Chapter 18

INCORPORATING NOVEL ECOSYSTEMS INTO MANAGEMENT FRAMEWORKS

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18.1 INTRODUCTION

How might the existence of hybrid and novel ecosystems alter ecosystem management? Non-native species invasions, climate change, pollution and land development all are creating ecosystems that consist of new combinations of species, and often have altered functioning and structure. A common goal in ecosystem management is to maintain native populations and traditional functions by removing the species, disturbances and conditions that lead to degradation (Grumbine 1997), and thus return ecosystems to their

pre-disturbance trajectories or states. The emergence of novel ecosystems forces managers to reconsider this paradigm because, at times, no amount of management action will reverse ecological changes. New management goals may continue to recognize the value of protecting species and ecosystem processes, although they might not include continuity with the historical system. In these cases, managers might choose to utilize non-traditional or alternative management strategies derived through a broad suite of planning tools to reach management goals.

This chapter aims to provide a framework that helps managers, whether scientists or stewards, navigate the decisions that lead to new management approaches in hybrid and novel ecosystems. We first present a decision-making flowchart (Fig. 18.1) that can be used as a roadmap to navigate possible management actions. We also explore the role of both ecological and social barriers in the creation and maintenance of hybrid and novel ecosystems (Fig. 18.2). Finally, five case studies (Chapters 19–23) highlight examples of challenging decision points (Box 18.1) which managers will likely face as they work to incorporate hybrid and novel ecosystems into strategies for restoration, conservation and management.

18.2 THE NOVEL ECOSYSTEM DECISION FRAMEWORK

An overview of the decision framework is given in Figure 18.1, where various options for intervention are
**Box 18.1** Difficult questions raised when managing novel ecosystems

**Ecological**
- Do sufficient data exist to define a reference state/historical baseline?
- How do we determine if ecosystem changes are reversible?
- How do we make management decisions when we have incomplete knowledge about the target ecosystem and the drivers causing ecosystem change?
- How do we manage novel ecosystems to maintain past or obtain future ecosystem values when we cannot alter the drivers of change (e.g. climate change)?
- How do we maintain desirable characteristics of a hybrid ecosystem that we might lose if we implement restoration to a historical state?

**Social**
- When interventions to restore ecosystems are technically possible, when is it acceptable for economic and social factors to prevent action?
- How do we balance competing desires for ecosystems to be restored to a historical state or for intrinsic values versus managed to provide currently desired goods and services?
- How do constraints on managers’ time and budgets affect their ability to identify ecosystem novelty?
- When managing novel ecosystems with limited budgets, how do we decide which species and functions to protect and maintain?
18.4 ARE ECOSYSTEM CHANGES REVERSIBLE? IDENTIFYING HYBRID AND NOVEL ECOSYSTEMS

18.4.1 Role of historical information

The question of whether ecosystem changes are reversible (Fig. 18.1) implies that ecosystems have changed from some former state. To inform management goals (including restoration) it is helpful to define this former state, although this process can be remarkably difficult. Managers outside of Europe often choose ecosystems that existed before the arrival of European settlers, aiming for ecosystems that were ‘untouched’ by humans. Historically this failed to recognize the close relationship many indigenous peoples had (and have) with the land, although this is improving (e.g. Berkes et al 1998). Furthermore, the effects of climate change are clear (see Chapter 10); many managers realize restoration references need to consider not just what was historical in the ecosystem, but also the extent to which a system’s biophysical envelope may have changed because of factors other than anthropogenic drivers.

Despite these challenges, we argue that working to understand the historical structure and conditions in an ecosystem is useful for planning current management strategy. This is because information on historical states can both inform restoration of hybrid ecosystems where changes are determined to be reversible as well as highlight the presence of a novel ecosystem. In short, information about ecosystem changes can help determine the next steps for ecosystem management and intervention.

Importantly, historical ecosystem references always provide more of a guide than a strict template for determining current management action. Due to the dynamic nature of ecosystems and imperfect knowledge of past conditions, using information from multiple reference sites or using multiple types of historical
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Recognition of an altered ecosystem state starts the process of determining what the underlying drivers of change might be. When these drivers cannot be addressed through management interventions, managers may decide to treat the ecosystem as if it were novel and consider the management actions presented in Figure 18.3. Chapters 3 and 24 offer a more detailed discussion of thresholds, as well as Suding and Hobbs (2009) and the Thresholds Database at: http://www.resalliance.org/index.php/thresholds_database.

18.4.2.1.2 Positive feedback loops
The presence of positive feedback loops (also called amplifying feedbacks) may also be good indicators of novel ecosystems. Positive feedback loops occur when an initial ecosystem change results in continued changes in the same direction. These feedbacks continually drive an ecosystem away from its original state, making it hard for managers to return it to the original state (Suding and Hobbs 2009). Such positive feedback loops are often associated with threshold dynamics in ecosystems (Suding and Hobbs 2009).

A classic example of a positive feedback resulting in the shift of an ecosystem state is the invasion of non-native species that alter disturbance regimes such that the new regime favors the ongoing spread of the invader (D’Antonio and Vitousek 1992). An example is the invasion of Bromus tectorum (cheatgrass) which was introduced into the US in the late 1800s and had invaded grass and shrubland ecosystems throughout the west by the 1930s (Mack 1981; Menakis et al. 2002). Areas invaded by cheatgrass have uncharacteristically large accumulations of litter; this build-up of fuel increases the fire-return interval in summer-dry areas, which favors the quick-growing grass and leads to a conversion of native ecosystems to cheatgrass-dominated grasslands. Other examples of positive feedback loops include the simultaneous build-up of a non-native seed bank and depletion of a native seed bank, such as that which occurs on old fields in south-western Australia (Standish et al. 2007).

18.4.2.1.3 Multiple interacting drivers of ecosystem change (cumulative effects)
Changes to ecosystem structure and function stem from a variety of internal and external drivers. Examples of internal drivers include management systems, land conversion, species harvesting and some forms of pollution. Examples of external drivers include information will often yield the most accurate model from which to assess novelty (Swetnam et al. 1999: Chapter 24). The case study on meadows in Atlantic Canada (Chapter 19) provides an example of how incomplete historical information about ecosystems can affect restoration outcomes. How managers addressed these informational shortcomings is discussed and an after-the-fact summary of the pros and cons of working to restore ecosystems to historical states is provided.

18.4.2 Identification of barriers to ecosystem recovery

Both ecological and social factors can influence ongoing ecosystem change and can be barriers to restoration (Fig. 18.2). Examples of ecological barriers include reduced seed banks that lead to population decline of native species, altered disturbance regimes that favor non-native species spread or the presence of non-native species that prevent recruitment of desired native species. Examples of social barriers that can affect management decisions include limited budgets for restoration, social norms and human welfare needs, and gaps in knowledge about the efficacy of management actions. In the following sections we describe a number of ecological and social factors that can signal the presence of a novel ecosystem.

18.4.2.1 Ecological barriers

18.4.2.1.1 The presence of thresholds
Chapter 3 focused mainly on ecological barriers in the form of thresholds: tipping points where an ecosystem moves from one ecological state to another. An ecological state is defined by the abiotic and biotic attributes of an ecosystem along with the feedbacks and dynamics that contribute to these attributes. When a tipping point is crossed, changing feedbacks and dynamics result in a new array of attributes. Examples of possible tipping points include species extinctions or distribution shifts, habitat fragmentation, nutrient deposition, changing disturbance regimes, increases in numbers and abundances of invasive species or the development of colonization barriers such as shrinking or absent seed banks, (e.g. Scheffer 2009).

The threshold concept is broadly useful for identifying novel ecosystems because the recognition of state shifts indicates the possibility that traditional management actions may no longer produce desired management outcomes. Recognition of an altered ecosystem state starts the process of determining what the underlying drivers of change might be. When these drivers cannot be addressed through management interventions, managers may decide to treat the ecosystem as if it were novel and consider the management actions presented in Figure 18.3. Chapters 3 and 24 offer a more detailed discussion of thresholds, as well as Suding and Hobbs (2009) and the Thresholds Database at: http://www.resalliance.org/index.php/thresholds_database.
climatic change, nitrogen deposition and non-native species invasion. Often multiple drivers cumulatively impact an ecosystem, resulting in a cascade of changes in the abiotic and biotic characteristics of the ecosystem, as well as possible changes to ecosystem dynamics (Suding et al. 2004). In these cases, novel ecosystems may result from the inability of managers to simultaneously address all drivers in a way that will mitigate ongoing ecosystem changes.

18.4.2.1.4 Drivers of ecosystem change occurring at scales beyond the scope of management

Novel ecosystems may occur when managers are unable to address ecosystem change drivers because of a disjunct between the scale at which the driver is operating and the scale at which management can be targeted. Managers may have little control over the activities and developments that occur outside their reserve boundaries but impact ecosystems within their jurisdiction.

Because management actions can be limited to the individual reserve, park or other area within their jurisdiction, finding management solutions to address change drivers that are not under their control may be difficult. If a mismatch exists in scale of driver and scale of management, restoring an ecosystem to a reference state is highly unlikely. In these cases, managers may need to rely on tools that can span such property boundaries, such as environmental regulation and policy or conservation easements and other incentive-based programs. Chapter 20 describes an example of how mismatches in the scale of driver and scale of management action can limit the ability of managers to restore ecosystems and can lead to novel ecosystems.

18.4.2.2 Social barriers

At times, management strategies solely consider ecological barriers to recovery. This may be due to
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Incorporating novel ecosystems into management frameworks involves understanding that social factors are as important as ecological barriers for ecosystem recovery. The reality is that social factors can be both as important to ecosystem management and as difficult to address as ecological barriers.

Deciding when social barriers to ecosystem recovery are insurmountable is beyond the scope of this chapter. However, understanding the impact of social factors on the ability of managers to reach management goals is key in creating achievable management strategies. For example, in the case study of ecosystem management on St George Island, Alaska (see Chapter 21), the management of introduced reindeer depends on the collaboration of a diverse group of stakeholders with, at times, contrasting management goals. As a result, the current management strategy perpetuates the presence of the reindeer, and thus a hybrid ecosystem, rather than restoring the ecosystem to its historical trajectory. Undoubtedly, social factors will be an ongoing consideration in management decisions, and successful management strategies in changing and novel ecosystems will likely require increased communication and collaboration among ecologists, land owners, policy makers, managers, and other ecosystem stewards.

A number of social factors that affect management decisions are described below.

18.4.2.2.1 Limited management budget
Limited budgets, and thus insufficient funds for restoration, are one of the most pervasive management constraints and can lead to the maintenance of hybrid ecosystems. While resource shortfalls may sometimes be alleviated by strategic planning that allows for readjustment of funding assignments or the development of collaborations, budgets may be controlled by government allotments or organizational processes that prevent the dedication of sufficient resources to restore hybrid systems to reference states. Additionally, realistic levels of resourcing are not always available to meet the objectives of a project.

18.4.2.2.2 Social norms and property systems
When ecosystems span a mosaic of land uses and types of owners, the values of the people living on the land and/or managing the land will affect ecosystem management. In particular, it may be difficult to coordinate actions across property boundaries when adjacent landowners use properties for different purposes or value different aspects of the environment (Wiens 2009). For example, stopping the spread of a non-native plant may require the coordinated effort of adjoining property owners (Aslan et al. 2009); if some owners value the plant while others consider it a threat to native vegetation, it may be hard to coordinate management action (Gardener et al. 2010).

In other cases, norms based on strongly held community beliefs may prevent managers from undertaking action that leads to ecosystem restoration. For example, in some cases managers have the knowledge to reestablish self-sustaining populations of top predators to areas that were historically part of their distribution. A number of social factors can however influence management possibilities including: the belief that top predators can be a threat to human and/or livestock safety; beliefs that an increase in predators results in declines in valued prey populations (see Wassner et al. 2011 for a test of this assumption); or perceptions that the reintroduction of predators with legal protection is an infringement of private property rights (e.g. Bangs and Fritts 1997; Smith and Ferguson 2006; Levy 2009).

When social norms differ across landscapes or are contrary to recovery, restoration may at times be limited to public lands or require increased communication between managers and landowners to determine acceptable and appropriate management goals. There are a number of tools managers can use to incorporate social considerations into management decisions including stakeholder analysis, participatory action, scenario planning (Peterson et al. 2003), outreach and education. These tools help stakeholders understand differing social values and build relationships and collaborations. Adaptive management can also be used to fill knowledge gaps. At a broader scale, environmental regulations and policy may help to address some of the social barriers to ecosystem recovery.

18.4.2.2.3 Gaps in knowledge
A variety of types of knowledge gaps can hinder people’s ability to restore ecosystems. For example, insufficient knowledge of ecosystem change drivers can prevent the recognition of reversible change. Such knowledge gaps might be addressed through ecosystem assessments as described earlier in the chapter.

Incomplete understanding of the effects of widely used but unsuccessful management strategies is a
second knowledge gap that may prevent ecosystem recovery. One example of this is where management activities can have a narrow focus on the restoration of plants and abiotic conditions, leading to the belief that successful revegetation is synonymous with successful faunal restoration. This is an extension of the Field of Dreams hypothesis (Palmer et al. 1997), originally based on wetland restoration where “getting the hydrology and soil right” seemed to be the most important ingredient for restoration success. Some studies point out that passive fauna recolonization of revegetated sites does not occur in all cases however, due to factors such as the specialized habitat needs of individual faunal species or the isolation of restored sites from source populations (Kanowski et al. 2006). In these cases active intervention is in fact required. Careful consideration of final recovery goals is needed to ensure actions can lead to desired outcomes.

Finally, knowledge gaps may stem from insufficient technology or methodologies to reverse ecosystem changes. In such cases, the ability to restore ecosystems might change as methodologies are developed through targeted research or as a consequence of new technologies. Some ecosystems might initially be managed as novel because of this, but managed in a way that preserves opportunities for later restoration.

In cases where management action is irreversibly constrained by social barriers, managers have a couple of options. The first option is to continue with the status quo. This may mean mitigating degradation when possible and, at times, allowing the system to passively move to a novel ecological state. A second option is to maintain the ecosystem in a hybrid state, regardless of the ecological possibility of returning it to its historical trajectory. This option might entail reassessment of management goals and reprioritization of management actions (see Chapter 21).

18.4.3 When uncertainty persists

Despite best efforts to understand if an ecosystem change is reversible, this may remain unclear. Perhaps the drivers of ecosystem change are not yet clearly understood, or maybe social and economic constraints are such that pursuing management to restore ecosystems is out of the question. In such situations, managers may be unwilling to label the target ecosystem novel. Instead, they might bet that future innovations in management techniques, results from an ongoing ecosystem assessment or coalitions with stakeholders will eventually allow for ecosystem recovery. Because of this, Figure 18.1 includes a pathway at the decision point focusing on ‘reversibility’, accounting for this uncertainty (i.e. an answer of ‘yes/maybe’ to the question of whether ecosystem changes are reversible is possible). A number of possible management options for when such uncertainty persists are provided in the section on managing hybrid ecosystems (Section 18.5.1).

18.5 NAVIGATING THE MANAGEMENT OF HYBRID AND NOVEL ECOSYSTEMS

After barriers to ecosystem recovery are identified and an ecosystem is determined to be either hybrid or novel, managers will have a number of choices of how to proceed with management actions (Fig. 18.1).

18.5.1 Hybrid management choices

When an ecosystem is determined to be hybrid, managers have a number of possible options (Fig. 18.1). Although changes in active management techniques are an option, it is also possible that the ecosystem might recover passively. Recent work highlights how scarce restoration resources can be conserved through careful decisions about where to focus restoration activities in those ecosystems that require no or minimal active intervention to recover, versus those ecosystems that need active management (Prach and Hobbs 2008; Sawtschuk et al. 2010; Holl and Aide 2011). Whether an ecosystem will recover without intervention depends on a number of factors including ecosystem type, level of degradation and connectivity with the surrounding landscape (Prach and Hobbs 2008). For example, passive restoration is not always effective for restoring higher trophic levels. If management goals include restoration of fauna, then some form of active restoration may be necessary (Majer 2009). An ecosystem assessment that includes identification of ecosystem changes, the drivers of change and the barriers (ecological and social) to ecosystem recovery will provide the best available information to determine the possibility of passive recovery.

When passive recovery is not an option, management options for the hybrid ecosystem may include: (1) fully restoring the ecosystem through active interven-
tion; (2) managing the ecosystem in a hybrid state either by partially restoring it or deciding to allow ecosystem changes to persist; or (3) deciding to manage the ecosystem as novel despite possibilities of restoring it to a historical state (Fig. 18.1). Which of these options is chosen will likely depend on the ability of the manager to remove/alter the ecological and social barriers present in the ecosystem (see Fig. 18.2).

As mentioned in Section 18.4.3, there is also the possibility that, after identifying barriers to recovery, managers may continue to be uncertain if ecosystem changes are reversible. What are possible management options in this case? One choice is to mitigate ongoing degradation, while simultaneously developing the ecological and social capacity that will allow for desired management action. Such a tactic is common for species extinct in the wild but existing in captivity/seed banks. In addition to the educational, ethical and research benefits of these facilities, many of these also devote resources to continual propagation and genetic management of the captive population for the time when the extinction driver is eliminated and reintroduction is possible.

Another example of this strategy would be for managers to control weeds through targeted spraying while gathering information both on drivers of weed spread and on methods that can be used to overcome ecological and social barriers to ecosystem recovery. A drawback of this type of ongoing stop-gap action is that it can become the final project objective, rather than a temporary goal pursued while methods are found to stop and reverse ongoing degradation. If this occurs, such management will require continued resource input with a slim hope of ecosystem recovery. Importantly, this tactic could prevent managers from identifying an ecosystem as novel, thereby preventing the implementation of an alternative management strategy that could be more likely to achieve management goals.

Another management choice in cases where managers are uncertain about the reversibility of ecosystem change is to preserve the foundational building blocks of ecosystems while simultaneously developing the ecological and social capacity that will allow for required management action. This may involve identifying key ecosystem characteristics – abiotic, biotic or dynamic – that influence ecosystem structure and function, focusing for example on actions such as preservation of soil, vegetation cover, keystone and engineer species, genetic diversity, habitat connectivity and maintenance of disturbance regimes. Although a focus on such ecosystem foundations does not guarantee that recovery goals will be met at some point in the future, conserving integral characteristics of ecosystems may offer a greater potential for future restoration than simple mitigation of ongoing degradation by ensuring that some of the self-sustaining aspects of the ecosystem remain intact.

Lastly, acknowledging uncertainty allows managers to move forward with management action. Managers might choose to manage the ecosystem as novel, but continue to collect information about barriers to ecosystem recovery. When developing management strategies based on chosen goals, managers might opt for conservative management based on actions that can be easily reversed rather than those that may be harder to control. For example, a manager deciding whether or not to plant a non-native species to maintain an existing ecosystem function may decide that the consequences for neighboring ecosystems are too great to warrant its introduction.

### 18.5.2 Novel management choices

Managers also have a number of management choices when ecosystems are recognized as being novel (Fig. 18.1 & Fig. 18.3). While the restoration to a historical state in these cases is very unlikely, an ecosystem identified as novel is not devoid of conservation value. It is possible that a subset of native species and historical functions may be present, and some traditional goals of ecosystem management can still be pursued.

As described in Chapter 3, the management of novel ecosystems may require the development of new techniques and methods to address unique and multiple drivers of change. For example, such approaches might target new species interactions to mitigate the effects of irreversible change drivers such as by using grazing to reduce impacts of non-native plant invasion. While such methods do not eliminate new drivers of change, they may enable managers to retain ecosystem values such as target native species or traditional functions. In the case of using cattle to reduce weed cover, this technique may not reverse non-native species invasion but may allow for the persistence of a diverse native flora by reducing competition with the invading species.

While exact actions may vary depending on management goals, managers might consider the role
of adaptive management for determining how best to manage new patterns and processes in a novel ecosystem. Experiments monitored over time provide data on the impacts of chosen manipulations, which can be used to understand if actions result in achievement of management goals. When ecosystems fail to recover, these monitored ecosystems provide data for future management trials. Further, monitoring data can be used to examine species responses to management actions and to background changes leading to novel processes. Identifying which species have the highest resilience to such changes, or which species can adapt to perform an important function, can be paramount in these situations. For example, demonstrating that an endangered species is benefitting from a new species in a system (e.g. southwestern willow flycatcher in tamarisk in the Grand Canyon; see Section 18.5.2.1 for more details on this example) can provide options for species recovery and avoid management mistakes. Chapter 22 provides an example of how adaptive management helped determine a management strategy for the identified novel Miconia-Cinchona ecosystem on the Galapagos Islands. Importantly, it also illustrates how novel ecosystem management can result in native species conservation, despite novel conditions.

In all situations, it will likely be critical to identify goals that guide novel ecosystem management. The identification of such goals may highlight particular actions that are more effective than others at managing desired ecosystem attributes and characteristics in these novel ecosystems. For example, an at-risk species might be the focus of management actions at times, while a locally valued function may set the agenda at other times.

18.5.2.1 Goal: Conserve target species or biodiversity

The first goal listed in Figure 18.3 is to conserve native species or biodiversity. A key strategy for conserving a target native species is to remove immediate threats, ensure basic requirements and aim for a novel ecosystem that provides the species with functionally similar habitat to the historical ecosystem. Such habitat would provide the resources needed for the species’ survival, but in this case species or ecosystem features not found in the target species’ historical or traditional habitat may provide these resources.

The potential role of non-native species in providing resources for rare native species is likely to be particularly important in situations when restoration of the native species that formerly provided shelter or an energy source is impractical due to limited economic resources or changes in the physical environment (Schlaepfer et al. 2011). For example, the riparian habitat frequented by southwestern willow flycatchers (Empidonax traillii extimus; listed as endangered under the US Endangered Species Act) in the US southwest historically consisted of a mix of native willows (Salix spp.), cottonwoods (Populus spp.) and other native trees. The non-native invasive tamarisk (Tamarix spp.) has replaced much of the native vegetation along riverbanks as a result of human activity and changes in riparian hydrology. Initial reports suggested tamarisk were causing a drop in water table levels and reducing habitat quantity and quality for this native riparian bird species. Nevertheless, results of recent field studies reveal that in some areas up to 75% of flycatchers nest in tamarisk and that fledgling success associated with nests built in tamarisk was indistinguishable from success associated with nests built in native trees (Sogge et al. 2008).

Such strategies may inevitably lead to novel species combinations in these ecosystems, raising questions of the value of allowing non-native species to become naturalized. In the flycatcher example, it may be difficult in many areas to reestablish native woody species that formerly supported the flycatcher because of the extensive modifications to flooding regimes that have occurred. Although removing tamarisk may be a step toward restoring historical vegetation in these regions, doing so may unexpectedly cause direct harm to an endangered native species that now depends, in part, on tamarisk (Schlaepfer et al. 2011). As with many decisions about controlling non-native species, managers familiar with the ecosystem they are trying to manage can couple their knowledge of ecosystem dynamics with knowledge of the demonstrated and potential impacts (both negative and positive) of the non-native on species and ecosystem functions to determine a best plan of action to move forward.

18.5.2.2 Goal: Restore/maintain function or service

The second goal in Figure 18.3 focuses on restoring or maintaining ecosystem functions or services, where services are defined as ecosystem processes that benefit human welfare (Daily 1997). Ecosystem functions can be influenced by both abiotic and biotic components of
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an ecosystem. For example, resistance of an ecosystem to invasive plants may be influenced by the availability of soil nutrients as well as competition by extant species at a location (Theoharides and Dukes 2007; also see Chapter 3). In novel ecosystems one or both of the abiotic/biotic components may have been altered from a historical state; to restore/maintain a function, management efforts may therefore need to address one or both of these ecosystem components.

Over the past decade, substantial effort has been spent on understanding the role of biota on ecosystem functioning (Loreau et al. 2002; Hooper et al. 2005; Thompson and Starzomski 2007; Naeem et al. 2009). As a result, some general concepts mentioned in Chapter 3 may be key to understanding how altered species composition in novel ecosystems might contribute to target functions. These include: functional groups classified as a set of species with either similar responses to or effects on ecosystem processes (Gitay and Noble 1997); redundancy, the idea that species are at least partially substitutable (Naeem et al. 2002); and biodiversity’s contribution to ecosystem multifunctionality: the idea that increased numbers of species or functional groups in an ecosystem result in higher levels of multiple ecosystem functions (Zavaleta et al. 2010). As discussed in Chapter 3, some ecosystem functions and services may only require that a particular functional group be present. In this case, managers may be able to use species in the same functional group as replacements (Parker et al. 2010). It is also possible that supplemental species might be chosen to be more robust to ongoing novel conditions that are not favoring native species (see a more detailed discussion of this topic in Chapter 14). The introduction of non-native tortoises to Mauritius’ Round Island provides an example where functionally similar non-natives (Aldabrachelys gigantean and Astrochelys radiata) fulfilled the role of the extinct native giant tortoise (Cylindraspis sp.) (Griffiths et al. 2010). By restoring tortoises to the island, managers expect populations of native palms and other trees whose seeds were spread by tortoise herbivory to increase.

Importantly, although species can be grouped into functional groups based on similar characteristics, not all traits in such similarly grouped species are redundant (Chapter 3; Eviner 2004). Because of this, loss of species from an ecosystem (even if the system is supplemented with other species) may result in an ecosystem that only partially operates like a historical system or a contemporary reference ecosystem. Returning to the case of non-native tortoise introduction on Round Island, while such ecological substitutes have the potential to help managers reach ecosystem recovery goals, careful examination of species interactions will be a part of all such programs to avoid unexpected and negative surprises from the use of non-native species to maintain functioning. Treating these sorts of strategies as adaptive management experiments can enhance the success of the project.

Another goal when managing for function in novel ecosystems might be to ensure ecosystems are able to adapt to ongoing ecosystem changes. Because even species in the same functional group are not truly redundant, managers might be worried that truncated subsets of native species may not provide the same range of ecosystem functions over time (Walker et al. 1999; Winfree and Kremen 2009). In this case, a management tactic may be to preserve high diversity in the ecosystem. There is increasing evidence that such high diversity supports higher levels of multiple ecosystem functions (Zavaleta et al. 2010; Isbell et al. 2011), as well as a more stable function over time (Tilman and Downing 1996). While conserving biodiverse ecosystems is often a common goal for many managers, there may also be a benefit in, at times, focusing conservation efforts on single important species. In particular, some species have been shown to have increased importance (e.g. contribute more to biomass, or have stronger link strength within a food web e.g. Berlow 1999; Hooper et al. 2005) when conditions change. Management efforts that target such important species may help ensure ecosystems can adapt as conditions in novel ecosystems continue to change.

18.5.2.3 Goal: Managing for new species composition or functions

The third goal in Figure 18.3 highlights the management of the new species combinations or functions in novel ecosystems as a management goal. As with managing for native species and traditional functions, managers might need to develop new management methods, possibly through the use of adaptive management. Decisions to manage for new species combinations or functions can at times be at the expense of remaining native species and traditional functions. It is beyond the scope of this chapter to discuss when such options may be preferred or how to make this decision. However, the spreading footprint of people on ecosystems, species and global processes indicates
that this will be an issue that is increasingly encountered in ecosystem management. Some have termed ecosystems exhibiting thoroughly novel characteristics as ‘designer ecosystems’, a term that conveys an uneasy sentiment about human agency (Pimm 1996; MacMahon and Holl 2001). Untethering management goals from traditional conservation and restoration values opens up the prospect of ecosystems managed for purely human interests (see Chapter 37). Assessing the risks of actions that begin to move away from traditional ecosystem management and restoration constraints will be essential. We encourage a cautious approach, so that the development of new approaches for the management of novel ecosystems continues to manifest important features of biodiversity conservation. For an example of the creation of designer ecosystems, see Chapter 23.

**18.6 IS THE COST/RISK ACCEPTABLE?**

A final decision point when managing novel ecosystems (Fig. 18.1) concerns the cost and/or risk of favored actions. As discussed in the section on social barriers, the success of ecosystem management often relies on adequate funding. One possibility, as managers formulate management strategies based on initial goals, is that solutions are too expensive or possibly the adaptive management needed to figure out optimal solutions is too expensive. There are a variety of commonly used planning tools that can help managers determine if their chosen actions are fiscally feasible, including cost–benefit analysis and many optimization tools (Fischer et al. 2009; Wilson et al. 2009). Optimization tools are commonly used to help managers create reserves that contain the best combination of ecosystem attributes to conserve target species and habitats (systematic conservation planning). More recently, managers are also using optimization tools to understand how the costs of conservation actions can affect the success of conservation planning (Carwardine et al. 2010; Wilson et al. 2011). These tools may be valuable for deciding on priority actions for novel ecosystem management.

A manager’s choice of novel ecosystem management actions may also depend on the risks associated with those actions. Risk may be in the form of uncertainty that chosen management actions will have desired outcomes or, alternatively, risk may be in the form of unknown surprises resulting from management actions in novel ecosystems that have few or no analogous ecosystems to refer to for guidance. See Chapter 22 for an example of ecological surprises from novel ecosystem management.

There are a number of tools to help address the risk associated with novel ecosystem management. As discussed earlier in the chapter (Section 18.5.2), adaptive management through careful tracking of different management strategies provides clues to how novel ecosystems might behave in different management regimes. Scenario planning, used to identify a number of possible outcomes, is a second tool that can allow managers to plan for possible surprises from management action (Peterson et al. 2003). For example, urban planners often use scenarios to present their creative yet realistic visions of future cities (e.g. Weller 2009). In the case of novel ecosystems, the process of designing alternative management scenarios may similarly highlight creative options not likely to be encountered in other management approaches. This process may be particularly helpful in engaging stakeholders and building consensus around novel ecosystem management strategies. A final tool used to help define risks associated with management is structured decision making. Here decision-makers use formats such as decision trees to use available information and make optimal choices in the face of uncertainty (Polasky et al. 2011; Gregory et al. 2012). It is possible to make decision trees more transparent and the decisions more deliberate by assigning levels of uncertainty associated with each decision. This method often involves estimating the probability of desired and undesired outcomes at each fork of the tree and, against these estimates, a measure of the likely consequences of each outcome can be determined (Hammond et al. 1999).

When either the cost of management action or risk stemming from novel ecosystem management actions is deemed unacceptably large, managers may have the following options. First, they can change the scale or scope of intervention. Alternatively, ongoing research in the form of adaptive management may highlight additional options for reaching goals as seen in Chapter 22 with the management of invasive species in the Galapagos Islands. Finally, a last choice may be to alter management goals. Where the novel ecosystem management goal was originally maintenance or recovery of a target species or valued ecosystem function, reprioritization may result in shifting management focus to a different species or function of interest. Alternatively,
managers might decide to manage for a novel composition of species or functions.

18.7 CONCLUSION: WHY CONSIDER NOVEL ECOSYSTEMS IN MANAGEMENT DECISIONS?

Ecosystems are undergoing intensifying change as a result of anthropogenic drivers at all scales – local, regional and global. Some of these impacts are difficult to reverse, and to try to do so would likely lead to failure of restoration programs. In these cases, where there is evidence that we have moved out of reach of the past, novel ecosystem management offers possibilities for thoughtfully choosing alternative management goals and priorities.

In this chapter we have provided some guidelines for managers faced with the task of successfully managing hybrid and novel ecosystems. Our goal was not to provide a single path for managers to follow because, in reality, there are multiple paths leading to a number of different goals. Rather, our aim was to outline some of the difficult questions and potential pitfalls associated with the management of altered and changing ecosystems and offer guidelines for how managers might proceed. We see this chapter as the beginning of a dialogue focused on hybrid and novel ecosystem management. While we have positioned the manager at the helm, in charge of making critical management decisions, we acknowledge that the most successful road to management of these ecosystems will require the combined efforts of managers, ecologists, policy makers, social scientists and stakeholders.

REFERENCES


