scale perspective.

When identifying areas for conservation action, decisions about data resolution influence which and how many areas are selected (Pressey & Logan 1995; Rouget 2003). A spatial scale mismatch can occur when the resolution of the data that is used to understand the ecological and social setting fails to reflect the heterogeneity of the area (Table 1), which can limit the effectiveness of planning decisions (e.g. Rouget 2003). The limited availability of fine-resolution data across a planning region, and limited resources for acquiring new data (Margules et al. 2002), will result in the inevitable use of coarse-resolution data (Mills et al. 2010).

Most spatial conservation planning exercises involve representation of species diversity patterns, but relatively few consider ecological processes or dynamic threats to biological diversity (Pressey et al. 2007; Pressey & Bottrill 2009). Lack of consideration of key ecological processes that sustain biological diversity at the assessment stage can lead to functional mismatches where actions fail to prevent disruption of some of these key ecological processes, thus jeopardizing their existence and of the species they sustain (See Pressey et al. 2007).

Formulation of actions and strategies

When conservation actions are not formulated at appropriate scales, the threats, risks, constraints, opportunities, complexities and dynamics of the social-ecological system that affect the success of conservation actions may not be accounted for. An example of scale mismatch is when actions are formulated at a particular governance level, such as a state or county level, but are applied to an ecosystem or ecological process that transcends governance boundaries. For instance, in the conservation of migratory species, actions might be developed for cross-country migration of species but can fail to develop actions for migration within country or within region migration (e.g. Gilmore et al. 2007). Another example relates to wintering waterbirds in the United Kingdom where recreational use of inland waters are based on short-term behavioral responses of birds to disturbance that are averaged across sites and habitats (O'Connell et al. 2007). This generalized approach to planning does not account for site and time specific impacts, resulting in spatial and temporal mismatches. For example, disturbance activities by humans may only happen at particular times of the year or may only affect specific locations, and birds may use a range of lakes for different needs (O'Connell et al. 2007).

Threats to biological diversity operate at diverse spatial and temporal scales. Therefore effective conservation planning requires the scheduling of multiple actions that can operate at these diverse scales. In addition, some actions might need to be threat-specific (Salafsky et al. 2002; Pressey et al. 2007) – addressing relevant ecological processes such as those associated with connectivity, population dynamics in fragments, and maintenance of patch dynamics (Carwardine et al. 2008) – thereby ameliorating the potential for mismatches at the functional scale.

Implementation and management

The need for more effective implementation of conservation actions is increasingly recognized as a key challenge in conservation planning (Balmford & Cowling 2006; Knight et al. 2008; Pressey & Bottrill 2009). Many of the challenges faced in implementation stem from a disjointed planning process, where early stages in the process are not integrated into a broader planning framework that focuses upon the implementation of conservation actions. This occurs, for example, when spatial prioritization analyses do not account for the constraints and opportunities for implementation (Pierce et al. 2005; Knight et al. 2008), or when planning units used in the prioritization of areas are dissimilar to areas where management will be implemented – making it difficult to translate plans into implemented actions (Pierce et al. 2005).

Spatial scale mismatches in implementation lead to on-ground activities undertaken at scales that cannot resolve the conservation issue (see Table 1). This can sometimes be driven by a lack of resources for implementation or because key organizations or individuals have not been engaged (e.g. Waudby et al. 2007). An example of spatial scale mismatch relates to conservation efforts for Australia's endangered bridled nailtail wallaby

(*Onychogalea fraenata) (Environment Protection and Biodiversity Conservation Act 1999)*, where a centralized state program, unable to effectively implement actions at a local scale and over the long-temporal scales required for maintaining subpopulations, has failed to stop the decline of the species (Kearney et al. in press).

Temporal scale mismatches at the implementation stage occur for example when funding does not match the long-term nature of ecological processes relevant to the conservation problem, resulting in partly attained or unattained conservation objectives (e.g. Waudby et al. 2007). Temporal scale mismatches can also occur when actions are implemented at a rate that does not reflect the rate of change of the ecological system of interest, for example when actions are delayed due to political timeframes, or for the pursuit of scientific certainty (e.g. Grantham et al. 2009).

Another temporal scale mismatch relates to lack of continuity of personnel throughout the planning and implementation process (Pierce et al. 2005; Walters 2007; Pressey & Bottrill 2009). The implementation of actions is an incremental and often lengthy process, requiring the long-term presence of stakeholders to adapt plans to reflect changes in the ecological and social system (Pierce et al. 2005; Pressey & Bottrill 2009; Grantham et al. 2010). Such changes include changes in areas of interest, new data on threats and species diversity, changes in funding or changes in the interests of local communities where implementation is to occur (Pressey & Bottrill 2009). In addition, the continued presence of stakeholders is important for mainstreaming plans into the activities of organizations responsible for planning and development (Pressey & Bottrill 2009), therefore facilitating implementation. There are already examples of conservation plans accounting for this temporal mismatch by ensuring long-term involvement of implementing stakeholders (e.g. Green et al. 2009; Henson et al. 2009).

Review and adaptation

Monitoring is key to evaluate outcomes, and to facilitate learning and inform adaptation decisions (Stem et al. 2005; Ferraro & Pattanayak 2006; Field et al. 2007; Lindenmayer & Likens 2010). Scale mismatches at the review and adaptation stage of the conservation process manifest when ecological changes occur at scales smaller or larger (or longer or shorter) than the scale of monitoring operations and are not detected (Table 1). Consequently, such mismatches limit the ability to respond to changes, which can limit an adaptive approach to conservation.

Decisions related to monitoring activities include the ecological metrics to be used, the locations where monitoring activities will be undertaken, and the duration and frequency of monitoring activities (Spellerberg 1994; Lindenmayer & Likens 2010). All these decisions can result in some level of spatial, temporal or functional mismatch with respect to the scale of the conservation problem. For example, choosing appropriate indicators for monitoring activities (Lambeck 1997; Carignan & Villard 2002; Tulloch et al. 2011) is an uncertain decision process that bears the risk of choosing indicators that do not provide a whole-of-systems view of the problem (Simberloff 1998), and can fail to account for the multi-scale requirements of the species or ecological features for which the indicator is assumed to be a surrogate (Lindenmayer et al. 2002). Insufficient data, the cost of monitoring activities, as well as the potential difficulties of applying the most appropriate indicator (Tulloch et al. 2011), are obstacles that can sustain this type of scale mismatch problem (Lindenmayer et al. 2002; Lindenmayer & Likens 2010).

How can scale mismatches be dealt with in conservation planning?

Emerging planning approaches

For conservation planning to operate at diverse spatial, functional and temporal scales, conservation practitioners need to apply tools that take into account the multi-scalar nature of conservation problems. Planning approaches that account for functional scale mismatches at the assessment and formulation stages are emerging. For example, Pressey *et al.* (2007) discuss approaches for planning for physical and biological processes that require management over large or specially configured areas. Such approaches include moveable conservation areas, variable representation targets, and the use of specific design criteria (e.g. Briers 2002; Nicholson et al. 2006; Leroux et al. 2007). Threats are also starting to be considered, firstly when scheduling conservation actions so that threatened areas or species are given priority and areas with non-abatable threats are avoided (e.g. Burgman et al. 2001; Game et al. 2008), and secondly through the explicit consideration of the impacts of multiple threats (e.g. Evans et al. 2011). Developments in conservation planning approaches also have the potential to deal with spatial and temporal mismatches that characterize the more traditional conservation planning methods, which only account for static views of the ecological, human, and social characteristics of the area of interest threats. Recent advancements include methods for balancing divergent priorities at multiple spatial scales (Moilanen & Arponen 2011), and prioritizing actions through time in the face of dynamic threats, uncertainty, and changing costs of activities (Costello & Polasky 2004; Meir et al. 2004; Wilson et al. 2006).

New quantitative planning methods such as those discussed above are an attempt to deal with the multi-scale nature of conservation problems. They are useful for dealing with scale mismatches that arise at the assessment and action formulation stages of the

conservation planning process (Figure 1), where species diversity and other biological data are compiled, conservation targets are set, and priority conservation areas or actions are identified (See Margules & Pressey 2000). However, scale mismatches at the implementation, management and adaptation stages can still transpire. In addition, the need for embedding quantitative planning methods in a social process that facilitates effective implementation is increasingly recognized (Knight et al. 2006a; Pressey & Bottrill 2009; Reyers et al. 2010), and there are examples of this already happening (e.g. Pierce et al. 2005; Knight et al. 2006b; Game et al. 2010). It is therefore timely to explore tools and approaches that can help deal with scale mismatches that impede effective implementation.

Social network analysis as a conservation planning tool

Social network analysis (SNA) could prove useful in the conservation planning process by providing insights into how implementation might be approached such that guidance can be given to those managing problems of scale mismatch. Some authors in the conservation planning literature have suggested integrating ecological assessments with social assessments of the region (Cowling & Wilhelm-Rechmann 2007) to facilitate an understanding of the social-ecological system dynamics affecting valued nature, and of the opportunities and constraints for implementation.

Such social assessments could include an examination of the social networks that exist in relation to conservation in the area of interest, including *who* affects conservation outcomes (either through their involvement with conservation activities, or with economic, subsistent and other types of activities that have a direct effect on conservation outcomes); *how* they are connected to each other through partnerships for action, or other types of collaborations (e.g. Prell et al. 2009; Vance-Borland & Holley 2011); and *what* their spatial,

temporal or functional scales of operation, or influence, are. Social network theory can then be applied to understand how this network of collaborations and social relations is characterized and helps facilitate multi-scalar conservation. For example, it can help uncover specific links between actors (individuals, groups or organizations) that could be used to promote cooperation and coordination of key activities at particular and required scales of action (e.g. Gass et al. 2009).

We define *conservation social networks* as the networks of relationships that link actors involved in conservation activities across space. These networks form the basis of social norms and community learning; hence they also link actors across time. Networks can be formal or informal. Informal networks will be present in the region where conservation planning is to occur – for example self-organized groups of concerned citizens mobilizing around specific issues (e.g. Newman & Dale 2007; Vance-Borland & Holley 2011), which can take many forms such as farmer advice networks (e.g. Isaac et al. 2007). On the other hand, formal networks (e.g. Carlsson & Sandstrom 2008) can be formed during the conservation planning process through the establishment of formal relationships such as agreements or partnerships between NGOs or government agencies around a particular conservation objectives (e.g. Bode et al. 2010). The different patterns of interactions between actors in a network give rise to different network structures (Borgatti & Foster 2003) that can inhibit or enable a suite of social processes often needed in conservation planning, such as cooperation, knowledge generation and learning, leadership and conflict resolution (e.g. Hahn et al. 2006; Olsson et al. 2007; Bodin & Crona 2009). SNA is used for analyzing the behavior of actors in a network based on its structure (or pattern of relations) (Emirbayer & Goodwin 1994). For example, one can study the density of ties within a network (the extent to which all actors are connected) to understand the capacity of integration and sharing of

knowledge within that network (Bodin & Crona 2009), while the level of fragmentation of a network (presence or lack of presence of distinct subgroups) can be useful for understanding capacity for collaboration within the network (Granovetter 1973), as well as access to new knowledge (Newman & Dale 2007; Bodin & Crona 2009). Structural analyses of conservation social networks can help inform implementation strategies. For example, a network that is connected through a few key actors (Figure 2a) might tell us that the best strategy is to engage with these few key actors, so that they can then coordinate action through their own networks. Alternatively, a network that is quite fragmented (Figure 2b) might require engagement with many different actors, and thus require greater financial investment at the implementation stage.

Analyzing network structures can help understand the degree to which multiple scales of action are linked or being coordinated, for example through identifying bridging actors (e.g. Olsson et al. 2007), or scale-crossing brokers, that link those operating at different scales who would otherwise be disconnected (Bodin et al. 2006). SNA can help identify different subgroups of actors in the network that might relate to particular required scales of action, and thus could drive implementation at those particular scales. For example, in the recovery plan process for the endangered Australian glossy black-cockatoo (*Calyptorhynchus lathami*) (Environment Protection and Biodiversity Conservation Act 1999) a variety of agencies, community groups, landowners and volunteers operating at different scales were effectively engaged for the implementation of the actions required for the persistence of this species (Waudby et al. 2007). Although, to our knowledge, a social network analysis was not performed as part of this recovery plan, this is an example of how the identification and engagement of key groups as part of the implementation strategy, through SNA or another stakeholder identification method, plays a key role in the successful

implementation of actions. The added benefit of SNA as a method for stakeholder identification is that it allows for a more targeted approach for stakeholder selection (Prell et al. 2009).

SNA tools could be most useful when combining them with other information about the social-ecological system of interest. It is useful not only to understand how each actor relates to others, but also how they relate to the ecological features of interest (Figure 2c) (Janssen et al. 2006). For example, different fishermen harvest different fish species, at different fishing locations, and some of those species and locations will be of greater importance for achieving conservation outcomes. It is not only important to identify key actors who can help connect to all other relevant actors – and other scales – but also those actors who can help connect to the most important ecological features, thereby enabling the targeting of actions to spatial scales that have the greatest potential for achieving conservation outcomes.

There are added benefits of applying SNA to conservation planning. Engagement is an expensive process and SNA can help minimize related costs by identifying either well connected actors, or specifically those who are linked to others who might prove difficult or costly to engage with directly (e.g. Prell et al. 2009). It can also help identify those actors who could help maximize understanding of the system complexity, due to their connections to actors who hold different types of knowledge. Or it can help uncover particular collaboration gaps that, if addressed, might connect key groups or actors who can collectively enhance conservation success (Vance-Borland & Holley 2011).

Structural analyses of networks can provide insights into how social networks affect planned outcomes, through their enabling or constraining of key social processes needed in the planning and implementation of conservation actions. However, acquiring a deep

appreciation of the role of social networks will likely require not only an understanding of structural aspects, such as the presence or absence of links between two or more key actors or groups, but also information on the value or effectiveness of such links. For example, engaging an actor that is well connected to many other actors operating at different scales (a structural characteristic) might not be of benefit if that actor is perceived as distrustful by the actors they are connected to (e.g. Gass et al. 2009), or if the actor lacks legitimacy (Tyler 2006), their presence in the network over time is uncertain (McAllister et al. 2008), or cultural, institutional and other contextual aspects affects the actor's willingness to act (e.g. Bodin & Crona 2008).

Conclusions

Strategic decisions at the onset of a conservation project can be informed by an understanding of some of the challenges that can arise during the process of development and implementation of conservation actions, which include potential mismatches in spatial, temporal and functional scales. We have discussed how scale mismatches can manifest at each stage of the conservation planning process, which can lead to a plan that does not account for the threats, risks, constraints, opportunities, and the complexities and dynamics of the social-ecological system, and limited or no implementation. In addition, scale mismatches can also affect the adaptive capacity of conservation institutions during project development and implementation, due to an impeded ability to detect – and therefore learn from, ecological changes occurring at scales other than the scale of operation.

An understanding of how these scale mismatches manifest at the various stages of project development and implementation can inform a pre-emptive diagnosis of the likelihood of success of conservation initiatives. This information could be employed in

prioritization analyses to develop estimates of the likelihood of success of conservation actions in the context of particular locations, species or threats to be prioritized. Anticipating the potential for scale mismatches can inform the development of strategies for action, implementation and evaluation that can effectively deal with the mismatch problem. These strategies might involve trade-offs across a spectrum that spans (a) addressing the mismatch and ensuring strategies and actions are developed and applied at time and spatial scales that are appropriate for the problem at hand and (b) doing nothing to address the mismatch and rely on the likelihood (however reduced) that some positive conservation outcomes might still transpire. Such trade-offs might often depend on the resources available, on competing considerations that shape decisions about scale (Mills et al. 2010) and on the viability of strategies and actions that could address the mismatch.

The importance of social networks to solving conservation problems stems from how most environmental problems are characterized, as explained by Newman and Dale (2007): First, environmental problems are multi-scaled and thus require local actors to have connections to broader levels of society (and vice versa). Second, they are constantly evolving and require a flexible and open engagement process. Third, they require trans-disciplinary processes involving experts, government and local stakeholders. In this paper we have considered how social network analysis can be applied to conservation planning so as to improve its effectiveness on the ground, specifically through its usefulness as a tool that can help guide how conservation actions can be applied at the required spatial, temporal and functional scales.

Acknowledgements

We are thankful for the feedback from R. Loyola on the manuscript, and that of three anonymous reviewers. We also thank the Australian Research Council and CSIRO's Climate Adaptation Flagship who provided funding and support.

Literature Cited

1999. Environment Protection and Biodiversity Conservation Act 1999 in C. Government, editor. Commonwealth Government.

2007. Water Act 2007 in C. Government, editor. Commonwealth Government.

Authority, M. D. B. 2011. Proposed Basin Plan in C. o. Australia, editor. Murray–Darling Basin Authority.

Balmford, A., and R. Cowling. 2006. Fusion or Failure? The future of conservation biology. Conservation Biology **20**:692-695.

Berkes, F. 2006. From community-based resource management to complex systems: The scale issue and marine commons. Ecology and Society **11**(1).

Biggs, D., N. Abel, A. T. Knight, A. Leitch, A. Langston, and N. C. Ban. 2011. The implementation crisis in conservation planning: could "mental models" help? Conservation Letters **4**:169-183.

Bode, M., W. Probert, W. R. Turner, K. A. Wilson, and O. Venter. 2010. Conservation Planning with Multiple Organizations and Objectives. Conservation Biology

25:295-304.

Bodin, O., B. Crona, and H. Ernstson. 2006. Social networks in natural resource management: What is there to learn from a structural perspective? Ecology and Society **11(**2).

Bodin, O., and B. I. Crona. 2008. Management of Natural Resources at the Community Level: Exploring the Role of Social Capital and Leadership in a Rural Fishing Community. World Development **36**:2763-2779.

Bodin, O., and B. I. Crona. 2009. The role of social networks in natural resource governance: What relational patterns make a difference? Global Environmental Change-Human and Policy Dimensions **19**:366-374.

Borgatti, S. P., and P. C. Foster. 2003. The network paradigm in organizational research: A review and typology. Journal of Management **29**:991-1013.

Borgatti, S. P., A. Mehra, D. J. Brass, and G. Labianca. 2009. Network Analysis in the Social Sciences. Science **323**:892-895.

Briers, R. A. 2002. Incorporating connectivity into reserve selection procedures. Biological Conservation **103**:77-83.

Briggs, B. S. V. 2001. Linking ecological scales and institutional frameworks for landscape rehabilitation. Ecological Management & Restoration **2**:28-35.

Burgman, M. A., H. P. Possingham, A. J. J. Lynch, D. A. Keith, M. A. McCarthy, S. D. Hopper, W. L. Drury, J. A. Passioura, and R. J. Devries. 2001. A method for setting the size of plant conservation target areas. Conservation Biology **15**:603-616.

Carignan, V., and M. A. Villard. 2002. Selecting indicator species to monitor ecological integrity: A review. Environmental Monitoring and Assessment **78**:45-61.

Carlsson, L., and A. Sandstrom. 2008. Network governance of the commons. International Journal of the Commons **2**:33-54.

Carwardine, J., C. J. Klein, K. A. Wilson, R. L. Pressey, and H. P. Possingham. 2008. Hitting the target and missing the point: target-based conservation planning in context. Conservation Letters **2**:3-10.

Cash, D. W., W. N. Adger, F. Berkes, P. Garden, L. Lebel, P. Olsson, L. Pritchard, and O. Young. 2006. Scale and cross-scale dynamics: Governance and information in a multilevel world. Ecology and Society **11**:-.

Cosler, P., T. Flannery, R. Harding, D. Karoly, H. Possingham, R. Purves, D. Saunders, B. Thom, J. Williams, and M. Young. 2010. Sustainable Diversions in the Murray-Darling Basin. Wentworth Group.

Costello, C., and S. Polasky. 2004. Dynamic reserve site selection. Resource and Energy Economics **26**:157-174.

Cowling, R. M., and A. Wilhelm-Rechmann. 2007. Social assessment as a key to conservation success. Oryx **41**:135-136.

Cumming, G. S., D. H. M. Cumming, and C. L. Redman. 2006. Scale mismatches in social-ecological systems: Causes, consequences, and solutions. Ecology and Society **11**(1).

Daily, G. C., and P. R. Ehrlich. 1999. Managing earth's ecosystems: An interdisciplinary challenge. Ecosystems **2**:277-280.

Emirbayer, M., and J. Goodwin. 1994. Network Analysis, Culture, and the Problem of Agency. American Journal of Sociology **99**:1411-1454.

Evans, M. C. E. M. C., H. P. Possingham, and K. A. Wilson. 2011. What to do in the face of multiple threats? Incorporating dependencies within a return on investment framework for conservation. Diversity and Distributions **17**:437-450.

Ferraro, P. J., and S. K. Pattanayak. 2006. Money for nothing? A call for empirical evaluation of biodiversity conservation investments. PLoS Biology **4**:482-488.

Field, S. A., P. J. O'Connor, A. J. Tyre, and H. P. Possingham. 2007. Making monitoring meaningful. Austral Ecology **32**:485-491.

Folke, C., F. Berkes, and J. Colding. 1998a. Ecological practices and social mechanisms for building resilience and sustainability in F. Berkes, and C. Folke, editors. Linking social and ecological systems. Cambridge University Press, London, UK.

Folke, C., L. Pritchard, F. Berkes, J. Colding, and U. Svedin. 1998b. The problem of fit between ecosystems and institutions. IHDP Working Paper No. 2. International Human Dimensions Programme on Global Environmental Change (IHDP), Bonn, Germany.

Game, E. T., G. Lipsett-Moore, R. Hamilton, N. Peterson, J. Kereseka, W. Atu, M. Watts, and H. Possingham. 2010. LETTER: Informed opportunism for conservation planning in the Solomon Islands. Conservation Letters:no-no.

Game, E. T., M. E. Watts, S. Wooldridge, and H. P. Possingham. 2008. Planning for persistence in marine reserves: a question of catastrophic importance. Ecological Applications **18**:670-680.

Gass, R., M. Rickenbach, L. Schulte, and K. Zeuli. 2009. Cross-Boundary Coordination on Forested Landscapes: Investigating Alternatives for Implementation. Environmental Management **43**:107-117.

Gilmore, S., B. Mackey, and S. Berry. 2007. The extent of dispersive movement behaviour in Australian vertebrate animals, possible causes, and some implications for conservation. Pacific Conservation Biology **13**:93-103.

Granovetter, M. 1973. STRENGTH OF WEAK TIES. American Journal of Sociology **78**:1360-1380.

Grantham, H. S., M. Bode, E. McDonald-Madden, E. T. Game, A. T. Knight, and H. P. Possingham. 2010. Effective conservation planning requires learning and adaptation. Frontiers in Ecology and the Environment **8**:431-437.

Grantham, H. S., K. A. Wilson, A. Moilanen, T. Rebelo, and H. P. Possingham. 2009. Delaying conservation actions for improved knowledge: how long should we wait? Ecology Letters **12**:293-301.

Green, A., S. E. Smith, G. Lipsett-Moore, C. Groves, N. Peterson, S. Sheppard, P. Lokani, R. Hamilton, J. Almany, J. Aitsi, and L. Bualia. 2009. Designing a resilient network of marine protected areas for Kimbe Bay, Papua New Guinea. Oryx **43**:488-498.

Guerrero, A. M., A. T. Knight, H. S. Grantham, R. M. Cowling, and K. A. Wilson. 2010. Predicting willingness-to-sell and its utility for assessing conservation opportunity for expanding protected area networks. Conservation Letters **3**:332-339.

Hahn, T., P. Olsson, C. Folke, and K. Johansson. 2006. Trust-building, knowledge generation and organizational innovations: The role of a bridging organization for adaptive comanagement of a wetland landscape around Kristianstad, Sweden. Human Ecology **34**:573-592.

Henson, A., D. Williams, J. Dupain, H. Gichohi, and P. Muruthi. 2009. The Heartland Conservation Process: enhancing biodiversity conservation and livelihoods through landscape-scale conservation planning in Africa. Oryx **43**:508-519.

Isaac, M. E., B. H. Erickson, S. J. Quashie-Sam, and V. R. Timmer. 2007. Transfer of knowledge on agroforestry management practices: the structure of farmer advice networks. Ecology and Society **12**.

Janssen, M. A., O. Bodin, J. M. Anderies, T. Elmqvist, H. Ernstson, R. R. J. McAllister, P. Olsson, and P. Ryan. 2006. Toward a network perspective of the study of resilience in social-ecological systems. Ecology and Society **11**.

Kearney, F., R. R. J. McAllister, and N. D. MacLeod. in press. Conservation and grazing in Australia's north-east: the bridled nailtail wallaby. Pastoralism: Research, Policy and Practice.

Knight, A. T., R. M. Cowling, and B. M. Campbell. 2006a. An operational model for implementing conservation action. Conservation Biology **20**:408-419.

Knight, A. T., R. M. Cowling, M. Difford, and B. M. Campbell. 2010. Mapping Human and Social Dimensions of Conservation Opportunity for the Scheduling of Conservation Action on Private Land. Conservation Biology **24**:1348-1358.

Knight, A. T., R. M. Cowling, M. Rouget, A. Balmford, A. T. Lombard, and B. M. Campbell. 2008. Knowing But Not Doing: Selecting Priority Conservation Areas and the Research–Implementation Gap. Society for Conservation Biology **22**:610-617.

Knight, A. T., A. Driver, R. M. Cowling, K. Maze, P. G. Desmet, A. T. Lombard, M. Rouget, M. A. Botha, A. F. Boshoff, J. G. Castley, P. S. Goodman, K. Mackinnon, S. M. Pierce, R. Sims-Castley, W. I. Stewart, and A. V. Hase. 2006b. Designing Systematic Conservation Assessments that

Promote Effective Implementation: Best Practice from South Africa. Conservation Biology **20**:739-750.

Lambeck, R. J. 1997. Focal Species: A Multi-Species Umbrella for Nature Conservation. Conservation Biology **11**:849-856.

Lee, K. N. 1993. Greed, Scale Mismatch, and Learning. Ecological Applications **3**:560-564.

Leroux, S. J., F. K. A. Schmiegelow, S. G. Cumming, R. B. Lessard, and J. Nagy. 2007. Accounting for system dynamics in reserve design. Ecological Applications **17**:1954-1966.

Lindenmayer, D. B., and G. E. Likens. 2010. The science and application of ecological monitoring. Biological Conservation **143**:1317-1328.

Lindenmayer, D. B., A. D. Manning, P. L. Smith, H. P. Possingham, J. Fischer, I. Oliver, and M. A. McCarthy. 2002. The focal-species approach and landscape restoration: a critique. Conservation Biology **16**:338-345.

Margules, C. R., and R. L. Pressey. 2000. Systematic conservation planning. Nature **405**:243-253.

Margules, C. R., R. L. Pressey, and P. H. Williams. 2002. Representing biodiversity: data and procedures for identifying priority areas for conservation. Journal of Biosciences **27**:309-326.

Mascia, M. B., J. P. Brosius, T. A. Dobson, B. C. Forbes, L. Horowitz, M. A. McKean, and N. J. Turner. 2003. Conservation and the social sciences. Conservation Biology **17**:649-650.

McAllister, R. R. J., B. Cheers, T. Darbas, J. Davies, C. Richards, C. J. Robinson, M. Ashley, D. Fernando, and Y. T. Maru. 2008. Social networks in arid Australia: a review of concepts and evidence. Rangeland Journal **30**:167-176.

Meir, E., S. Andelman, and H. P. Possingham. 2004. Does conservation planning matter in a dynamic and uncertain world? Ecology Letters **7**:615-622.

Mills, M., R. L. Pressey, R. Weeks, S. Foale, and N. C. Ban. 2010. A mismatch of scales: challenges in planning for implementation of marine protected areas in the Coral Triangle. Conservation Letters **3**:291-303.

Moilanen, A., and A. Arponen. 2011. Administrative regions in conservation: Balancing local priorities with regional to global preferences in spatial planning. Biological Conservation **144**:1719-1725.

Newman, L., and A. Dale. 2007. Homophily and Agency: Creating Effective Sustainable Development Networks. Environment, Development and Sustainability **9**:79-90.

Nicholson, E., M. I. Westphal, K. Frank, W. A. Rochester, R. L. Pressey, D. B. Lindenmayer, and H. P. Possingham. 2006. A new method for conservation planning for the persistence of multiple species. Ecology Letters **9**:1049-1060.

O'Connell, M. J., R. M. Ward, C. Onoufriou, I. J. Winfield, G. Harris, R. Jones, M. L. Yallop, and A. F. Brown. 2007. Integrating multi-scale data to model the relationship between food resources, waterbird distribution and human activities in freshwater systems: preliminary findings and potential uses. Ibis **149**:65-72.

Olsson, P., C. Folke, V. Galaz, T. Hahn, and L. Schultz. 2007. Enhancing the fit through adaptive co-management: Creating and maintaining bridging functions for matching scales in the Kristianstads Vattenrike Biosphere Reserve, Sweden. Ecology and Society **12**(1).

Pierce, S. M., R. M. Cowling, A. T. Knight, A. T. Lombard, M. Rouget, and T. Wolf. 2005. Systematic conservation planning products for land-use planning: Interpretation for implementation. Biological Conservation **125**:441-458.

Polasky, S. 2008. Why conservation planning needs socioeconomic data. PNAS **105**:6505-6506.

Prell, C., K. Hubacek, and M. Reed. 2009. Stakeholder Analysis and Social Network Analysis in Natural Resource Management. Society & Natural Resources **22**:501-518.

Pressey, R. L., and M. C. Bottrill. 2008. Opportunism, Threats, and the Evolution of Systematic Conservation Planning. Conservation Biology **22**:1340-1345.

Pressey, R. L., and M. C. Bottrill. 2009. Approaches to landscape- and seascape-scale conservation planning: convergence, contrasts and challenges. Oryx **43**:464-475.

Pressey, R. L., M. Cabeza, M. E. Watts, R. M. Cowling, and K. A. Wilson. 2007. Conservation planning in a changing world. Trends in Ecology & Evolution **22**:583-592.

Pressey, R. L., and V. S. Logan. 1995. Reserve coverage and requirements in relation to partitioning and generalization of land classes: Analyses for western New South Wales. Conservation Biology **9**:1506-1517.

Reyers, B., D. J. Roux, R. M. Cowling, A. E. Ginsburg, J. L. Nel, and P. O. Farrell. 2010. Conservation Planning as a Transdisciplinary Process. Conservation Biology **24**:957-965.

Rouget, M. 2003. Measuring conservation value at fine and broad scales: implications for a diverse and fragmented region, the Agulhas Plain. Biological Conservation **112**:217-232.

Salafsky, N., R. Margoluis, K. H. Redford, and J. G. Robinson. 2002. Improving the practice of conservation: a conceptual framework and research agenda for conservation science. Conservation Biology **16**:1469-1479.

Sarkar, S., R. L. Pressey, D. P. Faith, C. R. Margules, T. Fuller, D. M. Stoms, A. Moffett, K. A. Wilson, K. J. Williams, P. H. Williams, and S. Andelman. 2006. Biodiversity conservation planning tools: Present status and challenges for the future. Pages 123-159. Annual Review of Environment and Resources. Annual Reviews, Palo Alto.

Simberloff, D. 1998. Flagships, umbrellas, and keystones: Is single-species management passe in the landscape era? Biological Conservation **83**:247-257.

Spellerberg, I. F. 1994. Monitoring ecological change. Cambridge University Press, Cambridge [England] ; New York :.

Stem, C., R. Margoluis, N. Salafsky, and M. Brown. 2005. Monitoring and evaluation in conservation: A review of trends and approaches. Conservation Biology **19**:295-309.

Tulloch, A., H. P. Possingham, and K. Wilson. 2011. Wise selection of an indicator for monitoring the success of management actions. Biological Conservation **144**:141-154.

Tyler, T. R. 2006. Psychological perspectives on legitimacy and legitimation. Pages 375-400. Annual Review of Psychology. Annual Reviews, Palo Alto.

Van Houtan, K. S. 2006. Conservation as virtue: a scientific and social process for conservation ethics. Conservation Biology **20**:1367-1372.

Vance-Borland, K., and J. Holley. 2011. Conservation stakeholder network mapping, analysis, and weaving. Conservation Letters **4**:278-288.

Walters, C. J. 2007. Is adaptive management helping to solve fisheries problems? Ambio **36**:304-307.

Waudby, H., T. How, D. Frazer, and C. Obst. 2007. South Australian Recovery Plan Review 2007: Findings, Patterns and recommendations. Report to the Federal Department for Environment and Heritage, Canberra.

Wilson, K. A., J. Carwardine, and H. P. Possingham. 2009. Setting Conservation Priorities. Year in Ecology and Conservation Biology 2009 **1162**:237-264.

Wilson, K. A., M. F. McBride, M. Bode, and H. P. Possingham. 2006. Prioritizing global conservation efforts. Nature **440**:337-240.

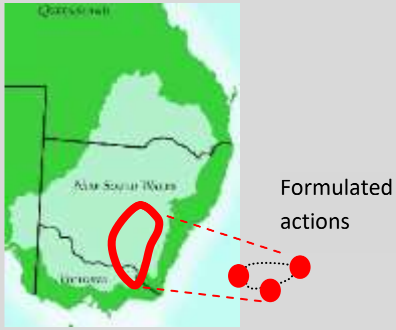
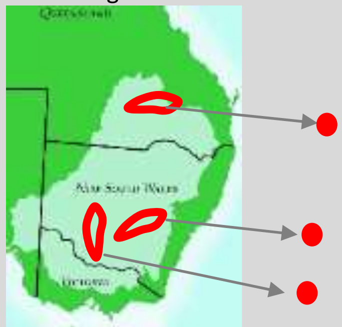
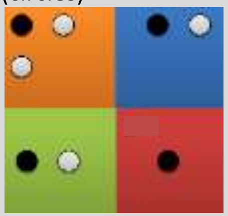
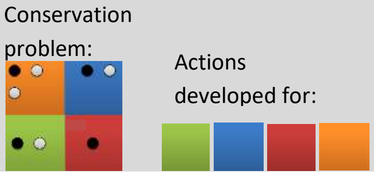
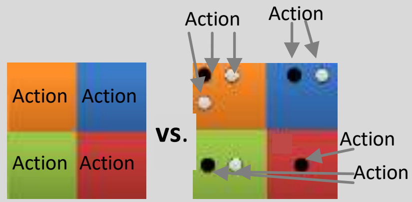
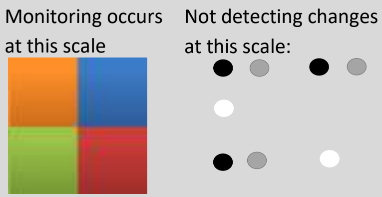
Wondolleck, J. M. 2000. Making collaboration work : lessons from innovation in natural resource management / Julia M. Wondolleck and Steven L. Yaffee. Island Press, Washington, D.C. :.

Wyborn, C. 2011. Landscape Scale Ecological Connectivity: Australian Survey and Rehearsals. Pacific Conservation Biology **17**:121-131.

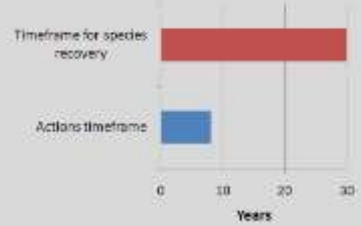
Young, M. D., and J. C. McColl. 2009. Double trouble: the importance of accounting for and defining water entitlements consistent with hydrological realities. Australian Journal of Agricultural and Resource Economics **53**:19-35.

Young, O. R. 2002. The institutional dimensions of environmental change: fit, interplay, and scale. MIT Press, Cambridge, Massachusetts, USA.

Table 1

	Assessment*	***Formulation of actions and strategies****	***Implementation & management****	***Review and adaptation****
Spatial mismatch (example 1)	The extent of the planning region is not defined according to ecological boundaries (A) but governance systems (state boundaries). 	Different plans, actions and strategies directed to the same ecosystem, which might be in conflict. No coordination between them might mean a lack of capacity for solving the conservation problem. 	The operational scale of the organizations involved for implementation may not be sufficient to drive on-ground implementation at the full scale of the conservation problem. 	Monitoring is undertaken at a scale at which involved organizations operate, which might not cover the full scale of the conservation problem. Consequently information for adaptation decisions can be misleading. 
Spatial mismatch (example 2)	The resolution of data (squares) may not reflect the heterogeneity of the socio-ecological system (circles) 	Actions and strategies are developed at a scale (square) that does not reflect the threats, risks, complexities and dynamics of the social-ecological system affecting the success of conservation actions (circles). 	Implementation may not occur at an adequate scale, with actions implemented to broadly or too narrowly to effectively address the issue. 	Monitoring operations might not detect ecological changes that occur at wider or finer scales, limiting the ability to respond and adapt to changes. 

<table>
<tr>
<td>Temporal mismatch example</td>
<td>Limited data collection and quick assessments, driven by the time horizons of organizations and funding bodies, do not cover the socio-ecological system in sufficient detail.

</td>
<td>Actions are formulated for a short time horizon, which do not address long-term ecosystem changes.


Alternatively, actions and strategies take time to be formulated missing critical short-term ecosystem changes (e.g. climate change).</td>
<td>Actions are implemented at timeframes that do not reflect the timeframe of ecological change.

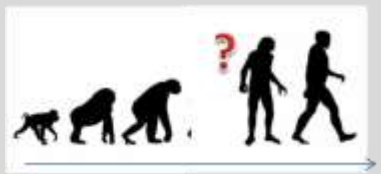
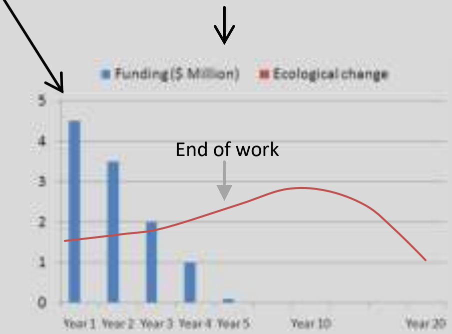
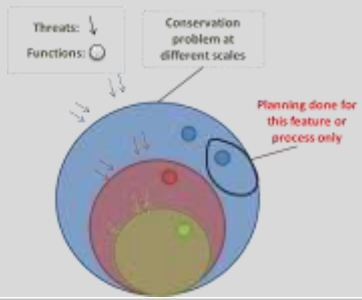
Lack of continuity of personnel throughout the planning process can result in ineffective implementation of conservation actions.
</td>
<td>Duration of monitoring activities is not enough to appropriately evaluate the effectiveness of conservation actions, or is not scaled to the frequency of the event being evaluated.

</td>
</tr>
<tr>
<td>Functional mismatch example</td>
<td>· Mismatch: The full scope of features, processes and threats to the ecological system are not accounted for as it is limited to the interests of funding bodies and their institutional frameworks.</td>
<td>- Mismatch: Actions that address only a limited subset of features, processes and threats affecting the ecological system.

</td>
<td>- Mismatch: Actions outside of the scope of implementing organizations are not selected, resulting in a partly implemented plan.</td>
<td>- Mismatch: Indicators chosen for monitoring activities do not provide a whole-of-systems view of the problem.</td>
</tr>
<tr>
<td colspan="5">· * Stages of project development and implementation (see Figure 1)</td>
</tr>
</table>

Table Legends

Table 1 –Examples of scale mismatches at each stage of the conservation planning process.

Figure Legends

Figure 1 – A generalized model of a conservation planning process (adapted from Knight et al. 2006a; Pressey & Bottrill 2009).

Figure 2 – Different networks suggesting different strategies for engagement and collaboration.