van Wilgen, B. W., G. G. Forsyth, and P. Prins. 2012. The management of fire-adapted ecosystems in an urban setting: the case of Table Mountain National Park, South Africa. *Ecology and Society* **17**(1): 8.
http://dx.doi.org/10.5751/ES-04526-170108

Insight, part of a Special Feature on Urban ecological and social-ecological research in the City of Cape Town

The Management of Fire-Adapted Ecosystems in an Urban Setting: the Case of Table Mountain National Park, South Africa

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ABSTRACT. The Table Mountain National Park is a 265-km² conservation area embedded within a city of 3.5 million people. The highly diverse and unique vegetation of the park is both fire prone and fire adapted, and the use of fire forms an integral part of the ecological management of the park. Because fires are both necessary and dangerous, fire management is characterized by uncertainty and conflict. The response of vegetation to fire is reasonably well understood, but the use of fire for conservation purposes remains controversial because of key gaps in understanding. These gaps include whether or not the vegetation is resilient to increases in fire frequency, how to deal with fire-sensitive forests embedded in fire-prone shrublands, and how to integrate fire and invasive alien plant control. National legislation emphasizes the need to protect communities from dangerous wildfires, and this compels fire managers to adopt a cautious approach to the application of fire. Ecological outcomes are optimized under a fire regime of relatively high-intensity, dry-season fires. Obtaining permission to burn under such conditions is not possible, and so the practice of prescribed burning is constrained, and this results in a fire regime dominated by wildfires. Ecological uncertainties, and the divergent requirements for maintaining healthy ecosystems on the one hand, and ensuring human safety on the other, result in a complex fire management environment. These complexities could be, and in some cases are being, alleviated by raising awareness, increasing fire management capacity, improving ecological monitoring of the effects of fire, and prioritizing areas for integrated fire and invasive alien plant management.

Key Words: *biodiversity conservation; ecosystem management; forestry; fynbos; pines; wildland–urban interface*

INTRODUCTION

Many of the world's ecosystems are both fire prone and fire adapted, and fires are necessary for the maintenance of healthy ecosystems in such environments (Bond and van Wilgen 1996). Fires also threaten infrastructure, livestock, and human life, especially in areas where significant development has taken place within or adjacent to such fire-prone ecosystems. The fire management of such areas is often characterized by both uncertainty and conflict. In fire-prone areas, the conservation of biodiversity and landscapes typically requires the judicious use of fire, often by means of prescribed burning, to maintain ecosystem health. Although the ecological understanding of the role of fire has advanced significantly over the past few decades (Keeley et al. 2012), it remains incomplete and thus contentious. In addition, the widespread introduction of fire-adapted alien plants into fire-prone ecosystems has seen them proliferate and spread (Brooks et al. 2004), resulting in ecosystem degradation and adding a further layer of complexity to fire management. Societal goals seek to reduce the risk of fire to people, assets, and infrastructure. The means to attain these goals through fire prevention and suppression are often in conflict with ecological goals.

In the case of "fynbos" (Mediterranean-climate shrublands endemic to the Western and Eastern Cape Provinces in South Africa), ecosystem health is best maintained by promoting a variable fire regime that will ensure the persistence of all elements of the biota, but that will include a significant proportion of relatively high-intensity fires in the dry summer season (van Wilgen et al. 1992, 1994, van Wilgen 2009). However, the deliberate use of fires in the dry season can be both dangerous and illegal. As a result, prescribed fires have been used conservatively, and the contemporary fire regime in fynbos vegetation is driven by unplanned wildfires (van Wilgen et al. 2010).

The Table Mountain National Park (TMNP) provides an example of a fire-prone and fire-adapted ecosystem surrounded by vulnerable development, and the managers of this area face the problems of reconciling conflicting ecosystem and safety-related goals. In this paper, we review the development of fire management policies and practices over the past half century in the area that is now the TMNP and explore means by which the achievement of seemingly conflicting goals can be facilitated.

THE TABLE MOUNTAIN NATIONAL PARK

Location and Biophysical Features

The TMNP, established in 1998, is a rugged 265-km² area on the Cape Peninsula (centered at 34° 09' S; 18° 23' E), surrounded by the city of Cape Town, South Africa. In 2004, it obtained World Heritage Site status as a globally important hotspot of plant and invertebrate biodiversity (Cowling et al. 1996). The dominant vegetation of the park comprises fire-adapted and fire-dependent fynbos shrublands, and the park is home to 2,285 plant species, of which 90 are endemic. Smaller areas of fire-prone *renosterveld* shrublands occur on

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relatively rich clay soils in the north of the TMNP. The vegetation also includes isolated patches of afro-montane forests in sheltered areas, such as Orange Kloof and Kirstenbosch. These forest patches do not readily burn, but their area can expand or contract under longer or shorter fire-return periods, respectively. Plantations of alien pines (*Pinus* sp.) and gums (*Eucalyptus* sp.) were established in parts of the TMNP before its proclamation. These plantations can be damaged by fire, and their protection from fire is an on-going management concern. Elevations range from sea level to 1086 m. Mean annual rainfall ranges from 1700 mm in the north to 400 mm in the south and falls predominantly in the winter months (June–August). The summers are dry and windy, and dry-season fires are a regular feature of the area (Forsyth and van Wilgen 2008).

Fire Regime

The fire regime of the TMNP is well known. Based on comprehensive records of fires in the park between 1970 and 2007, Forsyth and van Wilgen (2008) reported that most fires (90.5% of area burned) occurred in the dry summer and autumn, which are regarded as the ecologically acceptable season for fires (van Wilgen 2009). The mean fire-return period was 22 years, and a relatively small number of large fires dominated in terms of area burned. Of the 373 fires >1 ha on record, 40 fires >300 ha burned 75% of the area, whereas 216 fires <25 ha burned 3.4% of the area. Fires occurred under a wide range of weather conditions, but large fires were restricted to periods of high fire danger. Prescribed burning was a relatively unimportant cause of fires, and most (>85%) of the area was burned in wildfires.

Fire Ecology

Fynbos is fire prone and fire adapted and dependent on a regime of regular summer or early autumn burning (van Wilgen 2009, Bond 2012). The fire regime is characterized by variability around the mean fire-return interval and season (Forsyth and van Wilgen 2008; van Wilgen et al. 2010), and evidence from the TMNP suggests that this variability may well be necessary for plant species co-existence (Cowling and Gxaba 1990, Thuiller et al. 2007). Variation in the intervals between fires, in fire season, or in fire intensity induces variation in the density of overstorey shrubs (e.g., *Leucadendron laureolum* on the Cape Peninsula); this variation is, in turn, associated with the maintenance of diversity in understory species (Cowling and Gxaba 1990, Thuiller et al. 2007). Pre-fire stand densities were also found to affect the density of post-fire recruitment (Bond et al. 1995), resulting in alternating densities and species diversity on the same site between different fires. Thuiller et al. (2007) concluded that recurrent fires would buffer plant populations from extinction, by ensuring stable co-existence over time, despite localized extirpation by individual fires. There is some concern, however, that excessively short intervals between fires are becoming more frequent. These short-interval fires may impact negatively on populations of obligate re-seeding plants that may not have sufficient time to mature and set seed between fires (van Wilgen and Forsyth 1992, Forsyth and van Wilgen 2008). The effect of fire on the vegetation is further complicated by invasive alien plants. These include trees and shrubs in the genera *Pinus*, *Hakea*, and *Acacia*, which are widespread in the TMNP, where they are spread by fire and impact negatively on biodiversity, water resources, and soil stability. Fire regimes also differ in the *renosterveld* shrublands in that fire-return intervals are much shorter than in fynbos. Finally, the fuel properties of forest patches prevent fires from penetrating (van Wilgen et al. 1990), and many areas occupied by fynbos would become forest in the absence of fire (Manders and Richardson 1992).

Fire Management

The fire management of the area that is now the TMNP was historically characterized by attempts at coordination among the various landowners, largely with the aim of preventing or containing wildfires. In 1949, landowners formed the statutory Cape Peninsula Fire Protection Committee (FPC) to coordinate all activities relating to fire protection and wildfire suppression (Table 1). For the next two decades, fire management was focused exclusively on the prevention, containment, and suppression of wildfires. In 1968, following the emergence of evidence that fire was necessary for the maintenance of healthy fynbos, the Department of Forestry introduced a policy of regular prescribed burning (every 12–15 years) for all fynbos areas under its control (van Wilgen 2009), including those on the Cape Peninsula. This policy was adopted by some, but not all, of the other landowners on the Peninsula (van Wilgen 1996), and a limited number of prescribed burns, accounting for about 15% of the total area burned (Forsyth and van Wilgen 2008), were conducted between 1970 and 2008. Periodic large wildfires, particularly those on the relatively densely settled northern Peninsula, temporarily raised public awareness of fire, and each large fire event precipitated renewed action. For example, large fires in 1976 resulted in the proclamation of a total ban on open-air fires. Further large fires in January 2000 provided the catalyst for the so-called *Ukuvuka* Campaign (meaning "wake up" in isiXhosa), which raised significant funding for the reduction of fuel loads and fire hazard by clearing invasive alien shrubs and trees (Table 1). *Ukuvuka* also provided the impetus for the formation of the Cape Peninsula Fire Protection Association (FPA), which, in terms of new legislation (the Veld and Forest Fire Act, no. 101 of 1998, see below), replaced the Cape Peninsula FPC. In 1998, following a succession of Commissions of Enquiry into the management of the Peninsula between 1951 and 1994 that had called repeatedly for unified management (Hey 1978; Anon. 1994, unpublished manuscript), most of the state-owned land was transferred to the management of the newly proclaimed TMNP.

The TMNP compiled its first comprehensive fire management plan in 2000 (Forsyth et al. 2000). The plan calls for a flexible approach to fire management, recognizing the need for

Table 1. Salient events affecting the management of the Table Mountain National Park in the late 20th and early 21st centuries, and their relevance to fire management

Date	Event	Relevance to fire management
1949	Formation of the first statutory Fire Protection Committee	Coordination of all activities relating to fire protection and wildfire suppression
1968	Policy decision by the Department of Forestry to manage fynbos vegetation by means of prescribed burning (van Wilgen 2009).	This policy was adopted by some of the authorities responsible for parts of the Cape Peninsula (van Wilgen 1996)
1976	Occurrence of large wildfires in close proximity to the city of Cape Town.	Institution of a total ban on open-air fires
1978	Hey report on management of the Cape Peninsula (Hey 1978)	Fire management policies of protection and prescribed burning were supported as "sound and realistic." Recommendations included better coordination of management, and a limit on any development above 152 m contour
1983	Establishment of the Cape Peninsula Nature Area (later the Cape Peninsula Protected Natural Environment)	Fire management policies remained divergent among different landowners (van Wilgen 1996)
1985	10-year management plan produced (Anon. 1985)	Focus on fire protection, establishment of a network of firebreaks, fire lookouts, and access roads
1986	Large fire on front face of Table Mountain	Heightened public awareness of fire problem
1993	Table Mountain Fund established by WWF (South Africa)	Limited funding for applied research that supports biodiversity conservation
1995	Report of the Kahn Committee	Recommendations for the united management of all land within the Cape Peninsula Protected Natural Environment under a single authority
1998	Establishment of the Table Mountain National Park	Responsibility for fire management of natural vegetation falls under a single, unified authority
2000	Large fire covering 7400 ha	Establishment of the Ukuvuka campaign in response to large wildfires (Anon. 2004), with a focus on alien plant control projects to reduce fuel loads and fire hazard Strong support for the establishment of statuary Fire Protection Association
2000	First unified fire management plan for the Table Mountain National Park	Flexible approach to fire management, recognizing inevitability of wildfires as well as the need for occasional prescribed burning. Focus on close monitoring of fire patterns over time, with interventions dictated by fire regime thresholds (van Wilgen et al. 2011)
2004	Establishment of a Fire Protection Association	Shift in focus from fire protection and suppression to holistic, integrated fire management
2010	Review of fire management policies	Recognition of the importance of establishing an adaptive monitoring program and of raising awareness of ecological requirements for fire management within the Fire Protection Association

periodic prescribed burning, while at the same time adjusting prescribed burning schedules to account for inevitable wildfires. The safety of houses and other property along the park's borders also demands a degree of fire suppression for non-ecological reasons and it requires the careful execution of prescribed fires to avoid the risk of damage. Widespread alien plant invasions bring added requirements in terms of fire management; these plants (dominated by trees and shrubs) are spread by fire and require careful treatment before burning (Richardson et al. 1994). The fire management plan allows for both prescribed burning and tolerating wildfires in areas where they will do no ecological harm (van Wilgen et al. 1994). A perimeter firebreak has been established to protect the vulnerable boundaries with adjacent developed areas (the wildland–urban interface, Radeloff et al. 2005) and to assist with containing wildfires.

The National Park in an International Context

Several features of the TMNP are similar to those in Mediterranean-type ecosystems elsewhere in the world. Winters are generally cool to cold, and wet, whereas summers are warm and dry, leading to conditions that promote summer wildfires. The predominant vegetation is a shrubland formation, with similarities to European macchia or garrigue, Californian chaparral, or Australian kwongan shrublands. All of these vegetation types produce enough fine, dead material

and litter to support regular fires. In addition, areas of Mediterranean climate are usually densely settled, leading to significant interactions between society and the incidence and effects of fires. There are, however, important differences between the South African fynbos vegetation and associated human settlements (of which the TMNP is an example) and the situations found in other similar areas. These differences include the following:

- The fynbos "fire problem" does not reach the spectacular proportions found in some other similar systems worldwide, and the scale of the problem seems to be orders of magnitude less (Forsyth and van Wilgen 2008). For example, extensive fires in Californian chaparral destroyed 3361 homes in Los Angeles in 2003 (Keeley and Fotheringham 2006); similar conflagrations in Greece killed 84 people and destroyed 1000 homes and 1100 other buildings in 2007 (Polyzoidis 2007); and four people were killed and over 500 houses destroyed in a 10-h period in Canberra, Australia in 2003 (Doogan 2003). In contrast, typical fires in fynbos destroy 2–10 houses, and loss of human life is rare. The largest fire on record in the TMNP burnt 7000 ha and destroyed 14 homes in 2000 (Forsyth and van Wilgen 2008). Thus, it would be expected that the issue of fires and their management would receive comparatively less emphasis in the TMNP than in other similar areas globally.
- Both fynbos vegetation and Californian chaparral are invaded by alien plants, which change the fuels that are characteristic of the native vegetation. In California, these alien plants are predominantly grasses, which grow rapidly and allow the vegetation to burn far more frequently than it did before invasion, allowing fires to spread more quickly and to burn larger areas (Keeley et al. 2005). In fynbos, the invasive alien plants are dominated by trees and shrubs, which do not increase fire frequency, but do increase fire intensity and promote erosion after fires (van Wilgen and Scott 2001). Both the nature of the problem and its effects call for different approaches to management.
- Although no detailed comparative analysis exists, the climate of most Mediterranean-climate areas is hotter and drier than typical fynbos areas (Versfeld et al. 1992), leading to more severe fire weather. In areas of more severe fire weather, the fires themselves would be more damaging and more difficult to control, and this would demand greater investments in training and equipment.
- Human settlements and developments in many Mediterranean-climate areas are found within the natural vegetation, whereas in the case of the TMNP, isolated houses and settlements within the vegetation matrix are almost non-existent, and developments are confined to the outer boundaries of the natural vegetation. This hard boundary has come about as a result of the historic legal separation of mountain watersheds and areas where urban or other development was allowed, and it simplifies the fire management problem significantly.
- The levels of endemic plant biodiversity are higher in fynbos vegetation than in many other Mediterranean-climate areas. In the case of the TMNP in particular, the rich diversity of endemic plant species has led to its recognition as a World Heritage Site. The presence of localized, rare, endemic species that would be vulnerable to changes in fire regimes could further complicate the fire management of the TMNP.

All of these factors will lead to differences in the way that fires are perceived and managed, as well as the degree to which they are given priority.

FIRE MANAGEMENT AND ECOLOGICAL UNCERTAINTY

Fire in Fynbos and Renosterveld Shrublands

The role of fire in maintaining healthy fynbos vegetation was recognized as early as 1945 (Wicht 1945), and its use as a management practice became widespread in the 1970s (van Wilgen 2009, Bond 2012). The use of fire as a management practice nonetheless remains contentious to a certain degree, despite advances in the understanding of its role in maintaining healthy vegetation. The major contemporary concern relates to the return period between fires. Moll et al. (1978) recognized the need for fire, but were of the opinion that the TMNP was being burned too frequently. They contended that natural fynbos was adapted to fire-return intervals of 30–40 years (Moll et al. 1980), and that these had been reduced to a 4- to 8-year cycle, resulting in "a weakened plant cover leading to more rapid soil erosion and destruction of forest." Forsyth and van Wilgen (2008) confirmed that mean fire-return intervals had diminished over a 40-year period by 18.1 years, from 31.6 to 13.5 years. The area subjected to short (<6 years) intervals between fire covered >16% of the park in the last two decades of the record, compared with about 4% in the first two decades. The increase in short-interval fires was assumed to be correlated with increases in human population and, thus, sources of ignition, and it was recognized that they may threaten the continued existence of plant species that require longer intervals between fires to mature and set seed. Forsyth and van Wilgen (2008) recommended that areas subjected to short fire-return intervals should be considered for management interventions to re-establish extirpated fire-sensitive species, such as obligate re-seeding shrubs with relatively slow maturation rates. However, there is a concern that fire may not be frequent enough in *renosterveld* areas, and that these areas are being encroached upon by woody shrubs as a result of a lack of fire (Forsyth et al. 2007). *Renosterveld* shrublands grow on relatively nutrient-rich soils and have a

larger grassy component. Presumably, they would have burned (and been grazed) more frequently than fynbos, although very little is known regarding the fire regime in this vegetation type (Mucina and Rutherford 2006).

Managers of the TMNP have been advised to accommodate variability in the fire regime (in terms of post-fire age and season of burn) and to make management decisions (on whether or not to initiate fires, to allow wildfires to burn, or to suppress them) based on whether or not the seasonal or post-fire age distributions are approaching critical thresholds (van Wilgen et al. 2011). For example, if too great an area has burned too frequently, wildfires should be suppressed. On the other hand, if too great an area has been free of fire for a long time, prescribed burns would be initiated, or wildfires would be allowed to continue to burn. In doing this, the assumption is made that the ultimate goal of maintaining biodiversity will be promoted by the chosen fire patterns (Parr and Andersen 2006). The link between fire-regime patterns and biodiversity outcomes has not been explicitly made, however, although the logic for choosing particular patterns is based on an understanding of responses of plants to fires at particular return intervals and in particular seasons (van Wilgen et al. 2011). A monitoring program to assess trends in plant populations and the relationships between these trends and background trends in fire patterns is required. However, until such a program is implemented, and until robust assessments of outcomes are possible, these links will remain uncertain.

Maintaining the Forest–Fynbos Mosaic

The presence of fire-free forest patches embedded in a landscape dominated by fire-prone shrublands is an unusual feature of the Cape region (Bond 2012). Early approaches to management sought to protect these forests from fire, but the desired balance between fire-dependent fynbos and fire-sensitive forests is not clearly spelled out in contemporary fire management plans. The protection from fire since 1933 of extensive forest patches in Orange Kloof had led to a doubling in the area of forest, at the expense of fynbos, over 55 years (Luger and Moll 1993). These authors recognized that continued protection from fire would result in further expansion of forest at the expense of fynbos, possibly leading to the extinction of locally endemic plants, and deciding whether or not to burn this area would be "a tough management decision."

Fire and Invasive Alien Plants

Invasive alien trees and shrubs in the genera *Pinus*, *Hakea*, and *Acacia* constitute a major threat to the fynbos ecosystems of the TMNP (Richardson et al. 1996). These invasive plants are also fire adapted, and their ability to produce large numbers of seeds facilitates their proliferation and spread after fires. The inability of managers to deal effectively with very large numbers of seedlings that germinate after fire is a major obstacle to the successful control of these species (Pieterse and Cairns 1986, Richardson and Higgins 1998). Invasive alien trees and shrubs increase biomass and add to fuel loads, leading to increased fire intensity and erosion (van Wilgen and Scott 2001). Managers can either burn the area without felling the plants (burn standing), fell before burning (fell and burn), fell the trees and shrubs and remove them before burning (fell, remove, and burn), or fell trees and shrubs, collect them into stacks, and burn the stacks (fell, stack, and burn) (Holmes et al. 2000). These treatments will influence the degree to which additional biomass can affect fire intensity and soil damage (van Wilgen and Scott 2001). The fell, remove, and burn treatment will decrease fuel loads, but is expensive, time consuming, and impractical over large areas. Fell and burn results in densely packed fuel close to the ground, increasing impact, whereas fell, stack, and burn concentrates the fuel loads, and results in localized but increased fuel loads, increasing the impacts of fire under stacks, but preventing the impacts elsewhere. Burn standing ensures that additional fuel is elevated, reducing soil damage during fires, but adding to the effort required for the control of subsequent seedling regeneration. Holmes et al. (2000) concluded that practical problems associated with the burn standing and fell, remove, and burn treatments often left managers with little option but to apply the fell and burn or fell, stack, and burn treatments. The debate as to which of these options is best for the control of invasive alien plants is ongoing, and adds a further level of complexity to fire management.

Plantations of Alien Trees

Plantations of pines and gums were originally established for timber production long before the proclamation of the TMNP. These plantations need to be protected from fire, and the existence of these fire-sensitive plantations in a matrix of fire-prone fynbos complicates fire management. Current policy calls for the removal of the plantations, both to remove a seed source in the case of invasive pines and to restore natural vegetation and biodiversity on cleared sites. Many plantation areas once supported fire-dependent sandplain fynbos, a low shrubland vegetation type that has been reduced to tiny patches by development but that contains a few endemic species. One view is that these recently cleared areas have to be burned in high-intensity summer burns to stimulate germination of any remaining soil-stored seed (Rebelo 2010). As these plantation areas border on residential suburbs, the park's managers are prevented by law (see below) from conducting these high-intensity burns and are required to do so in safer periods. The argument for high-intensity summer burns is that the park authorities, who have a primary mandate for the conservation of biodiversity, should do everything within their means to ensure the survival of rare and endangered sandplain fynbos. Others have argued for the retention of plantations to provide shady recreational opportunities for the citizens of Cape Town (Moll 2011). This argument holds that sandplain fynbos cannot be restored as a functional ecosystem (as too much has

been irreparably converted by development) and that the few endangered endemic species can be conserved *ex situ*. It further holds that the restoration of sandplain fynbos will add areas that have to be managed using fire and that the park patently does not have the capacity to do this. In fact, they are already unable to conduct all the necessary prescribed burns in the areas already under their control, such as Orange Kloof or Kirstenbosch (Moll 2011).

FIRE MANAGEMENT AND THE SAFETY IMPERATIVE

Legislation relating to the management of wildfires in South Africa is embodied in the Veld and Forest Fire Act of 1998. This Act calls for integrated fire management, recognizing both the ecological role of fire for maintaining healthy ecosystems and the need to reduce the risks posed by fires. In reality, those responsible for the implementation of the Act adopt a primary focus on risk reduction and safety at the expense of ecological considerations. The Act provides for the establishment of Fire Protection Associations (FPAs), whose functions include the appointment of a Fire Protection Officer (FPO), the development of a wildfire management strategy, the definition of rules that will bind members, and the training of members to fight, contain, and prevent wildfires. The lighting of prescribed burns to achieve ecological goals is subject to approval by the FPO, whose primary concern is to ensure safety. The legislation also defines liabilities, which can be settled by means of civil suits, and provides for fines and/or imprisonment of offenders—strong deterrents to taking any risks with prescribed burning. The current business plan recognizes the environmental and ecological importance of fires, but does not give substance to this in its strategy, which has a focus on prevention, preparedness, response, and suppression (Anon. 2003).

The reconciliation of fire management goals that relate to safety, on the one hand, and to the maintenance of ecosystem health, on the other, remains among the most important and controversial aspects of ecosystem management. In the case of fynbos, ecosystem health is best maintained by promoting a variable fire regime that will cater to all elements of the biota, but that will include a significant proportion of relatively high-intensity fires in the dry summer season. The achievement of goals relating to safety calls for the prevention and suppression of high-intensity dry-season fires that threaten infrastructure and human safety. In some years, the funds allocated to fire management are exhausted by fire suppression activities (to address the imperative for safety), leaving little or no funds to conduct prescribed burns later in the year (Yeld 1999). The safe achievement of the goals of ecosystem health require prescribed burning under milder weather conditions; the opportunities for conducting prescribed burns are constrained by being limited to relatively few suitable days in early autumn, when suitable weather coincides with the ecologically acceptable burning season (van Wilgen and Richardson 1985).

The Fire Manager of TMNP was appointed as the FPO of the Cape Peninsula FPA. Other members (besides the TMNP) include foresters and many private landowners. All have a primary focus on safety and fire prevention and control. Managers of the park are also required, in terms of the by-laws of the City of Cape Town, to obtain permits to conduct prescribed burns. These include a permit in terms of the Community and Fire Safety by-law, and another in terms of the Air Pollution by-law. All applications to the City of Cape Town for permits follow tortuous bureaucratic procedures that include site visits and approval by relevant sub-councils. Although the City's by-laws stipulate that the process from date of receipt of application to date of approval should not exceed 21 days, this usually takes much longer (6 to 8 weeks) in reality. The focus of City officials appears to be on ensuring that correct procedures are followed, and no consideration is given to ecological requirements related to burning. To date, the City has not agreed to allow any high-intensity burning in the dry season. The cautious approach to fire management adopted by the City is understandable, but it further constrains the park managers in terms of applying the types of fire that would best achieve ecosystem goals.

RAISING AWARENESS AND CREATING CAPACITY

Wildfires tend to be infrequent but dramatic events. They are brought sharply into focus during and immediately after their occurrence, but fade rapidly from memory with time. Being able to deal sensibly with fires requires both a broad understanding of their ecological role (so that society can see them in perspective) and sufficient capacity at an acceptable level of preparedness (so that the response can be professional and effective). Most residents of suburbs close to the park, and citizens in general, remain broadly ignorant with respect to the ecological role of fire. Wildfires are regarded as ecological disasters by many, and people also raise objections frequently and vociferously if prescribed fires are carried out. Public opinion regarding the ecological role of fire is affected by the language used when fires are reported in the press, and on radio and television. For example, areas are reported as having been "destroyed by a raging fire" (Serra 2002) instead of "burned," or it is stated that "untold devastation has been wreaked" (Williams 2009). In general, the predominant impression created is one of harm. The requirement to burn under safe conditions (with a stable atmosphere and little or no wind) also means that smoke arising from prescribed burns does not dissipate for some time, leading to many complaints about smoke pollution. On occasions when infrequent prescribed burns spread beyond the boundaries of the area intended to be burned, the park's managers are accused of reckless behavior (Yeld 2007). These concerns are often raised in the local press or pursued as vigorous email debates, which increases the reluctance of park managers to attempt any dry-season burning. Efforts to raise awareness of the ecological importance and necessity of fire have nonetheless increased over the past decades. Several press reports have pointed to the beneficial aspects of burning (e.g., Yeld 2000, van Wilgen

2007, Erasmus 2009). The establishment of the TMNP has been accompanied by the establishment of information centers, and several popular books have been published that include accounts of the role of fire (e.g., Cowling and Richardson 1995, Paauw and Johnson 1999). There is, therefore, a small but growing sector of society that is well informed.

In terms of building capacity to manage fires, the TMNP benefits from the government-funded Working on Fire program, which was established at a national level to develop capacity in support of integrated national wildfire prevention, firefighting, and prescribed burning. It includes a component of job creation and development, aimed primarily at the unemployed youth, with fire teams being recruited from local communities and trained to become skilled firefighters. In partnership with the National Disaster Management Centre, Working on Fire supplies helicopters and fixed-wing aircraft to supplement local aerial fire-fighting and prescribed burning efforts. Capacity to deal with fires in the TMNP is also supplemented by 100 trained volunteer firefighters (http://www.capefires.com). The volunteers work closely with other service organizations, including the TMNP and Working on Fire. They are funded by corporate and organizational partners and individual donors, as well as from self-organized fundraising projects.

Increasing the levels of preparedness is also being fostered by the FireWise (South Africa) campaign (http://www.firewisesa.org.za/), a Working on Fire-initiated partnership that was formed by government in 2003 to develop an integrated national fire-fighting prevention and wildfire-fighting capacity. Its primary focus is to create awareness of the dangers of wildfires and to equip homeowners, community leaders, planners, and developers with the knowledge and skills relating to fire safety. It provides educational resources and places emphasis on individual responsibility for safer home construction and design and garden landscaping and maintenance.

Finally, promoting awareness on the FPA is vital. The Veld and Forest Fire Act requires both collaboration between landowners within FPAs and the recognition and inclusion of ecological goals into integrated fire management. In reality, most landowners and the municipal fire brigades have maintained a focus on prevention, suppression, and safety, and the concept of using prescribed burns to achieve ecological goals is novel in these circles. Park managers therefore, have an obligation to introduce these concepts into the agendas and management plans of FPAs. By ensuring an understanding within the FPA of the ecological role and importance of fire, TMNP's managers will be in a better position to reach agreement on trade-offs between safety and biodiversity objectives.

MONITORING, ASSESSMENT, AND PRIORITIZATION

The TMNP's fire records are captured on a spatial database, and these records are used to track shifts in the fire regime (Forsyth and van Wilgen 2008). However, it would be more important to track the ecological outcomes of fire management if the effectiveness of fire management for achieving ecosystem goals is to be gauged (van Wilgen and Forsyth 2010). Proposals for such monitoring include: (1) assessing whether available seed loads have reached sufficient levels to ensure adequate post-fire regeneration in obligate re-seeding plants (important for deciding whether to burn or to suppress fires); (2) monitoring levels of vitality in populations of obligate re-seeding plants that become senescent following lengthy fire-free periods (important for identifying areas that require burning); (3) establishing whether the post-fire recruitment levels in obligate re-seeding plants are adequate to replace parent plants killed in fires (if not, this would alert managers to potential declines); and (4) monitoring population trends in selected rare and/or endangered species (to alert managers to potential losses or declines) (van Wilgen et al. 2011). Currently, there is no monitoring program in place, and one needs to be established to be able to assess the effectiveness of fire management in future. These assessments need to take place within a framework of adaptive management, in which the feasibility of achieving outcomes can be re-examined as new understanding develops (van Wilgen and Biggs 2011).

Management goals also call for the reduction of the extent of invasive alien plants, and prescribed burning will form an important component of their control (arguably a much larger threat to the long-term conservation of biodiversity than any changes in the fire regime; see Richardson et al. 1996, van Wilgen 2009, Hoffmann et al. 2011). The narrow seasonal window of opportunity to conduct ecologically acceptable prescribed burns safely, a lack of funding, the need to incorporate the pre-fire treatment of invasive alien plants, and growing concerns about the safety of prescribed burning and legal liability in cases where prescribed burns escape, make the imperative to practice integrated fire and alien plant control very difficult to achieve. Given these constraints, park managers should direct the limited opportunities for prescribed burning to priority areas where fires are needed for the treatment of invasive alien plants.

CONCLUSION

The issues relating to the management of fire in the TMNP are similar to those of other fire-prone ecosystems with a significant wildland–urban interface. The most significant problem is finding acceptable trade-offs between meeting the ecological needs for fire and the societal needs for safety. However, fynbos vegetation has proven to be resilient under variable fire regimes, and management interventions have relatively limited influence on broad fire regimes, which are

driven by climatic and other factors (Brown et al. 1991, Seydack et al. 2007, van Wilgen et al. 2010, Bond 2012). In addition, the magnitude of the problem does not approach that of other Mediterranean-climate areas. Invasive alien plants represent a much larger threat to the conservation of biodiversity than fire alone, and the challenges associated with integrating fire and invasive alien plant management remain the largest problem facing the managers of the TMNP.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/vol17/iss1/art8/responses/

Acknowledgments:

We thank Noah Schermbrucker for locating articles in the press. BWvW thanks the DST/NRF Centre for Invasion Biology and the Working for Water programme for funding. This paper is a product of the Urban Ecology CityLab which is part of the CityLab programme of the African Centre for Cities at the University of Cape Town. The African Centre for Cities' CityLab programme is funded through the Mistra Urban Futures network (which is funded by Mistra the Foundation for Strategic Environmental Research and the Swedish International Development Cooperation Agency), the Provincial Government of the Western Cape (Department of Human Settlements) and the City of Cape Town.

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